**B. Tech. Programme from the Department of Chemical and Biochemical Engineering**

**B. Tech. in Chemical Engineering and Minor in Chemical Engineering.**

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| **Program Learning Objectives**   * This program aims to cultivate a comprehensive learning environment for students, equipping them with foundational and cutting-edge knowledge in chemical engineering so that students can thrive and excel in the global market. * The emphasis will be on tackling a variety of real-world engineering challenges, supported by a strong base in mathematical, scientific, and chemical engineering principles. * The program will impart expertise in designing and troubleshooting processes for the production of valuable products such as chemicals, fuels, foods, pharmaceuticals, and biologicals from raw materials and the optimization for maximizing productivity and product quality while minimizing costs. | **Program Learning Outcomes**   * Graduates should have the capability to develop systems, components, or processes that meet defined specifications, taking into account practical considerations such as economic feasibility, environmental impact, health and safety regulations, manufacturability, and sustainability. * After completion of the program, students will have acquired the expertise to tackle industrial and real-world challenges in chemical reactor design, separation and purification processes, reaction kinetics, modeling and simulation, automation and control, and heat, momentum, and mass balances, among other areas. |

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| **Sl. No.** | **Subject Code** | **SEMESTER I** | **L** | **T** | **P** | **C** |
| 1. | MA1101 | Calculus and Linear Algebra | 3 | 1 | 0 | 4.0 |
| 2. | CS1101 | Foundations of Programming | 3 | 0 | 3 | 4.5 |
| 3. | PH1101/PH1201 | Physics | 3 | 1 | 3 | 5.5 |
| 4. | CE1101/CE1201 | Engineering Graphics | 1 | 0 | 3 | 2.5 |
| 5. | EE1101/EE1201 | Electrical Sciences | 3 | 0 | 3 | 4.5 |
| 6. | HS1101 | English for Professionals | 2 | 0 | 1 | 2.5 |
| **TOTAL** | | | **15** | **2** | **13** | **23.5** |

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| **Sl. No.** | **Subject Code** | **SEMESTER II** | **L** | **T** | **P** | **C** |
| 1. | MA1201 | Probability Theory and Ordinary Differential Equations | 3 | 1 | 0 | 4 |
| 2. | CS1201 | Data Structure | 3 | 0 | 3 | 4.5 |
| 3. | CH1201/CH1101 | Chemistry | 3 | 1 | 3 | 5.5 |
| 4. | ME1201/ME1101 | Mechanical Fabrication | 0 | 0 | 3 | 1.5 |
| 5. | ME1202/ME1102 | Engineering Mechanics | 3 | 1 | 0 | 4 |
| 6. | IK1201 | Indian Knowledge System (IKS) | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **15** | **3** | **9** | **22.5** |

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| **Sl. No.** | **Subject Code** | **SEMESTER III** | **L** | **T** | **P** | **C** |
| 1. | CB2101 | Introduction to Chemical Engineering | 2 | 0 | 0 | 2 |
| 2. | CB2102 | Fluid Mechanics | 3 | 1 | 2 | 5 |
| 3. |  | Heat Transfer | 3 | 0 | 3 | 4.5 |
| 4. | CB2104 | Chemical Process Calculations | 3 | 1 | 0 | 4 |
| 5. | CB2105 | Chemical Engineering Thermodynamics | 3 | 0 | 0 | 3 |
| 6. | HS21XX | HSS Elective-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **17** | **2** | **5** | **21.5** |

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| **Sl. No.** | **Subject Code** | **SEMESTER IV** | **L** | **T** | **P** | **C** |
| 1. | CB2201 | Mechanical Operations | 2 | 0 | 3 | 3.5 |
| 2. | CB2202 | Mass Transfer-I | 3 | 0 | 0 | 3 |
| 3. | CB2203 | Fundamentals of Biochemical Engineering | 3 | 0 | 0 | 3 |
| 4. | CB2204 | Process Dynamics and Control | 3 | 0 | 2 | 4 |
| 5. | CB2205 | Chemical Reaction Engineering-I | 3 | 0 | 0 | 3 |
| 6. | XX22PQ | IDE-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **17** | **0** | **5** | **19.5** |

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| **Sl. No.** | **Subject Code** | **SEMESTER V** | **L** | **T** | **P** | **C** |
| 1. | CB3101 | Mass Transfer-II | 3 | 0 | 3 | 4.5 |
| 2. | CB3102 | Chemical Process Technology | 3 | 0 | 0 | 3 |
| 3. | CB3103 | Process Equipment Design | 1 | 2 | 0 | 3 |
| 4. | CB3104 | Chemical Reaction Engineering-II | 3 | 0 | 2 | 4 |
| 5. | CB3105 | Chemical Process Modeling and Simulation | 2 | 0 | 3 | 3.5 |
| 6. | XX31PQ | IDE-II | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **15** | **2** | **8** | **21** |

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| **Sl. No.** | **Subject Code** | **SEMESTER VI** | **L** | **T** | **P** | **C** |
| 1. | CB3201 | Process Plant Design and Economics | 3 | 0 | 0 | 3 |
| 2. | CB3202 | Transport Phenomena | 3 | 1 | 0 | 4 |
| 3. | CB3203 | Numerical Methods in Chemical Engineering | 3 | 1 | 0 | 4 |
| 4. | CB3204 | AI/ML for Chemical Engineers | 1 | 0 | 4 | 3 |
| 5. | CB3205 | Chemical Plant Safety and Hazards | 3 | 0 | 0 | 3 |
| 6. | CB32XX | DE-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **16** | **2** | **4** | **20** |

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| **Sl. No.** | **Subject Code** | **SEMESTER VII** | **L** | **T** | **P** | **C** |
| 1. | CB41PQ | DE-II | 3 | 0 | 0 | 3 |
| 2. | CB41PQ | DE-III | 3 | 0 | 0 | 3 |
| 3. | XX41PQ | IDE-III | 3 | 0 | 0 | 3 |
| 4. | HS31XX | HSS Elective-II | 3 | 0 | 0 | 3 |
| 5. | CB4198 | Summer Internship\* | 0 | 0 | 12 | 3 |
| 6. | CB4199 | Project – I | 0 | 0 | 12 | 6 |
| **TOTAL** | | | **12** | **0** | **24** | **21** |

**\* For specific cases of internship after 6th Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:**

**Note :**

**a)** (i) Summer internship (\*) period of at least 60 days’ (8 weeks) duration begins in the intervening vacation between semester VI and VII that may be done in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

**a)** (ii) Further, on return from internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

**b)** (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

**b)** (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

**b)** (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

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| **Sl. No.** | **Subject Code** | **SEMESTER VIII** | **L** | **T** | **P** | **C** |
| 1. | CB42XX | DE-IV | 3 | 0 | 0 | 3 |
| 2. | CB42XX | DE-V | 3 | 0 | 0 | 3 |
| 3. | CB42XX | DE-VI | 3 | 0 | 0 | 3 |
| 4. | CB4299 | Project – II | 0 | 0 | 16 | 8 |
| **TOTAL** | | | **9** | **0** | **16** | **17** |

Total Credits (including B. Tech. first year): **166**

**ELECTIVE GROUPS**

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| **Department Elective - I** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB3206 | Catalysis Science and Engineering | 3 | 0 | 0 | 3 |
| 2. | CB3207 | Biopharmaceutical Downstream Processing | 3 | 0 | 0 | 3 |
| 3. | CB3208 | Material Science and Engineering | 3 | 0 | 0 | 3 |
| 4. | CB3209 | Introduction to Microfluidics Technology | 3 | 0 | 0 | 3 |

