



SRI VENKATESWARA COLLEGE OF ENGINEERING,
(An Autonomous Institution, Affiliated to Anna University, Chennai – 600025)

M.Tech. Chemical Engineering

CURRICULUM AND SYLLABUS
REGULATION – 2022
CHOICE BASED CREDIT SYSTEM

| | | | | | |
|--------------------------------|---|--|------------|---------------------------------|------------|
| Curriculum Revision No: | 0 | Board of Studies recommendation date : | 03.10.2022 | Academic Council Approved date: | 08.10.2022 |
| Salient Points of the revision | | | | | |
| | | | | | |

SRI VENKATESWARA COLLEGE OF ENGINEERING,
(An Autonomous Institution, Affiliated to Anna University, Chennai – 600025)
REGULATIONS2022

CHOICE BASED CREDIT SYSTEM

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

- I. PEO 1: Function effectively to solve complex industrial problems using Chemical engineering concepts and also in expanding areas of Energy and Environmental industries.
- II. PEO 2: Pursue their careers in Research and Development towards an advanced degree in Chemical engineering and allied technical discipline.
- III. PEO 3: To become Professional Leaders in the complex work environment.

PROGRAM OUTCOMES (POs) (GRADUATE ATTRIBUTES)

1. Independently carry out research /investigation and development work to solve practical problems.
2. Write and present a substantial technical report/document.
3. Demonstrate a degree of proficiency over the area as per the specialization of the program. The proficiency should be at a level higher than the requirements in the appropriate bachelor program
4. Potential to analyze solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety.
5. Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
6. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PROGRAM SPECIFIC OUTCOMES (PSOs)

After the successful completion of the course, the students:

PSO1: Apply the knowledge of science and mathematics in the field of various chemical engineering processes to accomplish the contemporary needs of chemical and allied industries.

PSO2: Usage of modern engineering tools to design and conduct experiments to develop quality chemical processes by considering the cost, safety and environmental aspects.

PEOs – POs & PSOs MAPPING:

| POs | PEOs | | |
|-------|------|----|-----|
| | I | II | III |
| 1. | ✓ | ✓ | ✓ |
| 2. | | ✓ | ✓ |
| 3. | ✓ | ✓ | ✓ |
| 4. | ✓ | ✓ | ✓ |
| 5. | ✓ | ✓ | ✓ |
| 6. | ✓ | ✓ | ✓ |
| PSO 1 | ✓ | ✓ | ✓ |
| PSO 2 | ✓ | ✓ | ✓ |



SRI VENKATESWARA COLLEGE OF ENGINEERING
(An Autonomous Institution, Affiliated to Anna University, Chennai)

REGULATIONS 2022
CHOICE BASED CREDIT SYSTEM

CURRICULUM FOR SEMESTERS I TO IV AND SYLLABI FOR SEMESTERS I & II

SEMESTER I

| S.No. | Course Code | Course Title | Category [#] | Periods per Week | | | | Total Hours | Pre-requisite | Position |
|---------------------------|-------------|---|-----------------------|------------------|----------|----------|-----------|-------------|---------------|----------|
| | | | | L | T | P | C | | | |
| Theory Subjects | | | | | | | | | | |
| 1. | MA22183 | Mathematical and Statistical Methods for Chemical Engineering | PC | 3 | 1 | 0 | 4 | 60 | Nil | F |
| 2. | CL22101 | Advanced Thermodynamics for Chemical Engineers | PC | 3 | 1 | 0 | 4 | 60 | Nil | F |
| 3. | CL22102 | Advanced Separation Processes | PC | 3 | 0 | 0 | 3 | 45 | Nil | F |
| 4. | CL22103 | Advanced Chemical Reaction Engineering | PC | 3 | 1 | 0 | 4 | 60 | Nil | F |
| 5. | | Professional Elective - I | PE | 3 | 0 | 0 | 3 | 45 | Nil | M |
| 6. | CL22104 | Process Modeling and Simulation (Integrated) | PC | 3 | 0 | 2 | 4 | 75 | Nil | F |
| Practical Subjects | | | | | | | | | | |
| 7. | CL22111 | Instrumental Methods of Analysis Laboratory | PC | 0 | 0 | 4 | 2 | 60 | Nil | F |
| Total | | | | 18 | 3 | 6 | 24 | 405 | | |

SEMESTER II

| S.No. | Course Code | Course Title | Category# | Periods perWeek | | | | Total Hours | Pre-requisite | Position |
|---------------------------|-------------|---|-----------|-----------------|----------|----------|-----------|-------------|---------------|----------|
| | | | | L | T | P | C | | | |
| Theory Subjects | | | | | | | | | | |
| 1. | CL22201 | Advanced Transport Phenomena | PC | 3 | 1 | 0 | 4 | 60 | Nil | F |
| 2. | CL22202 | Advanced Process Control | PC | 3 | 0 | 0 | 3 | 45 | Nil | F |
| 3. | GR22251 | Introduction to Research Methodology and IPR | MC | 3 | 0 | 0 | 3 | 45 | Nil | F |
| 4. | | Professional Elective - II | PE | 3 | 0 | 0 | 3 | 45 | Nil | M |
| 5. | CL22203 | Chemical Process Design | PC | 3 | 0 | 0 | 3 | 45 | Nil | F |
| 6. | CL22204 | Software applications in Chemical industries (Integrated) | PC | 3 | 0 | 2 | 4 | 75 | Nil | F |
| Practical Subjects | | | | | | | | | | |
| 7. | CL22211 | Advanced Chemical Engineering Laboratory | PC | 0 | 0 | 4 | 2 | 60 | Nil | F |
| Total | | | | 18 | 1 | 6 | 22 | 375 | | |

SEMESTER III

| S.No. | Course Code | Course Title | Category# | Periods perWeek | | | | Total Hours | Pre-requisite | Position |
|------------------------|-------------|----------------------------|-----------|-----------------|----------|-----------|-----------|-------------|---------------|----------|
| | | | | L | T | P | C | | | |
| Theory Subjects | | | | | | | | | | |
| 1. | | Professional Elective -III | PE | 3 | 0 | 0 | 3 | 45 | Nil | M |
| 2. | | Professional Elective -IV | PE | 3 | 0 | 0 | 3 | 45 | Nil | M |
| 3. | CL22312 | Comprehension and Seminar | EE | 0 | 0 | 2 | 1 | 30 | Nil | F |
| 4. | CL22311 | Project Work Phase – I | EE | 0 | 0 | 12 | 6 | 180 | Nil | F |
| Total | | | | 6 | 0 | 14 | 13 | 300 | | |

SEMESTER IV

| S.No. | Course Code | Course Title | Category# | Periods perWeek | | | | Total Hours | Pre-requisite | Position |
|------------------------|-------------|-------------------------|-----------|-----------------|----------|-----------|-----------|-------------|---------------|----------|
| | | | | L | T | P | C | | | |
| Theory Subjects | | | | | | | | | | |
| 1. | CL22411 | Project Work Phase – II | EE | 0 | 0 | 24 | 12 | 360 | Nil | F |
| Total | | | | 0 | 0 | 24 | 12 | 360 | | |

PROFESSIONAL ELECTIVES (PE)

| S. No. | Course code | Course title | Category | Contact hours per week | L | T | P | C | Pre-Requisite | Fixed/ |
|---------------------|-------------|--|----------|------------------------|---|---|---|---|---------------|---------|
| | | | | | | | | | | Movable |
| ELECTIVE -I | | | | | | | | | | |
| 1 | CL22001 | Electrochemical Processes for Clean Technology | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 2 | CL22002 | Solar Energy Engineering | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 3 | CL22003 | Down Stream Processes in Petroleum Engineering | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 4 | CL22004 | Bioprocess Engineering | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 5 | CL22005 | Electrochemical Processfor Chemical Engineers | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| ELECTIVE -II | | | | | | | | | | |
| 1 | CL22006 | Process Integration | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 2 | CL22007 | Gas Transportation | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 3 | CL22008 | Environmental Policies and Legislation | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 4 | CL22009 | Fuel cell technology | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 5 | CL22010 | Chemical Reactor Analysis | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |

| S. No. | Course code | Course title | Category | Contact hours per week | L | T | P | C | Pre-Requisite | Fixed/ |
|-------------------------------|-------------|--|----------|------------------------|---|---|---|---|---------------|---------|
| | | | | | | | | | | Movable |
| ELECTIVE –III & IV | | | | | | | | | | |
| 1. | CL22011 | Design of Experiments and Parameter Estimation | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 2. | CL22012 | Micro and Nano fluidics | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 3. | CL22013 | Nanomaterials and its applications | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 4. | CL22014 | Surface Engineering | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 5. | CL22015 | HSE in Petroleum Industries | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 6. | CL22016 | Artificial Intelligence for Chemical Engineering | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |
| 7. | CL22017 | Process Design and Synthesis | PE | 3 | 3 | 0 | 0 | 3 | Nil | M |

MA22183 MATHEMATICAL AND STATISTICAL METHODS FOR CHEMICAL ENGINEERING

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 4 |

COURSE OBJECTIVES:

The student should be made to :

1. Compute algebraic, transcendental equations, system of linear and non-linear equations.
2. Find the solution of IVP and BVP of ordinary differential equations numerically.
3. Solve parabolic, elliptic and hyperbolic PDEs.
4. Select the appropriate statistical procedure and apply relevant statistical tests depending on the data provided.
5. Acquire knowledge in the design of experiments.

UNIT I ALGEBRAIC EQUATIONS (9+3)

Systems of linear equations: Gauss Elimination method, LU decomposition method pivoting techniques, Thomas algorithm for tridiagonal system –Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Raphson Method, Eigenvalue problems: Power method and Jacobi method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS (9+3)

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, shooting method, BVP: Finite difference method, orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

UNIT III BOUNDARY VALUE PROBLEMS (9+3)

Parabolic equations: explicit and implicit finite difference methods- Laplace and Poisson's equations in a rectangular region: Five-point finite difference schemes, Liebman's iterative methods, Dirichlet and Neumann conditions - different explicit and implicit methods; numerical stability analysis. Wave equation: Explicit scheme- Stability of above schemes.

UNIT IV TESTING OF HYPOTHESIS (9+3)

Sampling distributions and Standard error– Type I and Type II errors – Critical region– Tests based on Normal, t, χ^2 and F distributions for testing of mean, difference between two means, proportion, difference between two proportions, variance, ratio of two variances – Independence of attributes ($r \times c$ contingency table) - Goodness of fit- Non parametric test (concept only).

UNIT V ANALYSIS OF VARIANCE

(9+3)

Basic principles of experimentation-Analysis of variance-One-way classification – Completely randomized design - Two-way classifications - Randomised block design, Latin square design-problems- 2^2 factorial design (concept only)

TOTAL (L:45+T:15):60

PERIODS

COURSE OUTCOMES:

Upon successful completion of the course, students should be able to:

After completing this course, students should be able to:

1. Solve algebraic or transcendental equation, linear system of equations, IVPs and BVPs and calculate eigen values and eigen vectors of matrices using an appropriate numerical method.
2. Acquire the skill to solve ordinary differential equations using single step, multistep methods and finite element method.
3. Construct the methods for the numerical solution of boundary value problems for parabolic, elliptic and hyperbolic PDEs.
4. Perform large sample test and small sample testing of Hypothesis as well as calculate confidence interval for a population parameter for real time data.
5. Classify and apply the related analysis of variance techniques in all fields of scientific experimentation.

TEXT BOOKS:

1. Richard A. Johnson, "Miller and Freund's Probability and Statistics for Engineers, Pearson Education, Asia, 3rd Edition, 2013.
2. Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2015
3. Jain M. K., Iyengar S.R.K, Jain M. K., "Computational Methods for Partial Differential Equations", New Age international Publishers, 2007.

REFERENCES:

4. Gupta S.C. and Kapoor V.K., "Fundamentals of Mathematical Statistics", Sultan and Sons, New Delhi, 2005.
5. Arora P.N., Sumeet Arora and Arora S., "Comprehensive Statistical Methods", 3rd edition, S.Chand and company Limited, 2010.
6. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", 9th Edition, Cengage Learning, New Delhi, 2011
7. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, Third Edition 2015.