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| **Department Elective - II** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4101 | Industrial Pollution Control | 3 | 0 | 0 | 3 |
| 2. | CB4102 | Introduction to Computational Biology | 3 | 0 | 0 | 3 |
| 3. | CB4103 | Molecular Modeling and Simulation | 3 | 0 | 0 | 3 |

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| **Department Elective - III** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4104 | Electrochemical Energy Systems | 3 | 0 | 0 | 3 |
| 2. | CB4105 | Fertilizer Technology | 3 | 0 | 0 | 3 |
| 3. | CB4106 | Nanomaterials | 3 | 0 | 0 | 3 |
| 4. | CB4107 | Combustion Engineering and Technology | 3 | 0 | 0 | 3 |

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| **Department Elective - IV** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4201 | Membrane Separation | 3 | 0 | 0 | 3 |
| 2. | CB4202 | Energy Storage: Technologies and Applications | 3 | 0 | 0 | 3 |
| 3. | CB4203 | Process Integration | 3 | 0 | 0 | 3 |

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| **Department Elective - V** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4204 | Renewable Energy Sources | 3 | 0 | 0 | 3 |
| 2. | CB4205 | Advanced Separation Processes | 3 | 0 | 0 | 3 |
| 3. | CB4206 | Fluidization Engineering | 3 | 0 | 0 | 3 |

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| **Department Elective - VI** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4207 | Energy Management | 3 | 0 | 0 | 3 |
| 2. | CB4208 | Heterogeneous Catalysis: Fundamentals and Applications | 3 | 0 | 0 | 3 |
| 3. | CB4209 | Polymer Science and Technology | 3 | 0 | 0 | 3 |
| 4. | CB4210 | Petroleum Refinery Engineering | 3 | 0 | 0 | 3 |

**IDE floated by the Department (not applicable for B. Tech. Chemical Engineering students)**

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| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB2206 | Environmental Science and Engineering | 3 | 0 | 0 | 3 |
| 2. | CB3106 | Introduction to Sustainable Engineering | 3 | 0 | 0 | 3 |
| 3. | CB4108 | Bioprocess Engineering | 3 | 0 | 0 | 3 |

**Minor in Chemical Engineering:**

Total courses: 5

Total credits: 17

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| **Sl. No.** | **Semester** | **Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | Sem III | CB2103 | Heat Transfer | 3 | 0 | 3 | 4.5 |
| 2. | Sem IV | CB2201 | Mechanical Operations | 2 | 0 | 3 | 3.5 |
| 3. | Sem V | CB3102 | Chemical Process Technology | 3 | 0 | 0 | 3 |
| 4. | Sem VI | CB2202 | Mass Transfer-I | 3 | 0 | 0 | 3 |
| 5. | Sem VI | CB2205 | Chemical Reaction Engineering-I | 3 | 0 | 0 | 3 |
| **Total** | | | | **14** | **0** | **6** | **17** |

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| **Sl. No.** | **Subject Code** | **SEMESTER I** | **L** | **T** | **P** | **C** |
| 1. | MA1101 | Calculus and Linear Algebra | 3 | 1 | 0 | 4.0 |
| 2. | CS1101 | Foundations of Programming | 3 | 0 | 3 | 4.5 |
| 3. | PH1101/PH1201 | Physics | 3 | 1 | 3 | 5.5 |
| 4. | CE1101/CE1201 | Engineering Graphics | 1 | 0 | 3 | 2.5 |
| 5. | EE1101/EE1201 | Electrical Sciences | 3 | 0 | 3 | 4.5 |
| 6. | HS1101 | English for Professionals | 2 | 0 | 1 | 2.5 |
| **TOTAL** | | | **15** | **2** | **13** | **23.5** |

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| **Course Number** | MA1101 |
| **Course Credit**  **(L-T-P-C)** | 3-1-0-4 |
| **Course Title** | Calculus and Linear Algebra |
| **Learning Mode** | Lectures and Tutorials |
| **Learning Objectives** | To provide the essential knowledge of basic tools of Differential Calculus, Integral Calculus, Vector spaces and Matrix Algebra. |
| **Course Description** | This course provides a foundation for Calculus and Linear Algebra. Topics related to properties of single and two variable functions along with their applications will be discussed. In addition fundamentals of linear algebra and matrix theory with applications will also be discussed. |
| **Course Content** | **Differential Calculus (12 Lectures)**: Limit and continuity of one variable function (including ε-δ definition). Limit, continuity and differentiability of functions of two variables, Tangent plane and normal, Change of variables, chain rule, Jacobians, Taylor’s Theorem for two variables, Extrema of functions of two or more variables, Lagrange’s method of undetermined multipliers.  **Integral Calculus (10 Lectures)**: Riemann integral for one variable functions, Double and Triple integrals, Change of order of integration. Change of variables, Applications of Multiple integrals such as surface area and volume.  **Vector Spaces (12 Lectures)**: Vector spaces (over the field of real numbers), subspaces, spanning set, linear independence, basis and dimension. Linear transformations, range and null space, rank-nullity theorem, matrix of a linear transformation.  **Matrix Algebra (8 Lectures)**: Elementary operations and their use in getting the rank, inverse of a matrix and solution of linear simultaneous equations, Orthogonal, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal and unitary matrices and their elementary properties, Eigenvalues and Eigenvectors of a matrix, Cayley-Hamilton theorem, Diagonalization of a matrix. |
| **Learning Outcome** | Students completing this course will be able to:  1. Understand various properties of functions such as limit, continuity and differentiability.  2. Learn about integrations in various dimension and their applications.  3. learn about the concept of basis and dimension of a vector space.  4. define Linear Transformations and compute the domain, range, kernel, rank, and nullity of a linear transformation.  5. compute the inverse of an invertible matrix.  6. solve the system of linear equations.  7. Apply linear algebra concepts to model, solve, and analyze real-world problems. |
| **Assessment Method** | Quiz /Assignment/ MSE / ESE |

**Textbooks:**

1. Thomas, G. B., Hass, J., Heil, C. and Weir M. D., “Thomas’ Calculus”, 14th Ed., Pearson Education, 2018
2. Kreyszig, E., “Advanced Engineering Mathematics”, 10th Ed., Wiley India Pvt. Ltd, 2015

**Reference Books:**

1. Jain, R. K. and Iyenger, S. R. K., “Advanced Engineering Mathematics”, 5th Ed., Narosa Publishing House, 2017
2. Axler, S., “Linear Algebra Done Right”, 3rd Ed., Springer Nature, 2015
3. Strang, G., “Linear Algebra and Its Applications” 4th Ed., Cengage India Private Limited, 2005

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| Course Number | CS1101 |
| Course Credit | 3-0-3-4.5 |
| Course Title | **Foundations of Programming** |
| Learning Mode | Offline |
| Learning Objectives | * To understand the fundamental concepts of programming * To develop the basic problem-solving skills by designing algorithms and implementing them. * To learn about various data types, control statements, functions, arrays, pointers, and file handling. * To achieve proficiency in debugging and testing a C program |
| Course Description | This introductory course provides a solid foundation in programming principles and techniques. Designed for students with little to no prior programming experience, it covers fundamental concepts such as variables, data types, control structures, functions, and basic data structures. Students will learn to write, debug, and execute programs using a high-level programming language. Emphasis is placed on developing problem-solving skills, logical thinking, and the ability to write clear and efficient code. By the end of the course, students will be equipped with the essential skills needed to pursue more advanced studies in computer science and software development. |
| Course Outline | Introduction and Programming basics,  Expressions  Control and Iterative statements,  Functions, Arrays,  Recursion vs. Iteration  Pointers,  2D-Array with pointers,  Structures,  String,  Dynamic memory allocation,  File handling,  Contemporary programming languages, and applications  **Practical component**: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class. |
| Learning Outcome | * Understanding of Basic Syntax and Structure in C language * Proficiency in Data Types, Operators, and Control Structures * Function Implementation and learn to use them appropriately * Efficient Use of Arrays and Strings * Pointer Utilization * Ability to perform dynamic memory allocation and deallocation using malloc (), calloc (), realloc (), and free () functions. * Structured data management with structures and unions * Exposure of file Handling * Learning debugging and error Handling |
| Assessment Method | Internal (Quiz/Assignment/Project), Mid-Term, End-Term |

Suggested Reading

* Knuth, Donald E. The art of computer programming, volume 4A: combinatorial algorithms, part 1. Pearson Education India, 2011.
* P.J. Deitel and H.M. Deitel, C How To Program, Pearson Education (7th Edition)
* Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice−Hall
* A. Kelley and I. Pohl, A Book on C, Pearson Education (4th Edition)
* K. N. King, C PROGRAMMING A Modern Approach, W. W. Norton & Company

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| Course Number | **PH1101/PH1201** |
| Course Credit | 3-1-3-5.5 |
| Course Title | Physics |
| Learning Mode | Lectures and Tutorials |
| Learning Objectives | Complies with Program Goals 1 and 2 |
| Course Description | This course deals with fundamentals in Classical mechanics, Waves and Oscillations and Quantum Mechanics. As a prerequisite, the mathematical preliminaries such as coordinate systems, vector calculus etc will be discussed in the beginning. |
| Course Outline | Orthogonal coordinate systems (Plane polar, Spherical, Cylindrical), concept of generalised coordinates, generalised velocity and phase space for a mechanical system, Introduction to vector operators, Gradient, divergence, curl and Laplacian in different co-ordinate systems.  Central force problem and its applications.  Rigid body rotation, vector nature of angular velocity, Finding the principal axes, Euler's equations; Gyroscopic motion and its application; Accelerated frame of reference, Fictitious forces.  Potential energy and concept of equilibrium, Lennard-Jones and double-well potentials, Small oscillations, Harmonic oscillator, damped and forced oscillations, resonance and its different examples, oscillator states in phase space, coupled oscillations, normal modes, longitudinal and transverse waves, wave equation, plane waves, examples two- and three-dimensional waves.  Michelson-Morley experiment, Lorentz transformation, Postulates of special theory of relativity, Time dilation and length contraction, Applications of special theory of relativity. |
| Learning Outcome | Complies with PLO 1a, 2a, 3a |
| Assessment Method | Quiz, Assignments and Exams |

**Suggested Readings:**

**Textbooks:**

1. Engineering Mechanics, M. K. Harbola, 2nd ed., Cengage, 2012

2. D. Kleppner and R. J. Kolenkow, An introduction to Mechanics, Tata McGraw-Hill, New Delhi, 2000.

3. I. G. Main, Oscillations and Waves

4. H. G. Pain, The Physics of Vibrations and Waves, 1968

5. Frank S. Crawford, Berkeley Physics Course Vol 3: Waves and Oscillations, McGraw Hill, 1966.

**References:**

1. R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lecture in Physics, Vol I, Narosa Publishing House, New Delhi, 2009.

2. David Morin, Introduction to Classical Mechanics, Cambridge University Press, NY, 2007.

3. P. C. Deshmukh, Foundations of Classical Mechanics, Cambridge University Press, 2019

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| Course code | **CE1101/CE1201** |
| Course Credit  (L-T-P-C) | 1-0-3-2.5 |
| Course Title | **Engineering Graphics** |
| Learning Mode | Lectures and Practical |
| Learning Objectives | Complies with PLO-1a   1. The course on engineering drawing is designed to introduce the fundamentals of technical drawing as an important form of conveying information. 2. Apply principles of engineering visualization and projection theory to prepare engineering drawings, using conventional and modern drawing tools. 3. Practice drawing orthographic projections, isometric views, and sectional views, of simple and combined solids in different orientations. |
| Course Description | This course will introduce drawing as a tool to represent a complex three-dimensional object on two-dimensional paper through methods of projections. The course explains the use of different drafting tools and the importance of conventions for uniformity and standardization of the interpretation of the drawings. |
| Course Outline | Fundamental of engineering drawing, line types, dimensioning, and scales. Conic sections: ellipse, parabola, hyperbola; cycloidal curves.  Principle of projection, method of projection, orthographic projection, plane of projection, first angle of projection, Projection of points, lines, planes and solids.  Section of solids: Sectional views of simple solids- prism, pyramid, cylinder, cone, sphere; the true shape of the section. Methods of development, development of surfaces.  Isometric projections: construction of isometric view of solids and combination of solids from orthographic projections.  Introduction to AutoCad and solving isometric problems. |
| Learning Outcome | After attending this course, the following outcomes are expected:   1. The student will understand the basic concepts of engineering drawing. 2. The student will be able to use basic drafting tools, drawing instruments, and sheets. 3. The student will be able to represent three-dimensional simple and combined solid objects on two-dimensional paper. 4. The student will be able to visualize and interpret the orientation of simple and combine solid objects. |
| Assessment Method | Laboratory Assignments (30%), Mid-semester examination (25%) and End-semester examination (45%). |

**Suggested Readings:**

**Textbooks:**

1. N.D. Bhatt, Engineering Drawing, Charotar Publishing House.
2. Agrawal & Agrawal, Engineering Drawing, McGraw Hill.
3. Jolhe, Engineering Drawing.

**References:**

1. Engineering Drawing and Design by David Madsen

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| **Course Number** | EE1101/EE1201 |
| **Course Credit** | 3-0-3-4.5 |
| **Course Title** | Electrical Sciences |
| **Learning Mode** | Lectures and Experiments |
| **Learning Objectives** | Complies with Program goals 1, 2 and 3 |
| **Course Description** | The course is designed to meet the requirements of all B. Tech programmes. The course aims at giving an overview of the entire electrical engineering domain from the concepts of circuits, devices, digital systems and magnetic circuits. |
| **Course Outline** | Circuit Analysis Techniques, Circuit elements, Simple RL and RC Circuits, Kirchoff’s law, Nodal Analysis, Mesh Analysis, Linearity and Superposition, Source Transformations, Thevenin’s and Norton’s Theorems, Time Domain Response of RC, RL and RLC circuits, Sinusoidal Forcing Function, Phasor Relationship for R, L and C, Impedance and Admittance, Instantaneous power, Real, reactive power and power factor.  Semiconductor Diode, Zener Diode, Rectifier Circuits, Clipper, Clamper, UJT, Bipolar Junction Transistors, MOSFET, Transistor Biasing, Transistor Small Signal Analysis, Transistor Amplifier and their types, Operational Amplifiers, Op-amp Equivalent Circuit, Practical Op-amp Circuits, Power Opamp, DC Offset, Constant Gain Multiplier, Voltage Summing, Voltage Buffer, Controlled Sources, Instrumentation Amplifier, Active Filters and Oscillators.  Number Systems, Logic Gates, Boolean Theorem, Algebraic Simplification, K-map, Combinatorial Circuits, Encoder, Decoder, Combinatorial Circuit Design, Introduction to Sequential Circuits.  Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three-Phase Circuits, Power measurement in three phase system, Electromechanical Energy Conversion, Introduction to Rotating Machines (DC and AC Machines).  Laboratory:  Experiments to verify Circuit Theorems; Experiments using diodes and bipolar junction transistor (BJT): design and analysis of half -wave and full-wave rectifiers, clipping and clamping circuits and Zener diode characteristics and its regulators, BJT characteristics (CE, CB and CC) and BJT amplifiers; Experiment on MOSFET characteristics (CS, CG, and CD), parameter extraction and amplifier; Experiments using operational amplifiers (op-amps): summing amplifier, comparator, precision rectifier, Astable and Monostable Multivibrators and oscillators; Experiments using logic gates: combinational circuits such as staircase switch, majority detector, equality detector, multiplexer and demultiplexer; Experiments using flip-flops: sequential circuits such as non-overlapping pulse generator, ripple counter, synchronous counter, pulse counter and numerical display; Power Measurement by two Wattmeter method; Open and Short Circuit Tests of Transformer. |
| **Learning Outcomes** | Complies with PLO 1a, 2a and 3a |
| **Assessment Method** | Quiz, Assignments and Exams |