WEBLINKS:

1. <https://nptel.ac.in/courses/111/107/111107105/>
2. <https://nptel.ac.in/courses/111/107/111107063/>
3. <https://nptel.ac.in/courses/103/106/103106112/>

COURSE ARTICULATION MATRIX

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

CL22101 ADVANCED THERMODYNAMICS FOR CHEMICAL ENGINEERS

| L | T | P | C |
|----------|----------|----------|----------|
| 3 | 1 | 0 | 4 |

COURSE OBJECTIVES:

1. To introduce the basic concepts of chemical engineering thermodynamics and Maxwell's relations
2. To introduce phase transition and thermodynamic properties from volumetric and thermal data.
3. To acquaint the student with Wilson, NRTL, UNIQUAC equations and UNIFAC methods for ideal and non-ideal solutions.
4. To acquaint the student with pressure on vapor liquid equilibrium used in wide variety of situations.
5. To introduce the chemical equilibrium for the homogeneous gas and liquid phase reactions

UNIT I BASIC CONCEPTS 12

Energy and first Law; Reversibility and second Law; Review of Basic Postulates, equilibrium criteria, Legendre Transformation and Maxwell's relations.

UNIT II STABILITY AND PHASE TRANSITION 12

Stability of thermodynamic systems, first order phase transitions and critical phenomenon, phase rule, single component phase diagrams, thermodynamic properties from volumetric and thermal data.

UNIT III MULTICOMPONENT MIXTURES 12

Partial molar properties, fugacities in gas and liquid mixtures, activity coefficients, Ideal and Non-ideal solutions, Gibbs-Duhem equation, Wilson, NRTL, and UNIQUAC equations, UNIFAC method.

UNIT IV PHASE EQUILIBRIUM 12

VLE-Equations of state, corresponding states, Henry's Law, criticality, high pressure VLE. Other phase equilibria-SLE/LLE/VLLE.

UNIT V –CHEMICAL EQUILIBRIUM 12

Homogeneous gas and liquid phase reactions, heterogeneous reactions—phase and chemical equilibrium.

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Analyze the basic concept of fluid phase equilibria and Maxwell's relations.
2. Assess the stability and phase equilibria of the thermodynamic systems.
3. Explain the Wilson, NRTL, UNIQUAC equations and UNIFAC methods for ideal and non-ideal solutions.
4. Develop phase equilibrium based on vapor liquid equilibrium.
5. Identify chemical equilibrium for the homogenous gas and liquid phase reactions.

TEXT BOOKS:

1. Tester, J.W. and M. Modell, Thermodynamics and Its Applications, 3rd Edn, Prentice Hall, New Jersey, 1997
2. Rao, Y.V.C., Chemical Engineering Thermodynamics, University Press, Hyderabad, 2005

REFERENCES:

3. Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular Thermodynamics of fluid-phase Equilibria, 3rd Edn, Prentice Hall Inc., New Jersey, 1999
4. Dodge, B.F., "Chemical Engineering Thermodynamics", McGraw-Hill, 1960.
5. Smith, J.M., Van Ness, H.C., & Abbot M.C., "Introduction to Chemical Engineering Thermodynamics", McGraw Hill VII Edition 2004.
6. Narayanan K.V. "A Text Book of Chemical Engineering Thermodynamics" 53 Prentice Hall of India Pvt. Ltd. 2001.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 3 |
| 2. | 3 | 1 | 3 | 1 | 2 | 3 | 3 | 3 |
| 3. | 2 | 1 | 3 | 2 | 3 | 3 | 3 | 3 |
| 4. | 3 | 1 | 2 | 3 | 3 | 3 | 3 | 3 |
| 5. | 3 | 1 | 3 | 3 | 3 | 2 | 3 | 3 |

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

COURSE OBJECTIVES:

1. To impart knowledge on advanced separation processes and the selection of separation processes.
2. To enable students to understand the principles and processes of adsorption, membrane separation and chromatography and to design a membrane unit to achieve a specified separation
3. To introduce reactive separation technologies and its applications in Industries

UNIT I SEPARATION PROCESS**9**

Absorption, Adsorption, Distillation, Drying, Extraction, Leaching, Crystallization. Advances in separation techniques based on size, surface properties, ionic properties. Process concept, theory and equipment used in cross flow filtration, cross flow electro-filtration, dual functional filter, surface based solid-liquid separations involving a second liquid, siflofilter.

UNIT II MEMBRANE SEPARATIONS**15**

Types and choice of membranes, Plate and frame, spiral wound membranes, Tubular and hollow fiber membrane reactors, Membrane Permeates: Dialysis, Reverse osmosis, Nano filtration, ultra filtration, microfiltration, Donnan dialysis, Ceramic membranes, Membrane fouling, Economics of membrane operations. Characteristics of organic and inorganic membranes, basis of membrane selection, osmotic pressure, partition coefficient and permeability, concentration polarization. Liquid membrane separation, adsorptive separation-pressure, vacuum and thermal swing.

UNIT III IONIC SEPARATION**7**

Controlling factors, applications, types of equipment employed for electrophoresis, di-electrophoresis, ion exchange chromatography and electro dialysis, commercial process

UNIT IV REACTIVE SEPARATION PROCESSES**7**

Reactive distillation, extraction with reaction, absorption with reaction, adsorption with reaction, reactive membrane separation, reactive crystallization.

UNIT V – OTHER TECHNIQUES**7**

Separations involving lyophilization, pervaporation and permeation techniques for solids, liquids and gases, industrial viability and examples, zone melting, additive crystallization, supercritical fluid extraction.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Assess the recent advances in separation techniques based on the properties of substances.
2. Analyze the mechanism and equipment used in various membrane separation techniques.

3. Identify the mechanism and equipment used in ionic separations.
4. Assess the importance of Reactive separation Process.
5. Identify the importance of advanced separation techniques used in Industry.

TEXT BOOKS:

1. Separation Processes Principles, J.D. Seader, Ernest J. Henley, D. Keith Roper, John Wiley & Sons, 2011, 3rd Edition.
2. Transport Processes and Unit Operations, Geankoplis C. J., Prentice Hall of India Pvt. Ltd., New Delhi, 2004, 4th Edition.
3. KaushikNath, *Membrane Separation processes*, PHI, New Delhi 2008.

REFERENCES:

4. Nakagawal, O. V., “Membrane Science and Technology”, Marcel Dekker, 1992
5. Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
6. Phillip C. Wankat , Separation Process Engineering (2nd Edition),Prentice Hall,2007
7. Reactive Separation Processes, Santi Kulprathipanja, Taylor & Francis, 2002.
8. Rousseau, R. W., “Handbook of Separation Process Technology”, John Wiley, New York,
9. King C.J., “Separation Processes”, Tata McGraw Hill. 1982.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 1 | 1 | 3 | 2 | 3 | 2 | 3 | 3 |
| 2. | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3. | 1 | 1 | 3 | 2 | 3 | 2 | 3 | 3 |
| 4. | 1 | 1 | 3 | 2 | 3 | 2 | 3 | 3 |
| 5. | 1 | 1 | 3 | 2 | 3 | 1 | 3 | 3 |

1- Slight (Low), 2- Moderate (Medium) , 3- Substantial (High)

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 4 |

COURSE OBJECTIVES:

1. To study the design of heterogeneous reactors.
2. To learn the energy balance, temperature and concentration profiles in different reactors.
3. To analyze the advanced design aspects of multiple reactors.
4. To gain insight on the importance of population balance of particles.
5. To understand the role of Reaction Engineering in the mitigation of Global warming.

UNIT I**12**

Non-elementary Kinetics Importance: Approximations for formulations of Rate laws, Formulations of Kinetic model - Effect of flow on conversions in Reactors: Semibatch Reactors: Importance and examples of applications - Material Balance on Semibatch Reactor – Multiple reaction in Semibatch Reactors, Conversion vs. Rate in Reactors.

UNIT II**12**

Multiple Reactor systems with CSTR's: Exothermic and Endothermic Reaction with examples, CSTR with heat effects, multiple reactions in CSTR and PFR with heat effects, Semi batch Reactors with heat exchange. Design of PFR and Packed Bed Tubular Reactors: Volume of reactors calculations for non-isothermal reactors. Optimal Design of Reactors for Reversible exothermic reactions: Heat effects in semi batch unsteady state operation. Auto thermal Plug flow reactors and packed tubular reactors. PFR with inter stage cooling. Examples of optimal design of PFR and Semi batch and CSTR Exothermic Reactions.

UNIT III**12**

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

UNIT IV**12**

Fluidized bed reactor modeling: Fixed bed vs fluidized bed Why fluidized bed, important parameters pressure drop in fixed bed, Class I model Arbitrary Two Region Flow Models, Class II Chemical Reactor: Plug Flow or Mixed Flow Model.

UNIT V**12**

Application of Population Balance Equations for reactor modeling: Particle size distribution, Distribution Functions in Particle Measuring Techniques, Particle distribution model in colloidal particle synthesis in batch reactor, Moments of Distribution, Nucleation rate based on volumetric holdup versus crystal growth rate. Reaction engineering and mitigation of Global warming: CO₂ absorption in high pressure water, different techniques of mitigation of CO₂, methods of separations.

Recent advancements, automotive monolith catalytic converter example, removal and utilization of CO₂ for thermal power plants.

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Evaluate heterogeneous reactor performance considering mass transfer limitations.
2. Acquire knowledge on energy balance and obtain concentration profiles in multiphase reactors.
3. Estimate the performance of multiphase reactors under non-isothermal conditions.
4. Enumerate modern reactor technologies for mitigation of global warming.
5. Model population balance equations for batch, continuous and catalytic reactor modelling.

TEXT BOOKS:

1. Denbigh K.G. and Turner J.C.R., "Chemical Reactor Theory: An Introduction", 3rd Edition, Cambridge University Press, 1984.
2. Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, Wiley India, 2006.

REFERENCES:

1. Smith J.M., "Chemical Engineering Kinetics", 3rd Edition, McGraw-Hill Education, 1981.
2. Fogler H.S., "Elements of Chemical Reaction Engineering" 4th Edition, Prentice Hall India, 2008.
3. Froment G.F., Bischoff K.B. and Wilde J.D. "Chemical Reactor Design and Analysis" 3rd Edition, Wiley, 2010.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |
| 2. | 3 | 1 | 2 | 2 | 2 | 2 | 3 | 3 |
| 3. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 4. | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 |
| 5. | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 2 | 4 |

COURSE OBJECTIVES:

1. To understand the basics of model construction.
2. To learn about solving model equations and validation of the models.
3. To apply degree of freedom analysis to find out solution of linear and non-linear chemical system
4. To develop mathematical models for chemical processes
5. To analyze and simulate heat exchangers and reactors

UNIT I INTRODUCTION**15**

Introduction to modeling and simulation, classification of mathematical models, conservation equations, and auxiliary relations.

Lab Experiments:

1. Simulation studies of various unit operations using Aspen Plus
2. Thermodynamic property estimations using property estimation and property analysis in Aspen.

UNIT II STEADY STATE LUMPED SYSTEMS**15**

Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flow sheeting – sequential modular and equation-oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations.

Lab Experiments:

3. Simulate Mixer, splitter, heat exchangers, and reactive distillation column.
4. Solve linear and non-linear programming problems.

UNIT III UNSTEADY STATE LUMPED SYSTEMS**15**

Analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ODE initial value problems, matrix differential equations, simulation of closed loop systems.

Lab Experiments:

5. Simulation of Ideal Binary Distillation Column
6. Apply sensitivity, design specification and case study tools in Aspen

UNIT IV STEADY STATE DISTRIBUTED SYSTEM**15**

Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

Lab Experiments:

7. Simulation of Heat/Mass Transfer coefficient in 3 phase fluidized bed column
8. Modeling and Simulation of cyclone separator

UNIT V UNSTEADY STATE DISTRIBUTED SYSTEM**15**

Analysis laminar flow in pipe, sedimentation, boundary layer flow, conduction, heat exchanger, heat transfer in packed bed, diffusion, packed bed adsorption, plug flow reactor, hierarchy in model development, classification and solution of partial differential equations – Empirical

modeling, parameter estimation, population balance and stochastic modeling.