**Texts/References**

1. C. K. Alexander, M. N. O. Sadiku, Fundamentals of Electric Circuits, 3rd Edition, McGraw-Hill, 2008.
2. W. H. Hayt and J. E. Kemmerly, Engineering Circuit Analysis, McGraw-Hill, 1993.
3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 6th Edition, PHI, 2001.
4. M. M. Mano, M. D. Ciletti, Digital Design, 4th Edition, Pearson Education, 2008.
5. Floyd, Jain, Digital Fundamentals, 8th Edition, Pearson.
6. David V. Kerns, Jr. J. David Irwin, Essentials of Electrical and Computer Engineering, Pearson, 2004.
7. Donald A Neamen, Electronic Circuits; analysis and Design, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.
8. Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004.
9. A. E. Fitzgerald, C. Kingsley Jr., S. D. Umans, Electric Machinery, 6th Edition, Tata McGraw-Hill, 2003.
10. D. P. Kothari, I. J. Nagrath, Electric Machines, 3rd Edition, McGraw-Hill, 2004.
11. Del Toro, Vincent. "Principles of electrical engineering." (No Title) (1972).

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| Course Number | HS1101 |
| Course Credit | L-T-P-W: 2-0-1-2.5 |
| Course Title | English for Professionals |
| Learning Mode | Offline |
| Learning Objectives | This course aims to help the students **(a)** attain proficiency in written English through the construction of grammatically correct sentences, utilization of subject-verb agreement principles, mastery of various tenses, and effective deployment of active and passive voice to ensure coherent and impactful written expression; **(b)** enhance oral communication skills by honing public speaking abilities, acquiring strategies to deliver persuasive presentations, and cultivating a polished telephone etiquette, enabling confident and articulate verbal communication; **(c)** foster active listening capabilities by recognizing different types of listening, and applying proven methods and strategies to improve active listening skills; **(d)** strengthen reading skills, including comprehension, interpretation, and critical analysis, to grasp diverse written materials and derive meaning from various types of texts encountered in academic and professional contexts; **(e)** develop adeptness in written communication for business purposes, encompassing the understanding of essential writing elements, mastery of appropriate writing styles thereby enhancing prospects for successful job  interviews and subsequent professional endeavors. |
| Course Description | This academic course on communication skills aims to equip students with fluency in spoken and written English for effective expression in both academic and professional settings. By focusing on essential communication principles and providing practical experiences, students develop clarity, precision, and confidence in their communication. Through interactive discussions and exercises, students enhance critical thinking and adaptability in diverse contexts. Upon completion, students will excel in formal presentations, group discussions,  and persuasive writing, enhancing their overall communication proficiency. |
| Course Outline | **Unit I:** Introduction to professional communication – LSRW - Phonetics and phonology  Sounds in English Language – production and articulation – rhythm and intonation – connected speech - Basic Grammar and Advanced Vocabulary  Sounds in English Language – production and articulation – rhythm and intonation – connected speech – persuading and negotiating – brevity and clarity in language.  Unit II: Characteristics of Technical Communication: Types of communication and forms of communication - Formal and informal communication Verbal and non-Verbal Communication – Communication barriers and remedies Intercultural communication – neutral language  Unit III: Comprehension and Composition – summarization, precis writing Business Letter Writing CV/ Resume – E-Communication  Unit IV: Statement of Purpose, Writing Project Reports, Writing research proposal, writing abstracts, developing presentations, interviews – combating nervousness  Tutorial: Listening Exercises, Speaking Practice (GDs, and Presentations), and Writing Practice  Learning Outcome   * Attain proficiency in written English, enabling the construction of grammatically correct sentences and coherent written expression through the use of appropriate grammar, tenses, and voice. * Enhance oral communication skills, including public speaking, persuasive presentation, and polished telephone etiquette, fostering confident and articulate verbal expression. * Cultivate active listening abilities, recognizing different listening types, overcoming obstacles, and employing strategies for attentive and effective communication. * Develop proficient written communication skills for business purposes, demonstrating understanding of essential writing elements, appropriate styles, and the creation of reports, notices, agendas, and minutes that effectively convey information. |
| Assessment Method | Class test + Quiz = 20%; Mid-semester = 25%; Assignment = 15%; End semester = 40% |

Suggested Reading

1. Balzotti, Jon. Technical Communication: A Design-Centric Approach. Routledge, 2022.
2. Kaul, Asha, Business Communication. PHI Learning Pvt. Ltd. 2009
3. Laplante, Phillip A. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals. CRC Press, 2018.
4. Lawson, Celeste, et al. Communication Skills for Business Professionals, Second Edition. CUP, 2019.
5. Sharon Gerson and Steven Gerson. Technical Writing: Process and Product (8th Edition), London: Longman, 2013
6. Rentz, Kathryn, Marie E. Flatley & Paula Lentz. Lesikar’s Business Communication Connecting in a Digital world, McGraw-Hill, Irwin.2012
7. Allan & Barbara Pease. The Definitive Book of Body Language, New York, Bantam,2004
8. Jones, Daniel. The Pronunciation of English, New Delhi, Universal Book Stall.2010
9. Savage, Alice. Effective Academic Writing. OUP. 2014
10. Swan and Alter. Oxford English grammar course. OUP. 201

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| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Code** | **SEMESTER II** | **L** | **T** | **P** | **C** |
| 1. | MA1201 | Probability Theory and Ordinary Differential Equations | 3 | 1 | 0 | 4 |
| 2. | CS1201 | Data Structure | 3 | 0 | 3 | 4.5 |
| 3. | CH1201/CH1101 | Chemistry | 3 | 1 | 3 | 5.5 |
| 4. | ME1201/ME1101 | Mechanical Fabrication | 0 | 0 | 3 | 1.5 |
| 5. | ME1202/ME1102 | Engineering Mechanics | 3 | 1 | 0 | 4 |
| 6. | IK1201 | Indian Knowledge System (IKS) | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **15** | **3** | **9** | **22.5** |

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| --- | --- |
| **Course Number** | MA1201 |
| **Course Credit**  **(L-T-P-C)** | 3-1-0-4 |
| **Course Title** | Probability Theory and Ordinary Differential Equations |
| **Learning Mode** | Lectures and Tutorials |
| **Learning Objectives** | To introduce the basic concepts of probability, statistics, and Differential equations. |
| **Course Description** | This course aims to cover basic concepts of probability, statistics and ordinary differential equations. In particular, popular distributions, random sampling, various estimators and hypothesis testing will be discussed. Students will also get exposure to the linear ordinary differential equations and their solution techniques. |
| **Course Content** | **Probability (12 Lectures)**: Random variables and their probability distributions, Cumulative distribution functions, Expectation and Variance, probability inequalities, Binomial, Poisson, Geometric, negative binomial distributions, Uniform, Exponential, beta, Gamma, Normal and lognormal distributions.  **Statistics (10 Lectures)**: Random sampling, sampling distributions, Parameter estimation, Point estimation, unbiased estimators, maximum likelihood estimation, Confidence intervals for normal mean, Simple and composite hypothesis, Type I and Type II errors, Hypothesis testing for normal mean.  **Ordinary Differential Equations (20 Lectures)**: First order ordinary differential equations, exactness and integrating factors, Picard's iteration, Ordinary linear differential equations of n-th order, solutions of homogeneous and non-homogeneous equations (Method of variation of parameters). Systems of ordinary differential equations,  Power series methods for solutions of ordinary differential equations. Legendre equation and Legendre polynomials, Bessel equation and Bessel functions. |
| **Learning Outcome** | Students will get exposure and understanding of:   1. Random variables and their probability distributions 2. Understand popular distributions and their properties 3. Sampling, estimation and hypothesis testing 4. Solution of ordinary differential equations 5. Solution of system of ordinary differential equations 6. Special functions arising as power series solutions of ordinary differential equations |
| **Assessment Method** | Quiz /Assignment/ MSE / ESE |

**Text Books:**

1. Hogg, R. V., Mckean, J. and Craig, A. T., “Introduction to Mathematical Statistics”, 8th Ed., Pearson Education India, 2021
2. S.M. Ross “An introduction to Probability Models, Academic Press INC, 11th edition.
3. Miller, I. and Miller, M., “John E. Freund's Mathematical Statistics with Applications”, 8th Ed., Pearson Education India, 2013
4. S. L. Ross, Differential equations, 3rd Edition, Wiley, 1984
5. W. E. Boyce and R. C. Di Prima, Elementary Differential equations and Boundary Value Problems, 7th Edition, Wiley, 2001.

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| --- | --- |
| Course Number | CS1201 |
| Course Credit | 3-0-3-4.5 |
| Course Title | **Data Structure** |
| Learning Mode | Offline |
| Learning Objectives | * Understand the principles and concepts of data structures and their importance in computer science. * Learn to implement various data structures and understand how different algorithms works. * Develop problem-solving skills by applying appropriate data structures to different computational problems. * Achieving proficiency in designing efficient algorithms. |
| Course Description | This course provides a comprehensive study of data structures and their applications in computer science. It focuses on the implementation, analysis, and use of various data structures such as arrays, linked lists, stacks, queues, trees, and graphs. Through theoretical concepts and practical programming exercises, this course aims to develop problem-solving and algorithmic thinking skills essential for advanced topics in computer science and software development. |
| Course Outline | * Introduction to Data Structure, * Time and space requirements, Asymptotic notations * Abstraction and Abstract data types * Linear Data Structure: stack, queue, list, and linked structure * Unfolding the recursion * Tree, Binary Tree, traversal * Search and Sorting, * Graph, traversal, MST, Shortest distance * Balanced Tree   **Practical component**: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class. |
| Learning Outcome | * Understand Data Structure Fundamentals * Implement Basic Data Structures using a programming language * Analyse and Apply Algorithms * Design and Analyse Tree Structures * Understand the usage of graph and its related algorithms * Design and Implement Sorting and Searching Algorithms * Debug and Optimize Code |
| Assessment Method | Internal (Quiz/Assignment/Project), Mid-Term, End-Term |

Suggested Reading

* Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Data Structures and Algorithms, Published by Addison-Wesley
* Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein., Introduction to Algorithms,
* Mark Allen Weiss, Data Structures and Algorithm Analysis in Java
* Robert Sedgewick and Kevin Wayne, Algorithms
* Narasimha Karumanchi, Data Structures and Algorithms Made Easy

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| Course Number | **CH1201/CH1101** |
| Course Credit | **3-1-3-5.5** |
| Course Title | **Chemistry** |
| Learning Mode | Offline |
| Learning Objectives | The course aims to lay a foundation for all three branches of chemistry, viz. Organic, Inorganic, and Physical Chemistry. The course aims to nurture knowledge to appreciate the interface of chemistry with other science and Engineering branches by combining theoretical concepts and experimental studies. |
| Course Description | This course introduces basic organic chemistry, inorganic chemistry and Physical chemistry to understand fundamental laws that governs various reactions, reaction rates, equilibrium, and their applications in daily life through relevant experimentation. |
| Course Outline | **Module 1:** Thermodynamics: The fundamental definition and concept, the zeroth and first law. Work, heat, energy and enthalpies. Second law: entropy, free energy and chemical potential. Change of Phase. Third law. Chemical equilibrium. Conductance of solutions, Kohlrausch’s law-ionic mobilities, Basic Electrochemistry.  **Module 2:** Coordination chemistry: Crystal field theory and consequences color, magnetism, J.T distortion. Bioinorganic chemistry: Trace elements in biology, heme and non-heme oxygen carriers, haemoglobin and myoglobin; Organometallic chemistry.  **Module 3:** Stereo and regio-chemistry of organic compounds, conformational analysis and conformers, Molecules devoid of point chirality (allenes and biphenyls); Significance of chirality in living systems,organic photochemistry, Modern techniques in structural elucidation of compounds (UV–Vis, IR, NMR).  **Module 4 (Lab Component):** Experiments based on redox and complexometric titrations; synthesis and characterization of inorganic complexes and nanomaterials; synthesis and characterization of organic compounds; experiments based on chromatography; experiments based on pH and conductivity measurement; experiment related to chemical kinetics and spectroscopy. |
| Learning Outcome | Students will be able to 1**.** identify organic and inorganic molecules and relate them to daily life applications through experiments.  2. understand important hypothesis, laws and their derivations to intercept physical phenomenon of chemical reactions and apply them in hands-on experiments.  3. understand the importance of organic and inorganic molecules in our body and environment.  4. know important analytical techniques to intercept chemical entity.  5. approach organic and inorganic synthesis as a skillset for drug manufacturing, calculate limiting reagents and yields, use various analytical tools to characterize organic compounds, interpret and ascertain data related to Physical chemistry aspects and know laboratory safety measures, risk factors and scientific report writing skills. |
| Assessment Method | **Theory**: 20% Quiz and assignment, 30% Mid sem and 50% End semester exams for theory part (4 credits).  **Lab**: 60% lab report, lab performance and assignment, 20% End semester exam for practical part, 20% viva/quiz (1.5 credits).  **Overall Weightage**: Theory (70%), Lab (30%). |

**Suggested Reading:**

# Text books:

1. Vogel's Qualitative Inorganic Analysis, G. Svehla, 7th Edition, Revised, Prentice Hall, 1996.
2. A. J. Elias, S. S. Manoharan and H. Raj, "Experiments in General Chemistry", Universities Press (India) Pvt. Ltd., 1997.
3. A. J. Elias, A Collection of Interesting General Chemistry Experiments, revised edition, Universities Press (India) Pvt. Ltd., 2007.
4. F. Albert Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, Advanced Inorganic Chemistry - 6th Edition New Delhi: Wiley India, 2008.
5. K. Mukkanti, Practical Engineering Chemistry, B.S. Publications, Hyderabad, 2009.
6. Shriver and Atkins inorganic chemistry / Peter Atkins, Tina Overton, Jonathan Rourke, Mark Weller, Fraser Armstrong-5th Edition – Oxford: UOP. 2012.
7. Atkins’ Physical Chemistry, Peter Atkins, Julio de Paula, James Keeler, Oxford University Press, 11th Edition 2017.
8. K. L. Kapoor, A Textbook of Physical Chemistry, Vol: 1, 2 (6th Edition, 2019), Vol: 3 (5th Edition, 2020) MaGraw Hill.
9. G. R. Chatwal, S. K. Anand, Instrumental Methods of Chemical Analysis, 5th Edition, Himalaya Publications, 2023.