Lab Experiments:

9. CFD Simulation of flow over a flat plate
10. CFD Simulation of flow over a sphere.

TOTAL: 75 PERIODS

OUTCOMES:

1. Upon successful completion of the course, students should be able to:
2. To impart knowledge on the fundamentals of modeling and simulation, system analysis and evaluation.
3. Apply degree of freedom analysis to find out solution of linear and non-linear chemical system.
4. Develop mathematical model for Chemical Processes and simulate tank systems.
5. Analyze and simulate heat exchangers and reactors, and identify the solution of boundary value problems.
6. Evaluate the mathematical model and validate with the simulation results obtained in the chemical processes.

TEXT BOOKS:

1. Ramirez, W., "Computational Methods in Process Simulation", 2nd Edn., Butterworths, New York, 2000.
2. Luyben, W.L., "Process Modelling Simulation and Control", McGraw-Hill Book Co.,1973.

REFERENCES:

1. Asghar Husain, "Chemical Process Simulation", Wiley, 1986
2. Felder, R. M. and Rousseau, R. W., "Elementary Principles of Chemical Processes", John Wiley, 2000.
3. Franks, R. G. E., "Mathematical Modelling in Chemical Engineering", John Wiley, 1967.

At the end of the course add the Course articulation matrix as per the following format:

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 2. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 3. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 4. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 5. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |

CL22111 INSTRUMENTAL METHODS OF ANALYSIS LABORATORY

| | | | |
|----------|----------|----------|----------|
| L | T | P | C |
| 0 | 0 | 4 | 2 |

COURSE OBJECTIVES:

1. Introduction of the student to the fundamentals of instrumental methods of spectroscopic and chemical analysis.
2. Development of the capability of choosing the instrumental technique suitable to best solving a specific analytical problem.
3. Introduction of the role of instrumental analytical quality control.
4. Acquire knowledge about the widely used analytical Instruments
5. Train students to perform practical work on real samples to get acquainted with instrumentation and equipment which is needed in monitoring of environmental pollution.

LIST OF EXPERIMENTS:

1. Analysis of Sample Mixture Using Gas Chromatography
2. High Performance Liquid Chromatography (HPLC)
3. Thermo-gravimetric Analysis
4. Estimation of Amount of Copper and Chromium in the given water sample
5. Estimation of Iron in the given water sample
6. Cyclic Voltametry
7. Tafel Plot
8. Determination of Absorption Curve and Concentration of different dyes using UV-Visible Spectrophotometer
9. Determination of Chromium and Manganese Concentration in solution
10. Determination of Arsenic in solution

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon successful completion of the course, students should be able to:

- CO1:** Estimate the heavy metal quantity present in sample using Atomic Absorption \ Spectroscopy (AAS).
- CO2:** To impart knowledge on the importance and applications of UV visible spectrophotometer analysis.
- CO3:** Assess the skill of operating Gas Chromatography for the analysis of fluids samples.
- CO4:** Assess the skill of operating High Performance Liquid Chromatography for the analysis of liquid samples.
- CO5:** Explore knowledge on determination of standard redox potential and corrosion rate of a given sample.

At the end of the course add the Course articulation matrix as per the following format:

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----------|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 1 | 2 | 1 | 1 | 2 | 3 | 3 | 3 |
| 2. | 3 | 1 | 3 | 1 | 1 | 2 | 3 | 3 |
| 3. | 2 | 1 | 3 | 2 | 2 | 1 | 3 | 3 |
| 4. | 1 | 3 | 1 | 2 | 2 | 1 | 3 | 3 |
| 5. | 2 | 2 | 1 | 3 | 1 | 2 | 3 | 3 |

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 4 |

COURSE OBJECTIVES:

1. To familiarize the student with basic concepts of transport phenomena and brief review of mathematics.
2. To enable students to understand the equations of change for isothermal flow and for nonisothermal flow.
3. To introduce them to the equations of change for multi component systems and aspects of dimensional analysis.
4. To equip the students to perform macroscopic balances involving transport properties.

UNIT I EQUATIONS OF CHANGE FOR ISOTHERMAL SYSTEMS**12**

Equation of Continuity, Equation of Motion, Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, Dimensional Analysis of the Equations of Change. Velocity Distributions with more than one Independent Variable: Time Dependent Flow of Newtonian Fluids. Time Smoothed equation of velocity, temperature and concentration.

UNIT II EQUATIONS OF CHANGE FOR NON ISOTHERMAL SYSTEMS**12**

The Energy Equation, Special forms of the Energy Equation, The Boussinesq Equation of Motion for Forced and Free Convection, Use of the Equations of change to Solve Steady-State Problems, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems. Temperature Distributions in Solids and in Laminar Flow. Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids, Steady Heat Conduction in Laminar, Incompressible Flow and Empirical Expressions for the Turbulent Heat Flux.

UNIT III EQUATIONS OF CHANGE FOR BINARY/MULTI COMPONENT SYSTEMS**12**

Concentration Distributions with more than One Independent Variable: Time-Dependent Diffusion, Steady-State Transport in Binary Boundary Layers, Time-Smoothing of the Equation of Continuity for binary system, Semi-Empirical Expressions for the Turbulent Mass Flux. Interphase Transport in Multi-Component Systems: Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions

UNIT IV MACROSCOPIC BALANCES – PART I**12**

Macroscopic Balances for Isothermal Systems: The Macroscopic Mass Balance, Momentum Balance, Mechanical Energy Balance, Estimation of the Viscous loss, Use of the Macroscopic Balances for Steady-State Problems, Macroscopic Balances For Non-Isothermal Systems: Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use Of The Macroscopic Balances To Solve Steady State Problems With Flat Velocity Profiles

UNIT V MACROSCOPIC BALANCES – PART II**12**

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

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Remember and apply the fundamental knowledge involving Equations of Change for Isothermal systems.
2. Acquire and apply the fundamental knowledge involving Equations of Change for Non – Isothermal systems.
3. Gain and apply the fundamental knowledge for Interface transport and estimating the concentration distributions among different scenarios
4. Practice the skill of preparing model in macroscopic scale for Isothermal and Non – Isothermal systems.
5. Analyze and/or construct the macroscopic model for any Multi Component systems.

TEXT BOOKS:

1. R.B. Bird, W.E. Stewart and E.W. Lightfoot, “Transport Phenomena”, John Wiley, Second Edition 2006.
2. Robert, S Brodkey, Harry C. Hershey, “Transport Phenomena A Unified Approach”, Brodkey Publishing 2003.

REFERENCES:

1. J.R. Welty, R.W. Wilson, and C.W.Wicks, Rorer G.E, Wilson R.W. “Fundamentals of Momentum Heat and Mass Transfer”, V Edition. John Wiley, New York, 2008
2. W.M.Deen.”Analysis of Transport Phenomenon”, II Edition, Oxford University Press, 2013.
3. Robert J Kee, Michael E Coltrn, Peter Glarborg, “Chemically Reacting Flow”, II Edition, Wiley,2018.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 |
| 2. | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 |
| 3. | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 |
| 4. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| 5. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |

<3 – Strong, 2 – Moderate, 1 – Weak>

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

COURSE OBJECTIVES:

- 1) To introduce dynamic response of open and closed loop systems, control loop components.
- 2) To analyze the stability of control systems along with instrumentation.
- 3) To study multi-variable control strategies.

UNIT I ADVANCED CONTROL STRATEGIES**9**

Introduction to advanced control strategies, Feed forward control, Cascade control, dead time compensator, splitrange control, selective and override control; automatic tuning and gain scheduling.

UNIT II INTERNAL MODEL CONTROL**9**

Model based control–internal model control: Structure; development and design; internal model control based PID controller design, Case studies.

UNIT III MULTI-VARIABLE CONTROL**9**

Control loop interaction: general pairing problem, relative gain array and application, sensitivity. Multivariable control: zeros and performance limitations, directional sensitivity and operability, decoupling, Case studies

UNIT IV DISCRETE SYSTEMS**9**

Z–Transform, Initial and final value theorems, properties, inverse Z– transform, Discrete– Time Response of dynamic system, Pulse Transfer Function, Closed Loop System Stability.

UNIT V DIGITAL FEEDBACK CONTROLLERS**9**

Design of digital feedback controllers, digital approximation of classical, effect of sampling, Dahlin’s algorithms, Dead–beat algorithm, ringing, IMC algorithm, simplified model predictive algorithm.

TOTAL: 45 PERIODS**OUTCOMES:**

- 1) Describe the dynamic response of advanced control systems.
- 2) Develop and design Internal Model based PID control system.
- 3) Enumerate the control loop interaction and multi-variable control strategies.
- 4) Acquire knowledge on discrete-time response of dynamic system.
- 5) Design of digital feedback controllers.

TEXT BOOKS:

- 1) Bequette, B.W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2003.
- 2) Coughnowr,D,“ProcessSystemsAnalysisandControl“,3rdEdn.,McGrawHill,New York, 2008.

REFERENCES:

- 1) Stephanopolous, G., "Chemical Process Control", Prentice Hall of India, New Delhi, 2003.
- 2) Pradeep B. Deshpande, Raymond H. Ash, Elements of Computer Process Control with Advanced Control Applications, Instrument Society of America, 1981.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| 2. | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 3 |
| 3. | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 3 |
| 4. | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| 5. | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |

| L | T | P | C |
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COURSE OBJECTIVES:

To impart knowledge on formulation of research problem, research methodology, ethics involved in doing research and importance of IPR protection.

UNIT I RESEARCH METHODOLOGY**9**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations. Effective literature studies approaches, analysis Plagiarism, Research ethics

UNIT II RESULTS AND ANALYSIS**9**

Importance and scientific methodology in recording results, importance of negative results, different ways of recording, industrial requirement, artifacts versus true results, types of analysis (analytical, objective, subjective) and cross verification, correlation with published results, discussion, outcome as new idea, hypothesis, concept, theory, model etc.

UNIT III TECHNICAL WRITING**9**

Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT IV INTELLECTUAL PROPERTY RIGHTS**9**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT V PATENT RIGHTS AND NEW DEVELOPMENTS IN IPR**9**

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Critically evaluate any research article based upon research methodology.
2. Correlate the results of any research and develop hypothesis, concept, theory and model.
3. Developing a research proposal, research presentation and review article in the field of engineering.
4. Enumerate the importance of intellectual property right in research.
5. Develop proposal for patent rights and identify the new developments in IPR

TEXT BOOKS:

1. Ranjit Kumar, Research Methodology- A step by step guide for beginners, Pearson Education, Australia, fourth edition, 2014
2. Ann M. Korner, Guide to Publishing a Scientific paper, Bioscript Press 2008
3. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

REFERENCES:

1. Kothari, C. R. Research Methodology - Methods and Techniques, New Age International publishers, New Delhi, fourth edition, 2019
2. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students”, Juta & Company, 1996.
3. Robert P. Merges, Peter S. Menell and Mark A. Lemley, “Intellectual Property in New Technological Age”, Aspen Publishers, 2016.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 |
| 2. | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 |
| 3. | 3 | 3 | 3 | 3 | 3 | - | 3 | 3 |
| 4. | 2 | 2 | 3 | 2 | 2 | 1 | 3 | 3 |
| 5. | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 3 |

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| 3 | 0 | 0 | 3 |

OBJECTIVES:

To impart the knowledge on chemical engineering design of process Equipments

UNIT I DESIGN INFORMATION & FLUID MOVING EQUIPMENTS 10

General sources of physical properties, Accuracy required of engineering data, Prediction of physical properties. Flow of fluids: Properties and units, pipeline networks, optimum pipe diameter, non-Newtonian liquids. Pumps: Type, selection, performance curves, pump efficiency, NPSH, Head calculations, & power calculation. Compressors: Type, selection, performance curves, Head calculations and power calculations.

UNIT II HEAT TRANSFER EQUIPMENTS 10

Process Design of Heat Exchanger: Basic design procedure and theory, Design and sizing of Shell and Tube Heat exchangers with types and arrangements of fluids, plate type heat exchanger. Mechanical design of heat exchanger: Mechanical design of shell & tube heat exchanger. Condensers: Heat-transfer fundamentals. Design of vertical and horizontal condensers. Reboilers: Boiling heat-transfer fundamentals, Pool boiling, Convective boiling, Design of forced-circulation reboilers.