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|  | PLO-1 | PLO-2 | PLO-3 | PLO-4 | PLO-5 | PLO-6 | PLO-7 | PLO-8 |
| CLO-1 | X | X | X | X | X | X | X | X |
| CLO-2 | X | X |  | X | X |  |  |  |
| CLO-3 | X | X | X | X |  | X | X |  |
| CLO-4 | X | X |  | X | X | X | X | X |
| CLO-5 |  |  | X | X | X |  |  | X |

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| --- | --- |
| Course Number | **ME1201/ME1101** |
| Course Credit | **0-0-3-1.5** |
| Course Title | **Mechanical Fabrication** |
| Learning Mode | Fabrication work – hands on fabrication work in Workshop |
| Learning Objectives | Complies with PLOs 3-4.   * This course aims to develop the concepts and skills of various mechanical fabrication methods. * Fabrication of metallic and non-metallic components, fabrication using bulk and sheet metals, subtractive and additive manufacturing methods, and assemble the parts |
| Course Description | This course is designed to fulfil the need of hand on experience about various approaches (conventional and CNC, subtractive and additive) of mechanical fabrication approaches.  Prerequisite: NIL |
| Course Outline | The jobs for various shops should be planned such that they are the parts of an assembled item. The student groups will fabricate different parts in various shops which will involve some amount of their creativeness/input particularly in design and/or planning.  Various components as required for the assembled part can be made using the following shops:  **Sheet Metal Working:**  Development, sheet cutting and fabrication of designated job using sheet metal (ferrous/nonferrous); Joining of required portions by soldering, in case part is desired to be made leak proof.  **Pattern Making and Foundry:**  Making of suitable pattern (wood); making of sand mould, melting of non-ferrous metal/alloy (Al or Al alloys), pouring, solidification. Observation/identification of various defects appeared on the component.  **Joining:**  Butt/lap/corner joint job fabrication as required of low carbon steel plates; weld quality inspection by dye-penetration test (non-destructive testing approach)of the component made. Demonstration of semi-automatic Gas Metal Arc welding (GMAW).  **Conventional machining:**  Operations on lathe and vertical milling to fabricate the required component. The fabrication of the component should cover various lathe operations like straight turning, facing, thread cutting, parting off etc., and operations using indexing mechanism on vertical milling.  **CNC centre:**  Fundamentals of CNC programming using G and M code; setting and operations of job using CNC lathe or milling, tool reference, work reference, tool offset, tool radius compensation to fabricate the component with a designed profile on Al/Al-alloy plate.  **3D printing (Fused Filament Fabrication): (2 weeks)**  Create the model, select appropriate slicing and path for fabrication of a 3D job by layer deposition (additive manufacturing approach) using polymeric material. Demonstration on pattern fabrication using 3D printing. |
| Learning Outcome | * This course would enable the students to develop the concept of design, fabrication (subtractive and additive) for various engineering applications**.** Fabrication of components and assemble them. * The practical skill and hands on experience for various fabrication methods from bulk, sheet metal using conventional as well as CNC machines. |
| Assessment Method | Fabrication of components in each of the shops required for assembly of the given part; submission of reports for each shop, and quiz assessment. |

**Text and Reference books:**

1. Hajra Choudhury, HazraChoudhary and Nirjhar Roy, 2007, Elements of Workshop Technology, vol. I,Mediapromoters and Publishers Pvt. Ltd.
2. W A J Chapman, Workshop Technology, 1998, Part -1, 1st South Asian Edition, Viva Book Pvt Ltd.
3. P.N. Rao, 2009, Manufacturing Technology, Vol.1, 3rd Ed., Tata McGraw Hill Publishing Company.
4. M.Adithan, B.S. Pabla, 2012, CNC machines, New Age International Publishers

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| **Course Number** | **ME1202/ ME1102** |
| **Course Number** | **Engineering Mechanics** |
| **L-T-P-C** | 3-1-0-4 |
| **Pre-requisites** | Nil |
| **Semester** | Spring |
| **Learning Mode** | Lectures |
| **Learning Objectives** | Complies with PLOs 1, 4   * The objective of this first course in mechanics is to enable engineering students to analyze basic mechanics problems and apply vector-based approach to solve them. |
| **Course Outline** | * + - 1. **Rigid body statics**: Equivalent force system. Equations of equilibrium, Free body diagram, Reaction, Static indeterminacy.       2. **Structures**: 2D truss, Method of joints, Method of section. Beam, Frame, types of loading and supports, axial force, Bending moment, Shear force and Torque Diagrams for a member.       3. **Friction**: Dry friction (static and kinetic), wedge friction, disk friction (thrust bearing), belt friction, square threaded screw, journal bearings, Wheel friction, Rolling resistance.       4. **Centroid and Moment of Inertia**       5. **Introduction to stress and strain**: Definition of Stress, Normal and shear Stress. Relation between stress and strain, Cauchy formula.   **Stress in an axially loaded member and stress due to torsion in axisymmetric section** |
| **Learning Outcomes:** | Following learning outcomes are expected after going through this course.   * Learn and apply general mathematical and computer skills to solve basic mechanics problems. * Apply the vector-based approach to solve mechanics problems. |
| **Assessment Method** | Mid semester examination, End semester examination, Class test/Quiz, Tutorials |

**Reference Books**

1. H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002.
2. F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol I - Statics, 3rd Ed, Tata McGraw Hill, 2000.
3. J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol I - Statics, 5th Ed, John Wiley, 2002.
4. E.P. Popov, Engineering Mechanics of Solids, 2nd Ed, PHI, 1998.
5. F. P. Beer and E. R. Johnston, J.T. Dewolf, and D.F. Mazurek, Mechanics of Materials, 6th Ed, McGraw Hill Education (India) Pvt. Ltd., 2012.

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| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Code** | **SEMESTER III** | **L** | **T** | **P** | **C** |
| 1. | CB2101 | Introduction to Chemical Engineering | 2 | 0 | 0 | 2 |
| 2. | CB2102 | Fluid Mechanics | 3 | 1 | 2 | 5 |
| 3. | CB2103 | Heat Transfer | 3 | 0 | 3 | 4.5 |
| 4. | CB2104 | Chemical Process Calculations | 3 | 1 | 0 | 4 |
| 5. | CB2105 | Chemical Engineering Thermodynamics | 3 | 0 | 0 | 3 |
| 6. | HS21XX | HSS Elective-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **17** | **2** | **5** | **21.5** |

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| --- | --- |
| **Course Number** | **CB2101** |
| **Course Credit**  **(L-T-P-C)** | **2-0-0-2** |
| **Course Title** | **Introduction to Chemical Engineering** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To build an interest and basic understanding on the scope and importance of Chemical Engineering subjects.  To introduce the career and research opportunities in the area of Chemical Engineering. |
| **Course Description** | In this course, basic introduction to various subjects/topics comprising the broad discipline of chemical engineering and their applications in real scenarios will be highlighted. The course will also give an overview of recent developments and emerging areas of the field. |
| **Course Content** | Chemical process industries and the evolution of Chemical Engineering domain; Roles of chemical engineers– conventional and modern scenarios; Basics of units and dimensions; Equations of state; Material and energy balances; Introduction to unit operations and unit processes; Chemical reactions; Heat and mass transfer and process control; Safety in chemical industries including historical case studies; Sustainable development via chemical engineering; Emerging trends and R&D scenario in Chemical Engineering; Interaction with other engineering disciplines. |
| **Learning Outcome** | Knowledge on various subjects and their applications relevant for chemical engineers.  Identifying the importance of safety and sustainable development in chemical engineering context.  Awareness on research and development in chemical engineering. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. W. L. Badger, J. T. Banchero, Introduction to Chemical Engineering, McGraw Hill, 2017.
2. R. M. Felder, R. W. Rousseau, Elementary Principles of Chemical Processes, 3rd Ed., Wiley & Sons, 2005.
3. W. McCabe, J. Smith, P. Harriott, Unit Operations of Chemical Engineering, 7th Ed., McGraw Hill, 2005.