UNIT III HEAT TRANSFER EQUIPMENTS 10

Design of evaporator: Introduction, types of evaporators, methods of feeding of evaporators, general design and consideration of evaporator.

UNIT IV PROCESS DESIGN OF MASS TRANSFER COLUMNS 8

Design of driers: Introduction, types driers, design consideration of driers. Design of distillation and absorption column :Packed columns: Types of packing, Packed-bed height, Prediction of the height of a transfer unit (HTU), Column diameter (capacity), Column sizing approximation, Plate contactors and Plate hydraulic design

UNIT V PRESSURE VESSELS 7

Design of Pressure vessels Codes & Standards, selection of material, vessels operating at low temperatures and elevated temperatures, design conditions and stress, design of shell and its components, supports, stress from local loads and thermal gradients, thermal stresses in cylindrical shell.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

1. Impart knowledge on design information and data and Outline the essentials of fluid movers and related items.
2. Instruct the basics of process design of heat transfer equipments.
3. Apply the knowledge on heat transfer equipments.
4. Identify the methods of process design of separation columns.
5. Pertain the mechanical design of Pressure vessels

TEXT BOOKS

1. J.M. Coulson, J. Richardson, "Chemical Engineering", Vol. 6, Asian Books Printers, Fourth edition 2005.
2. M.V. Joshi, V.V. Mahajan, "Design of Process Equipment Design", Third edition, McMillan India, 1996.

REFERENCE BOOKS

1. R.H. Perry, "Chemical Engineers Handbook", Seventh Edition, McGraw Hill, 2004.
2. Brownell and Young, "Process Vessel Design", Wiley Eastern, 2009.
3. Ray Sinnott, Gavin Towler, Chemical Engineering Design - Principles, Practice and Economics of Plant and Process Design, Butterworth-Heinemann, 2007

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |
| 2. | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |
| 3. | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |
| 4. | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 3 |
| 5. | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 |

CL22204 SOFTWARE APPLICATIONS IN CHEMICAL INDUSTRIES (INTEGRATED)

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 2 | 4 |

COURSE OBJECTIVES:

1. To introduce the concepts of process plant simulation
2. To familiarize the computer – aided analysis of chemical processes
3. To gain knowledge on the use of Process simulation software
4. To understand the applications of Computational Fluid Dynamics in Chemical Industries
5. To acquaint with the machine learning algorithms and data analytics

UNIT I INTRODUCTION TO PROCESS SIMULATION 15

Introduction to Process Plant Simulation – Applications – Types of Chemical Process Simulators – Information Flow Diagram – Flow Sheetting Approaches – Convergence Analysis – Sensitivity Analysis – Design Specifications

Introduction to simulation software – ASPEN PLUS, HYSYS, MATLAB, ANSYS CFD

UNIT II COMPUTATIONAL FLUID FLOW AND HEAT TRANSFER 15

Governing Equations of Fluid Flow and Heat Transfer – Time Averaged Navier - Stokes Equation - Turbulence models – Finite Difference Approximation – Finite Volume Method – Convection – diffusion problems – Flow field Computation Algorithms – Grid Generations – CFD Simulation of fluid flow and heat transfer using ANSYS

UNIT III PROCESS PLANT SIMULATION USING ASPEN PLUS AND HYSYS 15

Simulation of pumps, compressors, expanders; Heat Exchange equipments – Shortcut and rigorous calculation methods – Process Heat Integration – Energy Analysis – Reactors – Separation columns

UNIT IV DYNAMIC SIMULATION AND OPTIMIZATION 15

Introduction to Dynamic Simulation – Control of distillation columns, pressure relief valves, Flow, level, temperature control

Formulation of Optimization problem – Plant-wide optimization – Non-traditional optimization techniques – Meta - Heuristic Algorithms – simulated annealing – genetic algorithms – differential evolution – Particle Swarm Optimization

UNIT V DATA ANALYTICS AND MACHINE LEARNING 15

Introduction to Machine Learning and Data analytics – Regression Analysis – Classification and Clustering – Support Vector Machines for regression and classification – Application of Artificial Neural Networks in process plant simulation – Neural Network based optimization – Machine Learning algorithms – Industry 4.0

TOTAL: 75 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Perform computer aided analysis of Chemical Industries
2. Execute steady state and dynamic simulation of process plants
3. Apply Computational Fluid Dynamics software to solve fluid flow and heat transfer problems
4. Formulate and Solve optimization problems using software tools
5. Apply machine learning algorithms in process plant simulation

TEXT BOOKS:

1. I.D. Gil Chaves, "Process Analysis and Simulation in Chemical Engineering", Springer, Switzerland, 2016.
2. Anderson, J. D., "Computational Fluid Dynamics: The Basics with Applications", McGraw Hill, 2012.
3. I.M. Mujtaba and M.A. Hussain, "Application of Neural Networks and other learning technologies in Process Engineering", World Scientific Publishing Company, 2006.
4. T.F. Edgar, D.M. Himmelblau and L.S. Lasdon, "Optimization of Chemical Processes", McGraw-Hill, 2001.

REFERENCES:

1. Luyben, W.L., "Process Modelling Simulation and Control", McGraw-Hill Book Co., 1973.
2. Asghar Husain, "Chemical Process Simulation", Wiley, 1986.
3. Juma Haydary, "Chemical Process Design and Simulation: Aspen Plus and Aspen Hysys Applications, Wiley, 2019.
4. B.V. Babu, "Process Plant Simulation", Oxford University Press, 2004.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |
| 2. | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |
| 3. | 3 | 2 | 3 | 3 | 1 | 3 | 3 | 3 |
| 4. | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |
| 5. | 3 | 2 | 3 | 3 | 1 | 3 | 3 | 3 |

1-Weak, 2-Medium, 3-strong

CL22211

ADVANCED CHEMICAL ENGINEERING LABORATORY

| L | T | P | C |
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| 0 | 0 | 4 | 2 |

COURSE OBJECTIVES:

1. Analyze characteristics of a fluidized bed dryer, compact heat exchangers, electrochemical phenomena such as corrosion.
2. Evaluate the performance of a process intensification in catalytic reactions, ultrasound assisted reactions, reactive distillation column, micro reactor and advanced flow reactor.
3. Design controller for a given process and evaluate the performance of membrane separation process for water purification.

LIST OF LABORATORY EXPERIMENTS

1. Ultrasonic cavitation based reactions
2. Helical Coil heat exchanger
3. Plate Type Heat Exchanger
4. Kinetics for solid catalyzed esterification reaction in a batch reactor
5. Reactive distillation in Packed Column
6. Characteristics of a fluidized bed dryer
7. Advanced Flow Reactor
8. Membrane Separation for water purification
9. Corrosion characteristics of a metal in a given electrolyte
10. Control of liquid level in non-interacting systems.
11. Identification and control of a three tank system.
12. pH control in a process.

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Evaluate the characteristics of a fluidized bed dryer, compact heat exchangers, electrochemical phenomena such as corrosion.
2. Evaluate the performance of process intensification in various reactors and reactive distillation column.
3. Design controller and determine the performance of membrane separation process for water purification.
4. Identify the use of PID for Control of liquid level in interacting and non-interacting systems
5. Distinguish the corrosion characteristics of a metal in different electrolytes.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 2. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 3. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 4. | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| 5. | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 3 |



CL22001 ELECTROCHEMICAL PROCESSES FOR CLEAN TECHNOLOGY

| L | T | P | C |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

COURSE OBJECTIVES:

1. To introduce the basic concepts of electrochemical reactor for electrode material synthesis followed by effluent treatment.
2. To enable the students to understand the different types of electrochemical reactor design.
3. To impart knowledge of transport in various membranes and diaphragms.
4. To acquaint the student with the treatment of wastewater containing organic and inorganic compounds using electrochemical processes.
5. To understand the different types of organic electro synthesis, limitations and the scope of electro synthesis.

UNIT I THE ELECTROCHEMICAL CELL AND REACTOR**9**

The electrochemical cell, Faraday's Law and current efficiency, Electrode potential and current density, The Electrochemical reactor – Production Capacity, Energy Requirements and Cell Voltage, Temperature Control, Hydrodynamics and mass transport, Reactor Operating Factors. Electrode Materials – Chemical Suitability, Electrode Materials in Synthesis and Effluent treatment.

UNIT II ELECTROCHEMICAL CELL DESIGN AND ENGINEERING**9**

Operating Factors in Electrochemical Reactor Design – Modes of Operation, In-cell and Excell Reactions, Recycle Operation, Electrical Power supply, Distribution of Powers in Electrolysers. Cell Design, Design Concepts. Electrochemical Reactor Designs – Parallel Plate. Electrolysers, General Purpose Flow Electrolyser, Other Reactor Design, Reactor Design for Multiphase Reactions. Electrochemical Reactor Analysis, Mass Transport and Reactor Design.

UNIT III ELECTROCHEMICAL MEMBRANE PROCESS**9**

Transport in Membranes and Diaphragms- Transport Process in Diaphragms, Membrane and the Transport of Ions. Ion-Selective Membranes in Salt Regeneration, Recycling and Effluent Treatment, Electro hydrolysis, Treatment of Plating Bath Rinse Waters and Waste Streams. Bipolar Membranes, Characteristics of Bipolar Membranes. Electrochemically enhanced Microfiltration and Ultra filtration.

UNIT IV TREATMENT OF INDUSTRIAL PROCESS STREAMS AND EFFLUENTS**9**

Treatment of Organic Chemicals-Direct Anodic Oxidation, Chlorine and Chlorinated compounds, Indirect Oxidation Process. Treatment of Waste Water Containing Inorganic Compounds- Cyanides and Thiocyanates, Chromium Liquors, Sterilisation of Water and Waste. Metal Recovery by Electrode position- Electrode position from Single Metal Ion Solutions, Metal separation from Mixed Metal Ion solutions, Combined Electrochemical Processes.

UNIT V ORGANIC AND INORGANIC ELECTROCHEMICAL SYNTHESIS**9**

Types of Organic Electro synthesis, Limitations in Solubility, Indirect electro synthesis, Heterogeneous Redox Catalysis, Electrosorbed hydrogen, Direct electro organic Synthesis, Examples of electro organic Synthesis. Inorganic electrochemical Process- The Electro winning and Refining of Metals, Electrochemical Generation of Arsine, Other Processes, The scope for Inorganic Electro synthesis.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Understand the basic principles of electrochemistry and electrochemical reactor for electrode material synthesis.
2. Design various electrochemical reactor using various mechanisms and theories of mass transfer.
3. Apply the principles of electrochemistry in mitigating the various membranes and diaphragms.
4. Describe the various electro deposition techniques and electro chemical energy storage systems.
5. Establish the fundamental knowledge of electrodes used in different electrochemical industries and its design.

TEXT BOOKS:

1. Scott. K., "Electrochemical processes for clean technology", Standards media, 1995
2. Goodridge F., Scott K., "Electrochemical Process Engineering. A guide to the design of electrolytic plant", Plenum press, 1995.
3. Cynthia, Zoski. G., "Handbook of electrochemistry", 1st edition, Elsevier science, 2007.
4. Picket, "Electrochemical Engineering", Prentice Hall, 1977.

REFERENCES:

1. Marcel Mulder, "Basic Principles of Membrane Technology", 2nd edition, Kluwer Academic Publishers, 2003.
2. Krishnan Rajeshwar, Jorge G. Ibanez, "Environmental Electrochemistry, Fundamentals and applications in Pollution Abatement", Academic Press, Inc, 1997.
3. Scott K., "Electrochemical reaction engineering", London, Academic Press, 1991.

At the end of the course add the Course articulation matrix as per the following format:

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 1 | 1 | 2 | 1 | 1 | 3 | 3 |
| 2. | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 |
| 3. | 3 | 1 | 2 | 3 | 2 | 1 | 3 | 3 |
| 4. | 2 | 1 | 2 | 3 | 2 | 1 | 3 | 3 |
| 5. | 3 | 1 | 2 | 3 | 2 | 1 | 3 | 3 |

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COURSE OBJECTIVES:

1. To impart knowledge on solar radiation and its measurements.
2. To develop and design an efficient solar energy collector.
3. To design various applications powered by solar energy systems.
4. To understand the basic concept of photo voltaic cell construction.
5. To differentiate the various solar energy storage systems.

UNIT I SOLAR RADIATION AND MEASUREMENTS**9**

Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyrogeometer, net pyradiometer-sunshine recorder, Solar Energy Industry in India, Advantages of Solar Energy, Solar Energy Potential in Industries.

UNIT II SOLAR ENERGY COLLECTOR SYSTEMS**9**

Solar Non-Concentrating Collectors- Design considerations – Classification air, liquid heating collectors –Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector - Solar green house, Solar space heating and cooling, Solar pumping systems.

UNIT III SOLAR POWERED SYSTEMS**9**

Design – Classification– Concentrator mounting –Focusing solar concentrators Heliostats. Solar powered absorption A/C system, water pump, chimney, drier, dehumidifier, still, cooker, Solar energy applications/solar energy gadgets, Construction details and application of wind mills.

UNIT IV SOLAR PHOTOVOLTAIC SYSTEMS**9**

Photo-voltaic cell – characteristics-cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts, Solar photovoltaic systems, solar lantern, solar street lights, solar fencing.

UNIT V ENERGY STORAGE SYSTEMS**9**

Energy Storage -Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds, Solar ponds, Solar grain dryers, solar refrigeration system.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Gain the knowledge on solar energy radiation, availability, solar energy potential in Industries.
2. Differentiate the design of concentrating and non-concentrating collectors with pumping systems.

3. Design an efficient solar powered gadgets, solar cookers and water heating systems.
4. Perform the calculation, analyse and optimize various parameters associated with the solar energy for a specific geography.
5. Compare the different types of energy storage systems based on transport processes.

TEXT BOOKS:

1. Yogi Goswami D., Frank Kreith, Jan. F. Kreider, “Principles of Solar Engineering”, 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003.
2. Edward E. Anderson, “Fundamentals for solar energy conversion”, Addison Wesley Publ. Co., 1983.

REFERENCES:

1. Duffie J. A and Beckman, W. A., “Solar Engineering of Thermal Process”, John Wiley, 1991.
2. Tiwari G. N. and Ghosal M. K., “Fundamentals of Renewable energy Sources”, Narosa Publishing House, New Delhi, 2007.
3. Shepherd W and Shepherd D. W., “Energy Studies”, Second Edition, Imperial College Press, London, 2004.

At the end of the course add the Course articulation matrix as per the following format:

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 1 | 3 | 3 | 3 | 1 | 2 | 2 |
| 2. | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 |
| 3. | 3 | 1 | 3 | 3 | 3 | 1 | 2 | 2 |
| 4. | 2 | 2 | 2 | 2 | 3 | 1 | 2 | 2 |
| 5. | 3 | 2 | 3 | 3 | 3 | 1 | 2 | 2 |

3 – Strong, 2 –Moderate, 1 – Weak

CL22003 DOWNSTREAM PROCESSES IN PETROLEUM ENGINEERING

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|----------|----------|----------|----------|
| 3 | 0 | 0 | 3 |

COURSE OBJECTIVES:

1. To illustrate the importance of crude oil as source of fuel and the size of refining industry
2. To summarize the various refinery processes and the products along with their specifications.
3. To show the challenges involved in refining from view point of economic considerations and environmental regulations.

UNIT I OVERVIEW OF PRODUCTION AND REFINING OF CRUDE OIL 9

Origin, formation, exploration and production of crude oil, Reserves and deposits in the world, Petroleum industry in India, Overall Refinery flow, Petroleum Products.

UNIT II COMPOSITION AND EVALUATION OF CRUDE OIL AND ITS PRODUCTS 9

Classification of crude oil, Composition of crude oil, Crude Assay, ASTM/TBP/EFV curves, Specifications and Test methods for: LPG, Naphtha, Gasoline, Kerosene, Diesel, Lube oil, Waxes, Bitumen and Coke.

UNIT III REFINERY PROCESS: DISTILLATION, CRACKING AND CONVERSION 9

Desalting of Crude, Preheating Train, Atmospheric Distillation of Crude oil, Vacuum Distillation, Catalytic Cracking, Thermal Cracking - Visbreaking, Fluid Catalytic cracking and Hydrocracking. Hydrocracking, Catalytic Reforming, Alkylation, Isomerization, Hydroprocessing, Hydrotreating, Coking

UNIT IV MANUFACTURE OF LUBE OIL AND BITUMEN 9

Evaluation of crude oils for lube oil base stocks, Lube oil processing, Propane deasphalting, Solvent Extraction, Dewaxing, hydrofining, clay contact process – Production of lubricating oils, Finishing Processes, Lube oil additives, Properties of Bitumen, Methods of Manufacture of Bitumen

UNIT V SUPPORTING PROCESS AND POLLUTION CONTROL IN REFINERIES 9

Product Blending, Hydrogen Production, Sulphur Recovery, Control of air and water pollution, solid waste management

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Elaborate the various upstream processes and the current scenario of Petroleum industry.
1. Classify the petroleum components and identify appropriate testing methodologies.
2. Compare and differentiate various processing methods in refineries.
3. Analyze the manufacturing techniques involved in lube oil processing.
4. Intricate the supporting processes and effluent control techniques applied in refineries.

TEXT BOOKS:

1. Gary, J.H and Handwerk, G.E., 'Petroleum Refining Technology and Economics', Fourth Edition, Marcel Dekker, Inc. 2001
Ram Prasad, 'Petroleum Refining Technology', First Edition, Khanna Publishers. 2013

REFERENCES:

1. Bhaskara Rao, B.K, 'Modern Petroleum Refining Processes', Fifth Edition, Oxford and IBH

- Publishing Co. Pvt. Ltd. 2007
2. Fahim, M.A., Alsahhaf, T.A. and Elkilani, A. 'Fundamentals of Petroleum Refining', Elsevier, 2010
 3. Nelson, N.L. (1985) 'Petroleum Refinery Engineering', McGraw Hill Book Co

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 2 |
| 2. | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 2 |
| 3. | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 2 |
| 4. | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 2 |
| 5. | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 2 |



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COURSE OBJECTIVES:

1. To learn the principles of bio processing for traditional chemical engineering in the design and development of processes involving biocatalyst.
2. To study engineering principles in the development of products based on living cells or sub components of such cells.
3. To learn and develop quantitative models and approaches related to bioprocesses.
4. To learn mechanistic models for enzyme catalyzed reactions for large scale production of bioproducts.

UNIT I INTRODUCTION**6**

Biotechnology and bioprocessing. An overview of biological basics. Basics of enzyme and microbial kinetics. Operating considerations for bioreactors: cultivation method, modifying batch and continuous reactors, immobilized cell systems, solid state fermentations.

UNIT II ADVANCE ENZYME KINETICS**10**

Models for complex enzyme kinetics, modeling of effect of pH and temperature, models for insoluble substrate, models for immobilized enzyme systems, diffusion limitations in immobilized enzyme system, electrostatic and steric effects.

UNIT III BIOREACTORS**10**

Selection, scale-up, operation and control of bioreactors: Scale-up and its difficulties, bioreactor instrumentation and control, sterilization of process fluids. Modifications of batch and continuous reactors, chemostat with recycle, multistage chemostat, fed-batch operation, perfusion system, active and passive immobilization of cells, diffusional limitations in the immobilized system, solid state fermenters.

UNIT IV HOMOGENEOUS & HETEROGENEOUS REACTIONS IN BIOPROCESS**10**

Reaction thermodynamics, growth kinetics with Plasmid instability, The Thiele Modulus and effectiveness factor, diffusion and reaction in waste treatment lagoon. Reactors and choice of reactors.

UNIT V RECOVERY & PURIFICATION OF PRODUCTS**9**

Strategies to recover and purify products, separation of insoluble products, cell disruption, separation of soluble products.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Illustrate the details on different cells and their use in biochemical processes.
2. Identifying the role of enzymes in kinetic analysis of biochemical reaction.
3. Analyze bioreactors, upstream and downstream processes in production of bioproducts

4. Elaborate the mechanistic models for enzyme catalyzed reactions for large scale production of bioproducts.
5. Demonstrate the fermentation process and its products for the latest industrial revolution

TEXT BOOKS:

1. Bailey J.E. and Ollis D.F., “Biochemical Engineering Fundamentals”, McGraw-Hill, 2e, 2017
2. Shuler M.L., Kargi F., ”Bioprocess Engineering”, Prentice –Hall, 1992

REFERENCES:

1. Doran P.M., “Bioprocess Engineering Principles”, Academic Press, 2e, 2012

At the end of the course add the Course articulation matrix as per the following format:

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2. | 3 | 1 | 1 | 3 | 2 | 1 | 2 | 2 |
| 3. | 2 | 1 | 2 | 3 | 2 | 1 | 2 | 2 |
| 4. | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| 5. | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 2 |

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COURSE OBJECTIVES:

1. To acquire the knowledge on fundamentals of reaction kinetics and thermodynamics behavior of electrolytic processes
2. To understand the basic concept of Heat and Mass Transfer application in Electrochemical Processes
3. To study the rate process to develop the reaction models
4. To understand the reactor dynamics and stability of different reactors.
5. To design and scale up the electrolytic reactor.

UNIT I INTRODUCTION OF ELECTROCHEMICAL ENGINEERING 9

Industrial importance of electrolytic processes, Basic concepts and definitions, Criteria for reactor performance, Electrochemical and catalytic reactions and reactors. Fundamentals of reaction kinetics, rate of electrochemical reaction, electrochemical thermodynamics, practical cell voltage requirements and polarization, single electrochemical reactions, potentiostatic operation of first order reaction and galvanostatic operation of first order reactions.

UNIT II MASS AND HEAT TRANSFER IN ELECTROLYTIC CELL 9

Basic aspects of fluid dynamics, mass transfer- mass flux in a fully developed turbulent regime, entrance and exit effects, obtaining numerical values of mass transfer coefficient by calculation and experiment, mass transfer in two-phase flow, energetic and energy balances, CSTR with general order reactions, effect of mass transport and side reaction.

UNIT III RATE PROCESSES AND REACTION MODELS 9

Rate processes, kinetics of elementary reactions, reaction mechanism and rate laws, transition state theory, derivation of kinetic relationships, and reaction models.

UNIT IV REACTOR MODELS 9

General considerations, batch reactor and continuous reactor. Fed batch, continuous, cell recycle, plug flow reactor, two stage reactors. Reactor dynamics and stability. Reactors with non-ideal mixing. Other types of reactors- fluidized bed reactors; packed bed reactors, bubble column reactors, trickle bed reactors

UNIT V ELECTROLYTIC REACTOR DESIGN AND SCALE UP 9

Electrolytic reactor designs, Electrolytic reactor selection, scale up of electrolytic reactors, effect of scale-up on mass transfer, effect of scale-up on current distribution, Multiple electrode models and time factors.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Illustrate the various reaction kinetics, mass transfer and fluid flow of various electrolytic processes.
2. Infer the concepts in Mass Transfer operations with its applications.
3. Illustrate the different rate processes involved in electrochemical reaction
4. Elaborate the procedure to design and scale up of the electrochemical reactors.
5. Explain the types of fluid flow in electrolytic processes.

TEXT BOOKS:

1. F.Goodridge, K.Scott, Electrochemical process engineering. A guide to the design of electrolytic plant, Plenum Press, 1995.
2. Bockris, John O'M, Bockris, Ralph E. White, B.E. Conway, Modern aspects of electrochemistry, volume 28, Plenum Press, New York 1985.
3. Newman and Thomas-Alyea, Electrochemical systems, 3rd edition, Wiley & Sons, Hoboken, 2004.

REFERENCES:

1. Pletcher. D and Walsh F.C, Industrial electrochemistry, 2nd edition, Chapman and Hall, London, 1990.
2. Hartmut Wendt, Gerhard Kreysa, Electrochemical engineering, Science and technology in Chemical and other industries, Springer, 1999.
3. Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals

Course Articulation Matrix

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 2 | 2 | 1 | 2 | 3 | 3 |
| 2. | 3 | 2 | 2 | 2 | 1 | 1 | 3 | 3 |
| 3. | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |
| 4. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| 5. | 3 | 3 | 2 | 2 | 1 | 1 | 2 | 2 |

*3 –Strong; 2 – Moderate; 1 - Weak

| L | T | P | C |
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COURSE OBJECTIVES:

1. To introduce to the students, the various opportunities in the process integration in chemical industries.
2. To make students familiar with the important concepts process integration for heat Recovery/minimization.
3. To get familiarized with case studies.