**Reference Books**:

1. J.M. Smith, H.C., Van Ness, M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 8th Ed., McGraw Hill Education (India), 2018.

2. S. Pushpavanam, Introduction to Chemical Engineering, PHI Learning Ltd., 2012.

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|  | CLO1 | CLO2 |
| PLO1 | X |  |
| PLO2 |  | X |
| PLO3 |  |  |

## CB2102: Fluid Mechanics

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| **Course Number** | **CB2102** |
| **Course Credit**  **(L-T-P-C)** | **3-1-2-5** |
| **Course Title** | **Fluid Mechanics** |
| **Learning Mode** | Classroom lectures and practical |
| **Learning Objectives** | To build an understanding on the importance and scope of fluid in rest (statics) and fluid in motion (dynamics) in process systems.  Learning basics of pressure development, fluid properties and their role in driving various types of flows and fluid response under different external/internal forces.  To study governing equations and dimensionless groups which drive the flow and their applications in the designing of pipe networks, pumps, etc. |
| **Course Description** | The course helps to develop a basic understanding of fluid mechanics and its application in chemical engineering. Equations and concepts in fluid statics, kinematics, and dynamics are covered in the course. |
| **Course Content** | Introduction to fluid mechanics; Definition and types of fluids; System and control volume; Fluid as a continuum; Velocity and stress field; Newton’s law of viscosity; Newtonian and non-Newtonian fluids; Fluid statics; Hydrostatic force on submerged bodies; Buoyancy and stability; Streamlines, pathlines, streaklines; Rigid body motion; Flow kinematics: Eulerian and Lagrangian approach; Integral analysis: mass and momentum balances; Bernoulli equation; Differential analysis of flow; Navier-Stokes equation; Dimensional analysis using Buckingham PI theorem; Flow similarity and model studies; Unidirectional flow; Compressible and incompressible flows; Viscous and inviscid flow; Irrotational flow; Laminar and turbulent flow; Skin friction and form friction; Friction factor; Fully developed flow through pipes and ducts; Head losses; Potential flow; Boundary layer theory; Boundary layer separation; Flow around immersed bodies; Drag and lift; Flow through packed and fluidized beds, Compressible flow; Flow measurement: Venturi and orifice meter; Fluid transportation- pumps, blowers and compressors. |
| **Learning Outcome** | Development and application of governing equations and laws of fluid systems.  Study on flow and pressure measuring equipment, frictional losses in pipes/conduits, laminar/turbulent flows, compressible/incompressible flows, boundary layer development and flows through porous beds.  Illustrating the physical significance of pertinent non-dimensional groups through dimensional analysis. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. R.W. Fox, A.T. McDonald, P.J. Pritchard, Introduction to Fluid Mechanics, Wiley, 7th Ed., 2009.
2. F.M. White, Fluid Mechanics, Mc-Graw Hill, 6th Ed., 2008.

**Reference Books:**

1. M. Denn, Process Fluid Mechanics, Prentice Hall, 1979.
2. V.L. Streeter, Fluid Mechanics, 5th Ed., Mc-Graw Hill, 1971.
3. R.B. Bird, W.E. Stewart, E. N. Lightfoot, Transport Phenomena, 2nd Ed., Wiley, 2006.
4. J. M. Coulson, J. F. Richardson, J. R. Backhurst and J. H. Harker, Chemical Engineering, Vol. 1, 5th Ed., Elsevier, 2015.
5. W. L. McCabe, J. C. Smith, P. Harriott, Unit Operations of Chemical Engineering, 7th Ed., Mc-Graw Hill, 2005.

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|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X | X |  |
| PLO3 |  | X | X |

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| **Course Number** | **CB2103** |
| **Course Credit**  **(L-T-P-C)** | **3-0-3-4.5** |
| **Course Title** | **Heat Transfer** |
| **Learning Mode** | Classroom lectures and practical |
| **Learning Objectives** | To understand the fundamentals of heat transfer mechanisms in fluids and solids and their applications to engineering problems.  To understand the basic principle and mathematical formulation of various heat transfer equipment used in process industries.  To perform experiments to understand the various heat transfer measurements that help to optimize the process parameters. |
| **Course Description** | This course helps to understand the fundamentals of heat transfer mechanisms in fluids and solids and their applications in various heat transfer equipment in process industries including conduction, convection and radiation problems, heat exchangers and evaporators. |
| **Course Content** | Introduction; Heat conduction; Fourier’s law; Thermal conductivity;; Thermal resistance; Critical thickness of insulation; One dimensional heat conduction; Heat generation; 2D heat conduction; Unsteady-state conduction, Various shapes (thin plate, thick plate, cylinder, sphere); Practical applications (Freezing of butter slab, meat loafs, Pasteurization of milk, Sterilization of canned jam/jelly); Heisler charts; extended surfaces; Laws of Black body radiation; Solid angle and radiation intensity; Radiation exchange between black and gray surfaces; Shape factor; electrical network analogy for thermal systems; Forced Convection; Differential equation of convection; Thermal boundary layer; Laminar and turbulent flow heat transfer; Natural Convection; Governing equations; Heat Exchangers; Types of heat exchangers; Overall heat transfer coefficient and fouling factor, Mean temperature difference; Effective-NTU approach; Condensation and boiling; Types of boiling; Correlations in saturated poll boiling; Film and drop condensation; Condensation on a vertical plate and horizontal tubes. |
| **Learning Outcome** | Ability to understand, analyze and solve conduction, convection and radiation problems.  Ability to design and analyze the performance of heat exchangers, evaporators and other heat transfer equipment.  Ability to conduct experiments and analyze the data to interpret the performance of the equipment. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. D. Q. Kern, Process Heat Transfer, 1st Ed. McGraw Hill, 2001.
2. S. P. Sukhatme, A Text Book of Heat Transfer, 4th Ed., Universities press, 2005.
3. J. P. Holman, Heat Transfer, 10th Ed., Mc-Graw Hill, 2017.

**Reference Books:**

1. W. H. McAdams, Heat Transmission, 2nd revised Ed., Mc-Graw Hill, 1973.
2. H. Martin, Heat Exchangers, 1st Ed., CRC press, 1988.
3. C. J. Geankoplis, Transport Processes and Unit Operations, 3rd Ed., Prentice Hall India Pvt. Ltd., New Delhi, 2002.
4. J. M. Coulson, J. F. Richardson, J. R. Backhurst and J. H. Harker, Chemical Engineering, Vol-1, 5th Ed., ‎ Butterworth-Heinemann Ltd, 1999.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB2104** |
| **Course Credit**  **(L-T-P-C)** | **3-1-0-4** |
| **Course Title** | **Chemical Process Calculations** |
| **Learning Mode** | Classroom lectures and tutorials |
| **Learning Objectives** | To learn the fundamental concepts of material balance and their applications.  To learn the fundamental concepts of energy balance and their applications.  To learn the overall concepts of combined material and energy balance and their diverse applications. |
| **Course Description** | This course is mainly about learning the concepts of material balance and energy balance and their applications (individual or combined) with reference to different chemical engineering systems/processes. |
| **Course Content** | Units and dimensions; Dimensional analysis, Rayleigh method and Buckingham method; Steady-state/unsteady state processes; Lumped and distributed processes; Single and multi-phase systems; Correlations for physical and transport properties; Equilibrium relations; Ideal gases and gaseous mixtures; Vapor pressure; Vapor liquid equilibrium; Some Thermodynamics cycle namely Rankine Cycle, Carnot Cycle etc.; Material balances: Non-reacting single-phase systems; Systems with recycle, purge and bypass; Processes involving vaporization and condensation; Intensive and extensive variables; Rate laws; Calculation of enthalpy change; Heat of reaction; Saturation humidity, humidity charts and their use; Energy balance calculations; Flow-sheet preparation; Degrees of freedom analysis. |
| **Learning Outcomes** | Familiarize with different units and dimensions.  Analyse and comprehend steady-state and dynamic processes.  Understand and calculate problems related to material balances.  Understand and calculate problems related to energy balances.  Understand and calculate problems related to combined material and energy balances. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. B. I. Bhatt; S. B. Thakore, Stoichiometry, McGraw Hill, 6th Ed., 2021.
2. O. A. Hougen, K. M. Watson and R. A. Ragatz, Chemical Process Principles, CBS Publishers, Part-1, 2nd Ed., 2004.
3. D. M. Himmelblau, Basic Principles and Calculations in Chemical Engineering, Prentice Hall of India, 8th Ed., 2014.