UNIT I INTRODUCTION AND APPLICATIONS OF PI**06**

Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram.

UNIT II OVERVIEW OF PINCH TECHNOLOGY**12**

Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology, Key steps of Pinch Technology: Concept of T_{min} , Data Extraction, Targeting, Designing, Optimization Super targeting, Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.

UNIT III NETWORK ANALYSIS IN HEAT EXCHANGER**09**

Heat exchanger networks analysis, Maximum Energy Recovery (MER) networks for multiple utilities and multiple, Chemical Engineering Pre-requisites: Knowledge of basic process design of process equipment. Pinches, design of heat exchanger network.

UNIT IV HEAT INTEGRATION IN UNIT OPERATIONS**09**

Heat integrated distillation columns, evaporators, dryers, and reactors.

UNIT V Z – CASE STUDIES IN PROCESS INTEGRATION**09**

Waste and waste water minimization, flue gas emission targeting, and heat and power Integration. Case studies.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Compare and contrast the given process for the maximum heat recovery.
2. Explain the opportunities for integration towards high-efficiency energy.
3. Illustrate the various Energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site.
4. Evaluate the process integration measures with respect to energy efficiency, green house gas emissions and economic performance.
5. Identifying the various opportunities for integration of high-efficiency energy

TEXT BOOKS:

1. Shenoy U.V.;"Heat Exchanger Network Synthesis", Gulf Publishing Company, 1995.
2. Smith R.;"Chemical Process Design", McGraw-Hill, New York, 1995

REFERENCES:

3. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B.E.A., Guy A. R., and Marsland
4. R. H.;"A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers.
5. Douglas, J.M., "Conceptual Design of Chemical Process", McGraw Hill, New York, 1988.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 1 | 2 | 1 | 1 | 1 | 3 | 3 |
| 2. | 3 | 1 | 2 | 2 | 2 | 2 | 3 | 3 |
| 3. | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| 4. | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 3 |
| 5. | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |

| L | T | P | C |
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COURSE OBJECTIVES:

Students gain knowledge on

1. Selection of right type of transport
2. Different Types of fluid flow
3. Various types of pipes
4. Pipeline protection techniques and
5. Design of pipeline.

UNIT I**9**

Introduction, widespread use, the various types, the advantages and the special features of pipelines.

UNIT II**9**

The fluid mechanics of various types of pipe flow including incompressible and compressible flows of Newtonian fluids, non-Newtonian fluids, flow of solid/liquid mixture (slurry), flow of solid/air mixture (pneumatic transport), and flow of capsules (capsule pipelines).

UNIT III**9**

Various types of pipes (steel, concrete, PE, PVC, etc.), valves (gate, globe, ball, butterfly, etc.) and pressure regulators in pipelines. Blowers and compressors (for gases). Various kinds of flow meters, sensors, pigs (scrapers) and automatic control systems used in pipelines.

UNIT IV**9**

Various means to protect pipelines against freezing, abrasion and corrosion, such as cathodic protection, Planning, construction and operation of pipelines, including modern use of advanced technologies such as global positioning systems (GPS), directional drillings, automatic control using computers, and pipeline integrity monitoring such as leak detection.

UNIT V**9**

.Structural design of pipelines —load considerations and pipe deformation and failure. Economics of pipelines including life-cycle, Cost analysis and comparison of the cost effectiveness of pipelines with alternative modes of transport such as truck or railroad. Legal, safety and environmental issues about pipelines

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Choose the right type of transport processes for gases
2. Elaborate the various types of pipes, pipeline protection techniques
3. Design pipeline for gas transportation
4. Enumerate the contribution for field development
5. Illustrate the pipeline integrity and environmental, legal, safety considerations and implications.

| L | T | P | C |
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COURSE OBJECTIVES:

1. To explain the role of law, policy and institutions in the conservation and management of natural resources as well as pollution control.
2. To gain the knowledge about Indian policies and legislations pertaining to prevention and control of water pollution, air pollution and waste management
3. To impart knowledge on Supreme Court judgements in landmark cases of environmental abuse and protection.

UNIT I INTRODUCTION**9**

Indian Constitution and Environmental Protection – National Environmental policies- Precautionary Principle and Polluter Pays Principle– Concept of absolute liability–multilateral environmental agreements and Protocols– Montreal Protocol, Kyoto agreement, Rio declaration– Environmental Protection Act, Water (P&CP) Act, Air (P&CP) Act– Institutional framework (SPCB/CPCB/MoEF).

UNIT II WATER (P&CP) ACT, 1974**8**

Power & functions of regulatory agencies- responsibilities of Occupier Provision relating to prevention and control Scheme of Consent to establish, Consent to operate–Conditions of the consents– Outlet– Legal sampling procedures, State Water Laboratory–Appellate Authority– Penalties for violation of consent conditions etc. Provisions for closure/directions in apprehended-pollution situation

UNIT III AIR (P&CP) ACT, 1981**8**

Power & functions of regulatory agencies-responsibilities of Occupier Provision relating to prevention and control Scheme of Consent to establish, Consent to operate– Conditions of the consents– Outlet– Legal sampling procedures, State Air Laboratory– Appellate Authority– Penalties for violation of consent conditions etc. Provisions for closure/directions in apprehended pollution situation.

UNIT IV ENVIRONMENT (PROTECTION) ACT 1986**13**

Genesis of the Act–delegation of powers–Role of Central Government–EIA Notification– Sitting of Industries – Coastal Zone Regulation - Responsibilities of local bodies mitigation scheme etc., for Municipal Solid Waste Management – Responsibilities of Pollution Control Boards under Hazardous Waste rules and that of occupier, authorization– Biomedical waste rules–responsibilities of generators and role of Pollution Control Boards

UNIT V PUBLIC INTEREST AND SUPREME COURT JUDGEMENTS IN LANDMARK CASES**7**

Relevant Provisions of Indian Forest Act, Public Liability Insurance Act, CrPC, IPC – Public Interest Litigation - Writ petitions - Supreme Court Judgments in Landmark cases of environmental abuse and protection.

TOTAL: 45 PERIODS**OUTCOMES:**

1. To impart the knowledge about the national environmental principles and policies.
2. Elaborate regulatory and legal aspects of Water act and Provisions for closure/directions in apprehended-pollution situation.

3. The importance of regulatory and legal aspects of Air act and Penalties for violation of consent conditions.
4. Explain the environmental protection act and responsibilities of pollution control boards.
5. Compare and contrast the different provisions and judgments towards environmental protection.

TEXT BOOKS:

1. Shyam Divan and Armin Roseneranz “Environmental law and policy in India”
Oxford University Press, Second Edition New Delhi, 2002.

REFERENCES:

2. CPCB, “Pollution control acts, Rules and Notifications” issued there under pollution control series-PCL/2/1992, Central Pollution control board, New Delhi, 1997
3. Greger I. McGregor, “Environmental law and enforcement”, First Edition, CRC Press, London, 1994.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| 2. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| 3. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| 4. | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| 5. | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |

| L | T | P | C |
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COURSE OBJECTIVES:

1. To teach students fundamental knowledge required in the development of fuel cell technology.
2. Thermodynamics, chemical reaction engineering, transport processes and electrochemical engineering perspectives of fuel cell technology.
3. To present a problem oriented in depth knowledge of fuel cell technology and to address the underlying concepts, method and application of fuel cell technology.

UNIT I INTRODUCTION**9**

Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermodynamics-heat, Work potentials, prediction of reversible voltage, fuel cell efficiency.

UNIT II FUEL CELL KINETICS**9**

Fuel cell reaction kinetics - electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electrocatalysis -design, activation kinetics, Fuel cell charge and mass transport -flowfield, transport in electrode and electrolyte.

UNIT III CHARACTERIZATION TECHNIQUES**9**

Fuel cell characterization - in-situ and ex-situ characterization techniques, i-V curve, frequency response analysis; Fuel cell modeling and system integration:-1D model – analytical solution and CFD models

UNIT IV RENEWABLE SOURCES**9**

Balance of plant; Hydrogen production from renewable sources and storage; safety issues, cost Expectation and life cycle analysis of fuel cells.

UNIT V APPLICATIONS OF FUEL CELL**9**

Fuel cell power plants: fuel processor, fuel cell power section(fuel cell stack), power conditioner; automotive applications, portable applications.

TOTAL: 45 PERIODS**OUTCOMES:**

Upon successful completion of the course, students should be able to:

1. Apply the principles of thermodynamics in the design and analysis of fuel cells
2. Formulate design equations for fuel cells using the principles of chemical kinetics
3. Develop mathematical models for fuel cells and its characterization
4. Perform life cycle analysis of fuel cells
5. Apply the fundamentals of components of fuel cell power plants in automotive and portable applications

TEXT BOOKS:

1. Gregor Hoogers, "Fuel Cell Technology Handbook", CRC Press, 2003
2. Supramaniam Srinivasan, "Fuel cells: From fundamental to application, 1st Edition, Springer, 2006.

REFERENCES:

1. Gregor Hoogers, Fuel cell technology– Handbook, CRC Press,2002.
2. Viswanathan, BandMAuliceScibioh, Fuel Cells– Principles and Applications Universities Press(2006).
3. R.P. O’Hayre, S. Cha, W. Colella, F.B. Prinz, “Fuel Cell Fundamentals”, Wiley, 2006.
4. S. Basu, “Fuel Cell Science and Technology”, Springer, 2007.
5. H. Liu, “Principles of Fuel Cells”, Taylor & Francis, 2006.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 |
| 2. | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 |
| 3. | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 |
| 4. | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 |
| 5. | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 |

CL22010 CHEMICAL REACTOR ANALYSIS

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COURSE OBJECTIVES:

- To learn the heterogeneous catalyzed reactions and the models involved in reactor design .
- To study mass and heat transfer mechanisms in the different reactors.
- To appreciate the importance of both external and internal transport effects in gas-solid and liquid-solid systems.
- To design isothermal and non-isothermal reactors for heterogeneous catalytic reactions.

UNIT I INTRODUCTION

9

Chemical factor affecting the choice of the reactor, fundamental mass, energy and momentum balance, Model for a semi-batch reactor, optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies, stability of operation and transient behavior for mixed flow reactor. Transient CSTR analysis, Hot spot equation.

UNIT II FIXED BED CATALYTIC REACTOR

9

Fixed bed catalytic reactor: The importance and scale of fixed bed catalytic processes, factors in preliminary design, modeling of fixed bed reactor. Pseudo-homogeneous model, the multi-bed adiabatic reactor, auto-thermal operation, non-steady-state model with axial mixing, two dimensional pseudo-homogeneous models. heterogeneous models, global and intrinsic rates, Mechanism of catalytic reactions.

UNIT III MULTIPHASE FLOW REACTOR

9

Multiphase flow reactor: Types of multiphase flow reactors, packed columns, plate columns, empty columns, stirred vessel reactors. Development of rate equations for solid catalyzed fluid phase reactions; Estimation of kinetic parameters. External mass and heat transfer in catalyst particles. Stability and selectivity, Packed bed reactor, slurry reactor; Trickle bed reactor and fluidized bed reactor. Intra-particle heat and mass transfer - Wheelers parallel pore model.

UNIT IV DESIGN OF MULTIPHASE FLOW REACTOR

9

Design model for multiphase flow reactors, gas and liquid phase in completely mixed and plug flow, gas phase in plug flow and liquid phase in completely mixed flow, effective diffusion model, two zone model, specific design aspects, packed absorber, two-phase fixed bed reactor, plate column, spray tower, bubble reactor, stirred vessel reactor. Computer - aided reactor design

UNIT V TEMPERATURE EFFECTS IN REACTOR

9

Temperature effects in reactor: Introduction, well mixed system with steady feed, the stability and start-up of CSTR, limit cycles and oscillatory reactions, the plug flow reactors, tubular reactor. diffusion control, prorogation of reaction zone.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

- Develop design equations of semi-batch reactors for its optimum functionality.

- Formulate mathematical models and design of fixed bed catalytic reactors.
- Develop rate equations for solid catalyzed fluid phase reactions carried out in multi-phase reactors.
- Perform design calculations of gas-liquid multi-phase flow reactors.
- Explain the temperature effects during the operation of reactors.

TEXT BOOKS:

1. Froment G, Bischoff K and De Wilde J, “Chemical Reactor Analysis and Design”, 3rd Edition, John Wiley and Sons, 2011
2. Denbigh K. G. and J.C. Turner, “ Chemical Reactor and Theory – an Introduction”, 3rd edition, Cambridge University Press,1984

REFERENCES:

1. Bruce Nauman, “ Chemical Reactor Design”, John Wiley & Sons,2nd Edition,2008
2. Fogler, H.S., “Elements of Chemical Reaction Engineering”,4th Edition, Prentice Hall, New Jersey, 1986.
3. Chemical Engineering Kinetics by J. M. Smith,3rd Edition,1983
4. Chemical Reactor Design and Operation by K. R. Westerterp, W. P. M. Van Swaaij and A. A. C. M. Beenackers.2nd Edition,1987.

COURSE ARTICULATION MATRIX

| COs | POs | | | | | | | |
|-----|-----|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | 3 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
| 2. | 3 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
| 3. | 3 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
| 4. | 3 | 3 | 2 | 3 | 1 | 2 | 2 | 1 |
| 5. | 3 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |

CL22011 DESIGN OF EXPERIMENTS AND PARAMETER ESTIMATION

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COURSE OBJECTIVES:

- Use statistics in experimentation.
- Understand the important role of experimentation in new product design, manufacturing process development, and process improvement.
- Analyze the results from such investigations to obtain conclusions; become familiar methodologies that can be used in conjunction with experimental designs for robustness and Optimization

UNIT I DESIGN OF EXPERIMENTS FOUNDATION - I 9

Design of experiments. Basic concepts, Different types of design, Simple comparative experiments, single factor experiments, Random effect model, Completely randomized design, Randomized block design, Incomplete block design, recovery of interblock information, Balanced incomplete block design and their (nonparametric) analysis

UNIT II DESIGN OF EXPERIMENTS FOUNDATION - II 9

Dirichlet's conditions – General Fourier series – Odd and even functions – Half range sine series and cosine series – Root mean square value – Parseval's identity – Harmonic analysis.

UNIT III DESIGN OF EXPERIMENTS FOUNDATION - III 9

Point Estimation Estimators as random variables, sample mean and the central limit theorem, normal approximations, assessing normality. Interval Estimation Confidence intervals for the mean when the variance is known, confidence interval for the mean when the variance is unknown, confidence intervals for a single proportion, sample size, Student distribution. Factorial designs - 2^k designs, confounding in factorial design, blocking in 2^k designs, fractional replications in 2^k designs, 3-level and mixed-level factorials and fractional factorials.

UNIT IV REGRESSION ANALYSIS 9

Linear Regression analysis: The linear regression model, Parameter estimation, accuracy of the coefficient estimates, checking the model, multiple linear regression, confidence and prediction intervals, potential issues, high leverage points, outliers. Matrix approach to linear regression, Variance-Covariance matrix, ANOVA in regression analysis, quantifying regression fits of experimental data, Extra sum of squares approach, confidence intervals on regression coefficients, lack of fit analysis.

UNIT V Z - RESPONSE SURFACE METHODOLOGY 9

Response surface designs and their analysis, central composite designs, hybrid and uniform cell design, Nested designs, staggered nested designs with factorial structure, split plot designs, blocking and efficiency.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Develop experiments for a critical comparison of outputs
2. Perform exploratory data analysis and probability distribution analysis of random variables
3. Apply statistical approach to propose hypothesis from experimental data
4. Perform regression analysis for quantifying regression fits of experimental data
5. Develop a model using response surface methodology in design of experiments and parameter estimation

TEXT BOOKS:

1. Devore, Jay L., Probability and Statistics for Engineering and the Sciences, 5th edition, Brooks- Cole, 1999.
2. Hicks & Turner, "Fundamental Concepts in the Design of Experiments, 5th edition, Oxford University Press, 1999.
3. D C Montgomery, Design and Analysis of Experiments, Wiley.

REFERENCES:

1. G E P Box and K B Wilson, J. R. Stat. Soc. Ser. B (Method.), 13 (1951) 1.D C Montgomery, Design and Analysis of Experiments, 3rdEdn (New York: Wiley, 1991) 270.
2. Saunders, Mark, Brown, Reva Berman. "Dealing with Statistics: What You Need to Know". McGraw-Hill Education.
3. C. F. Jeff Wu and Michael Hamada, Experiments: planning, analysis, and parameter design optimization, 2nd Ed., John Wiley & Sons, Inc., New York, 2002.
4. G. Casella (2008), Statistical Design, Springer

COURSE ARTICULATION MATRIX

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COURSE OBJECTIVES:

1. To introduce to the students, the various opportunities in the emerging field of micro and nano fluids.
2. To make students familiar with the important concepts applicable to small micro and nano fluidic devices, their fabrication, characterization and application
3. To get familiarize with the new concepts of real-time nano manipulation & assembly.

UNIT I INTRODUCTION**9**

Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility. Pressure Driven Liquid Microflow: apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro -flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.

UNIT II LAMINAR FLOW**9**

Hagen-Poiseuille eqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves & micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices. Ionic transport: Polymer transport – microtubule transport in nanotube channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.

UNIT III FABRICATION TECHNIQUES FOR NANOFUIDIC CHANNELS**9**

Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels Confinement of Biomolecules using Nanochannels. Hydrodynamics: Particle moving in flow fields – Potential Functions in Low Reynolds Number Flow – Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow.

UNIT IV MICROFLUIDICS AND LAB-ON-A-CHIP**9**

Introduction - concepts microfluidic devices, Advantages of microfluidic devices, Fluidic transport, Scaling - materials for the manufacture, (Silicon, glass, polymers) materials for the manufacture, Fluidic structures, Stacking - fabrication methods, Surface modifications – spotting; Detection mechanisms.

UNIT V Elements of Electrochemistry, Electrical Double Layer and Applications**9**

Electro chemistry, electrical double layer, Electro-chemical potential, chemical potential-acid and base, Electrolyte, electrical conductivity, semi-permeable membrane, Micro and nano fluidics devices application, Fabrication and design of microfluid device, Electrochemical sensing, Receptor and Transducer based classification of biosensors, Nanopores and nanopore membrane for biochemical sensing

TOTAL: 45 PERIODS

OUTCOMES:

At the end of the course, the student will be able to

- Explain the concepts of pressure driven and electro-kinetically driven micro-flows
- Analyze fluid flow in micro and nano-size devices using physical principles
- Illustrate the fabrication techniques of nanofluidic channels and its hydrodynamics
- Elucidate the applications of microfluidic devices and its fabrication methods
- Enumerate the transduction mechanisms in Bio-Micro-Electro-Mechanical Systems

TEXT BOOKS:

1. Joshua Edel “Nanofluidics” RCS publishing, 2009
2. Patric Tabeling “Introduction to Microfluids” Oxford U. Press, New York 2005

REFERENCES:

3. M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
4. G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998
5. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006.

COURSE ARTICULATION MATRIX

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CL22013 NANOMATERIALS AND ITS APPLICATIONS

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COURSE OBJECTIVES:

2. To introduce the basic concepts of Nanomaterials and nanostructures.
3. To learn the Storage of energy by employing Nanomaterials
4. To enhance the application in various fields oriented with Biological Sciences.
5. To gain the knowledge of applying analytical techniques associated with Nano for characterisation.
6. To know the process of synthesizing Nanomaterial along with its design concepts

UNIT I CONCEPTS OF NANOMATERIALS

9

Nanomaterials in daily life with examples (GMR read heads, NEMS goniometers, health care, energy materials, etc); Foundations of Quantum and Statistical Mechanics for nanomaterials, idea of tunneling, bound state and scattering, notion of quasiparticles, Light matter interaction; DOS, Bose-Einstein and Fermi-Dirac Statistics; Properties of individual nanostructures; Bulk nanostructured materials; Selection rules and spectroscopic techniques; carbon based nanomaterials; biological materials and biomimetic strategies for nanosynthesis; magnetic nanomaterials; nanodevices and nanomachines.

UNIT II NANOMATERIALS FOR SOLAR ENERGY & PHOTOVOLTAICS

9

Introduction of energy storage/conversion devices, State-of-the art status of portable power sources, Solar/photovoltaic (PV) cells as a source of green energy; Fundamentals, Materials, Design and Implementation aspects of PV energy generation and consumption; Solar cell technologies (Si-wafer based, Thin film, GaAs based, dye-sensitized, PESC and organic solar cells), Efficiency of solar cells and PV array analysis, Photovoltaic system design (stand alone and grid connected) and applications; Balance of system (BOS) with emphasis on role of storage batteries; Cost analysis, Case study for performance evaluation and problem identification in wide-spread commercialization of the technology.

UNIT III NANOBIO TECHNOLOGY

9

Introduction to Nanobiotechnology; challenges and opportunities associated with biology on the Nanoscale; nanobiotechnology systems; introduction to bioelectronics; Biologically relevant molecular nanostructures-Carbon nanotubes, quantum dots, metal based nanostructures, nanowires, polymer based nanostructures, protein and DNA based nanostructures; Characterisation techniques for biological molecular nanostructures.

UNIT IV ANALYTICAL TECHNIQUES

9

Ellipsometer; Surface profile analysis; Scanning Probe Microscope (AFM and STM); Auger Electron Spectroscopy; Scanning Electron Microscopy; Transmission Electron Microscopy; Energy Dispersive Spectrum; Confocal Microscope; Kerr Microscope; Ferromagnetic Resonance Microscope, X-ray Diffraction; Small Angle X-ray Scattering; High Power X-ray (Synchrotron) Diffraction; Neutron Diffraction, Microprobe station, Impedance measurement, Electrical transport measurement (ac and DC conductivity, TEP

measurement), Magnetic transport properties characterization, Vibrating Sample Magnetometer, SQUID, Electron Spin Resonance, UV-VIS Spectrophotometer; FT-IR Spectrophotometer; Micro-Raman Spectrometer; Thermal Gravimetric Analysis (TGA); Differential thermal analysis (DTA); Differential scanning calorimetry (DSC); BET surface area analyzer; Dynamic Light Scattering; Differential Mechanical Analysis (DMA); Universal testing machine (UTM).

UNIT V DESIGN AND SYNTHESIS OF NANOMATERIALS

9

Chemical Routes for Synthesis of Nanomaterials ; Metal Nanoparticles: Semiconductor Nanoparticles: Organic nanoparticles: Top-down techniques: photolithography, other optical lithography (EUV, X-Ray, LIL), particle-beam lithographies (e-beam, FIB, shadow mask evaporation), scanning probe lithographies.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

1. Students gained the basic concepts of Nanomaterials and nanostructures.
2. Helps to apply Nanomaterials for energy storage
3. Gain the real time application of Nanomaterials in Biological Sciences.
4. Students gained the hands-on how to apply the analytical techniques for characterising Nanomaterials..
5. Outgoing student know the process of how to synthesise Nanomaterial along with its design concepts

TEXT BOOKS:

1. Introductory Nanoscience, by Masuro Kuno, Garland Science (2011).
2. Fundamentals of Photovoltaic Modules and their Applications, G. N. Tiwari, S. Dubey & Julian C. R. Hunt, RSC Energy Series, 2009.
3. Bionanotechnology, by Elisabeth Papazoglou, Publisher: Morgan & Claypool
4. Nanoscale Handbook of microscopy for Nanotechnology, Nan Yao (Princeton Univ. USA) and ZHONG LIN WANG (Georgia Institute of tech. USA), Kluwer academic publisher (2005).
5. Metal Nanoparticles: Synthesis Characterization & Applications, Daniel L. Fedlheim, Colby A. Foss, Marcel Dekker, 2002

REFERENCES:

6. Fundamentals and Applications of Nanomaterials, by Z. Guo and Li Tan
7. Handbook of Advanced Electronic and Photonic Materials and Devices: Ferroelectrics & Dielectrics, Vol. 10, H. S. Nalwa (ed.), Academic Press, 2001.
8. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, Ying Wang, World Scientific, 2011

COURSE ARTICULATION MATRIX

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CL22014 SURFACE ENGINEERING

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COURSE OBJECTIVES:

To introduce the basic principles and importance of various surface modification techniques and to study their impacts in industrial applications.

UNIT I INTRODUCTION 9

Importance of surfaces and wear surface properties in engineering applications, Current status of surface engineering, Categories of wear, Low-stress abrasion, High-stress abrasion, Gouging abrasion, Cavitation, Slurry and impingement erosion, Fretting wear, Adhesive wear, Seizure, Galling, Oxidative wear, Pitting wear, Spalling, Impact wear and Brinelling.

UNIT II ELECTROPLATING & SURFACE HARDENING 9

Electroplating fundamentals, Electrodeposition from plating baths, Electroless plating, Metallizing, Selective plating, Hard anodizing, Other plating processes, Applicability of plating for wear resistance, Surface hardening – Carburizing, Nitriding, Cyaniding, Carbonitriding, Induction Hardening.

UNIT III THIN FILM COATING 9

Thermal evaporation, Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (PVD), Metal organic CVD, Plasma assisted CVD, Sputter coating, Ion plating, Thin film for wear application, Coating specifications.

UNIT IV HIGH ENERGY AND SPECIAL SURFACE MODIFICATIONS 9

Rebuilding and surface cements, Wear tiles, Electrospark deposition coatings, Fused carbide cloth, Ceramic coatings, Centrifuge-Cast wear coatings, Wear sleeves, Wear plates.

UNIT V HARDFACING APPLICATIONS 9

Arc welding and its types, Oxyacetylene welding, Furnace fusing, Thermal spray processes and their applications, Hardfacing transformation, Fusion alloys, Non fusion materials. Hardfacing in new designs, Hardfacing for repairs, Hardfacing with fusion processes, Nonfusion deposits, Weldability considerations, Finishing considerations.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of the course, students should be able to:

- Identify the wear phenomena and mechanism occurring on the surfaces of various substances.
- Select the suitable plating or hardening technique with respect to the application.
- Apply the appropriate thin film coating technology for a specific application.
- Investigate the application of high energy and other special technology in surface modifications.
- Apply suitable technique and consumables for hardfacing applications.

TEXT BOOKS:

1. Budinski, K.G., "Surface Engineering for Wear Resistance", Prentice Hall, New Jersey, 1988.
2. Hocking M.G., Vasantasree V. and Sidky P.S., "Metallic and Ceramic Coatings: Production, High Temperature properties and Applications." John Wiley & Sons, 1989.

REFERENCES:

3. Strafford, K.N., Datta, P.K., and Gray, J.S., "Surface Engineering Practice, Processes, Fundamentals and Applications in Corrosion and Wear", Ellis Harwood, 1990.
4. Mathews, A., "Advanced Surface Coatings: A Hand book of Surface Engineering", Spinger, 1991.
5. Varghese C.D, "Electroplating and Other Surface Treatments - A Practical Guide", TMH, 1993.

COURSE ARTICULATION MATRIX

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CL22015 HSE IN PETROLEUM INDUSTRIES

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OBJECTIVES:

1. To provide an overview of safety and environmental issues due to the petroleum industry.
2. To identify and assess hazards at any stage of operation.
3. To learn how to model and analyze accident scenarios in the petroleum industry.
4. To appraise the importance of HSE culture at petroleum industry.

UNIT I

9

Environmental impact and management: Impact of oil and gas industry in urban/rural areas, Oil & Hydrocarbons in the marine environment and impact on the atmosphere. Chemical disposal of offshore industry and environmental management. Toxicity, physiological, asphyxiation, respiratory, skin effect due to petroleum hydrocarbons & their mixture.

UNIT II

9

Classification of fires- The fire triangle- Distinction between fires and explosions- Flammability characteristics of liquids and vapors, Flammability diagrams. Toxic releases- models and methods, Dose assessment, Chemical risk analysis, Chemical exposure index (CEI). Corrosion in petroleum industry- Additives during acidizing, sand control, and fracturing.

UNIT III

9

Hazard identification- Hazard evaluation: Hazop and what-if reviews, Developing a safe process and safety management. Personal protection systems and measures. Safety instrumentation for process system in hydrocarbon industry- Safety aspects in functional training-Work permit system.

UNIT IV

9

Well Blowout fires and their control, BLEVE - Dispersion models. Suppression of hydrocarbon fires, toxic release, and firefighting equipment. Fire, explosion and accidental release: prevention methods. Event tree, and fault tree analyses. relevant Case Studies of investigation.

.UNIT V

9

Process Safety Management. HSE and culture: - Introduction - HSE and culture Characteristics of a sound HSE culture -Sources for understanding one's own HSE culture - Factors which can affect the HSE culture - Occupational Health and Safety Assessment Series.

TOTAL: (L: 45, T: 0): 45 PERIODS

OUTCOMES:

1. Appraise health, safety and environmental impact due to petroleum industry.
2. Contrast types of Fire, Toxic release, and Continuous monitoring methodology
3. Analyse scenarios and assessment of industrial risk associated with accidental release and fire explosions.
4. Access by modelling the different scenarios and investigation of accidents.
5. Embrace the safety culture in order to optimize the effectiveness of control measures.

TEXT BOOKS:

1. Chemical Process Safety, Roy E. Sanders, Butterworth Heinemann, 2nd Edition, 1999.
2. Guidelines for Process Hazards Analysis, Hazards Identification & Risk Analysis, Nigel Hyatt, CRC Publications, 2004.
3. Environmental Control in Petroleum Engineering, John C. Reis, Gulf Publishing Company, 1996.
4. Application of HAZOP and What if Reviews to the Petroleum, Petrochemical and Chemical Process Industries, Dennis P. Nolan, Noyes Publications, 1994.

REFERENCES:

5. Process Safety Analysis – An Introduction, Bob Skelton, Gulf Publishing Company, 1997.
6. Chemical Process Industry Safety, K S N Raju, McGraw Hill, 2014.
7. Oil Industry Safety Directorate (OISD) Guidelines, Ministry of Petroleum & Natural Gas, Government of India and Oil Mines Regulations-1984, Directorate General of Mines Safety, Ministry of Labor and Employment, Government of India.
8. Guidelines for Process Safety Fundamentals in General Plant Operations Centre for Chemical Process Safety, American Institute of Chemical Engineers, 1995.
9. Guidelines for Fire Protection in Chemical, Petrochemical and Hydrocarbon Processing Facilities, Centre for Chemical Process Safety, American Institute of Chemical Engineers, 2003.
10. Guidelines for Hazard Evaluation Procedures Centre for Chemical Safety, Wiley- AIChE, 3rd Edition, 2008.

COURSE ARTICULATION MATRIX

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CL22016 ARTIFICIAL INTELLIGENCE FOR CHEMICAL ENGINEERING

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OBJECTIVES:

- To provide an overview of safety and environmental issue in petroleum industry
- To resolve key issues in oil and gas industry
- To identify and assess hazard in any stage of operation

UNIT 1

9

What is Artificial Intelligence. Types of problems AI addresses like Computer Vision, Natural Language Processing, Robotics, Expert Systems, Object detection and Image segmentation.

Applications of AI in chemical engineering areas like fault diagnosis, Process control, Process design, Planning and operations, Modeling and simulation and Product design, development and selection like Separation Design, Heat-Exchanger Network Synthesis.

UNIT 2

9

Deep Artificial neural networks (DNN).

The working of the Rosenblatt perceptron, multilayer perceptrons. Activation functions and their importance in incorporating nonlinearities into the predictive models. The feed forward process in ANN layers with dense fully connected layers. The error (loss) functions as a measure of the ANN performance. Backpropagation algorithm for neuron learning.

UNIT 3

9

Convolution neural networks (CNN).

The drawbacks of Deep ANN. How CNN take into account the spatial patterns. The working of the CNN in pattern recognition. The role of kernels, pooling, padding and stride in CNN learning. How the kernels help in reducing the learning parameters (weight sharing). One, two and three dimensional convolutions.

UNIT 4

9

Some outstanding deep networks proposed like AlexNet, VGGNet, Inception, GoogleNet and ResNets. The problems they faced and how they resolved the problems. The concept of Transfer Learning and how one can use these proposed networks to solve other relevant problems.

UNIT 5

9

Sequence modeling using the Recurrent neural networks (RNN).

The application of this architecture in predictions based on sequential data. Various RNN architectures proposed like many to one, One to many and Many to many. The variants of RNN like Gated Recurrent Units (GRU) and the Long Short Term Memory (LSTM) architectures.

OUTCOMES:

1. Contrast and make effective decisions in Planning and operations.
2. Choose appropriate algorithms for solving given AI problems using DNN techniques.
3. Design and implement logical reasoning agents using CNN.
4. Design and implement agents that can reason under uncertainty.
5. Appraise the applications of Recurrent neural networks (RNN).

TEXTBOOKS

- 1) Raff, Edward. Inside Deep Learning: Math, Algorithms and Models. Manning Publications, 2022.
- 2) Quantrile, Thomas, Liu, Y. A, Artificial Intelligence in Chemical Engineering, Academic Press, 1991.

REFERENCE:

- 1) Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning. (Adaptive Computation and Machine Learning series). 2015.

COURSE ARTICULATION MATRIX

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CL22017 PROCESS DESIGN AND SYNTHESIS

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OBJECTIVES:

- To understand the systematic approaches for the development of conceptual chemical process designs.
- To learn the advances in problem formulation and software capabilities which offer the promise of a new generation of practical process synthesis techniques based directly on structural optimization.
- Learning chemical process synthesis, analysis, and optimization principles.
- Product design and development procedure and Process life cycle assessment.

UNIT I INTRODUCTION

9

Introduction to fundamental concepts and principles of process synthesis and design and use of flow sheet simulators to assist process design. Process Flowsheet Models: An Introduction to Design, Chemical process synthesis, analysis and optimization. Introduction to commercial process design software such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software.

UNIT II PRODUCT DESIGN AND DEVELOPMENTS

9

Process engineering economics and project evaluation Life Cycle Assessments of process: From design to product development, Engineering Economic Analysis of Chemical Processes, Project costing and performance analysis, Environmental concerns, Green engineering, Engineering ethics, Health and safety.

UNIT III NETWORKS

9

Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps.

UNIT IV SYNTHESIS OF SEPARATION TRAINS

9

Criteria for selection of separation methods, selection of equipment: Absorption, Liquid-liquid extraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation - Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4 Components, Feasibility and vapor flow rates for single columns, Residue curve basics, Non-ideal Distillation - Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropic systems, Topological analysis, Feasibility for single azeotropic columns, Binary VLE and pressure swing separation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, Detailed Residue Curve Maps, Residue curve maps: Interior structure.

UNIT V HEAT EXCHANGER NETWORK SYNTHESIS

9

Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network, Loops and Paths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, Stream Splitting, Performance targets, trade-off & utilities, Heat &

power integration, HENS as mathematical programming.

OUTCOMES:

1. Apply fundamental concepts and principles of process synthesis and design
2. Develop process engineering economics and life cycle assessment of process.
3. Design reactor network and analyze.
4. Demonstrate the synthesis of separation trains.
5. Complete collaboratively a preliminary process design within a given time frame

TEXT BOOKS:

1. Douglas, J. "Conceptual Design of Chemical Processes", New York, NY: McGraw-Hill Science /Engineering/Math, 1988. ISBN: 0070177627.
2. Seider, W. D., J. D. Seader, and D. R. Lewin. "Product and Process Design Principles: Synthesis, Analysis, and Evaluation",. 2nd ed. New York, NY: Wiley, 2004.

REFERENCES:

1. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., "Analysis, Synthesis, and Design of Chemical Processes", 2nd Edition, 2002, Prentice Hall .
2. Biegler L.T., Grossmann I.E. and Westerberg A.W., "Systematic Methods of Chemical Process Design", Prentice Hall, 1997.

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