**Reference Books:**

1. N. Chopey, Handbook of Chemical Engineering Calculations, Mc-Graw Hill, 3rd Ed., 2004.
2. R. M. Felder and R. W. Rousseau, Elementary Principles of Chemical Processes, Wiley, 3rd Ed., 2014.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  |  | X |
| PLO3 |  |  | X |

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| --- | --- |
| **Course Number** | **CB2105** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Chemical Engineering Thermodynamics** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To establish the basic thermodynamic principles and key relations for understanding the transfer processes.  To familiarize with various real-world engineering examples for how thermodynamics is applied in engineering practice. |
| **Course Description** | This course covers the basic postulates of classical thermodynamics and their applications to open and closed systems, the equation of states, properties of pure fluids and mixtures, phase equilibrium, and chemical reaction equilibrium. Applications are discussed through extensive problem work relating to practical topics. |
| **Course Content** | Introduction and basic definitions: System, Property, Energy, Work, Heat; Equilibrium; Reversible and irreversible processes; Equations of state and prediction of volumetric properties of fluids from PVT relationss; First law and other basic concepts; Second law: Heat engines, refrigerators and heat pumps, Carnot Cycle; Entropy: entropy balance and changes of pure substances, liquids, solids, and gases; Third law; Thermodynamic property relations: Maxwell relations, Isentropic processes; Vapour-Liquid equilibria (VLE): Phase rule, Gibbs-Duhem equation; Raoult's law and modified Raoult’s Law, Henry's law, High-pressure VLE; Solution thermodynamics: fundamental property relation, chemical potential and phase equilibria, partial and molar, Fugacity and fugacity coefficient, Ideal solution model; Excess properties, activity coefficient, Chemical reaction equilibrium: Homogeneous and heterogeneous reactions; multi-reaction equilibria, equilibrium criteria to chemical reactions. |
| **Learning Outcome** | Development of an intuitive understanding of thermodynamics.  Identify the problems that deal with the treatment of properties of solutions, phase equilibria and chemical reaction equilibria |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. J. M. Smith, H. C. Van Ness, M. M. Abbott, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill, 6th Ed., 2001.
2. S. I. Sandler, Chemical, Biochemical and Engineering Thermodynamics, Wiley India, 4th Ed., 2006.
3. Y. V. C. Rao, Chemical Engineering Thermodynamics, Universities Press, India, 1st Ed., 1997.

**Reference Books:**

1. J. M. Prausnitz, R. N. Lichtenthaler, E. G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria, Prentice Hall, 3rd Ed., 1998 .

2. J. W. Tester, M. Modell, Thermodynamics and its Applications, Prentice Hall, 3rd Ed., 1999.

3. R. C. Reid, J. M. Prausnitz, B.E.Poling, Properties of Gases and Liquids, McGraw-Hill, 4th Ed., 1987.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 | X | X |  |
| PLO3 |  |  |  |

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| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Code** | **SEMESTER IV** | **L** | **T** | **P** | **C** |
| 1. | CB2201 | Mechanical Operations | 2 | 0 | 3 | 3.5 |
| 2. | CB2202 | Mass Transfer-I | 3 | 0 | 0 | 3 |
| 3. | CB2203 | Fundamentals of Biochemical Engineering | 3 | 0 | 0 | 3 |
| 4. | CB2204 | Process Dynamics and Control | 3 | 0 | 2 | 4 |
| 5. | CB2205 | Chemical Reaction Engineering-I | 3 | 0 | 0 | 3 |
| 6. | XX22PQ | IDE-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **17** | **0** | **5** | **19.5** |

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| --- | --- |
| **Course Number** | **CB2201** |
| **Course Credit**  **(L-T-P-C)** | **2-0-3-3.5** |
| **Course Title** | **Mechanical Operations** |
| **Learning Mode** | Classroom lectures and practical |
| **Learning Objectives** | To understand various mechanical operations applicable in the Chemical Process Industries (CPIs).  To learn the principle and construction of the equipment.  To perform process evaluation of various unit operations. |
| **Course Description** | This course helps to understand basic principles of various mechanical operations, construction and working of the equipment including size measurement and classification methods and systems, fluid particle systems and equipment, size reduction equipment, solid-solid separation method system. |
| **Course Content** | Principles of crushing and grinding; Laws of crushing and grinding (Rittinger’s Law, Kick’s Law, Bond’s Law); Properties and handling of particulate solids: introduction, characterization of solid particles, determination of mean particle size, size distribution equations; Characteristics of industrial crushers and mills; Industrial screening; Effectiveness of screens; Cyclones; Fluid-particle mechanics; Free and hindered settling; Stoke’s Law and Newton’s Law; Industrial classifiers; Clarifiers and thickeners; Gravity separation, tabling and jigging; Floatation and its kinetics; Mixing of liquids and solids; Power requirement in mixing; Principles of filtration: Ergun Equation and Kozeny-Carman Equation; Filtration equipment; Transportation and storage of solids: introduction, storage techniques (bulk storage, bin storage, hoppers, silos), bulk solids conveying; Grade efficiency: measurement techniques, cut size, sharpness cut, construction of grade efficiency curve. |
| **Learning Outcomes** | Ability to understand size measurement and classification methods and systems.  Ability to understand fluid particle systems and equipment.  Ability to select suitable size reduction equipment, solid-solid separation method system.  Ability to analyse separation, filtration processes and solid-liquid separation equipment and systems. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, Mc-Graw Hill, 7th Ed., 2005.
2. J. M. Coulson, J. F. Richardson, J. R. Backhurst and J. H. Harker, Chemical Engineering, Elsevier, Vol-2, 5th Ed., 2015.
3. C. J. Geankoplis, Transport Processes and Unit Operations, Prentice Hall India Pvt. Ltd., New Delhi, 3rd Ed., 2002.

**Reference Books:**

1. A. M. Gaudin, Principles of Mineral dressing, Mc-Graw Hill, 1939.
2. R. H. Perry and C. H. Chilton, Chemical Engineer’s Hand Book, Mc-Graw Hill, 8th Ed., 2007.
3. A. F. Taggart, Handbook of Mineral Dressing: Ores and Industrial Minerals, Wiley, 1945.
4. Ghosal, Sanyal, and Dutta, Introduction to Chemical Engineering, McGraw Hill Education, 2014.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 |  | X |  |
| PLO3 |  |  | X |

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| --- | --- |
| **Course Number** | **CB2202** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Mass Transfer-I** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To learn the fundamental concepts of Mass transfer operations.  To develop numerical solutions to various mass transfer processes.  To familiarize with various equipment that uses these principles for useful separation processes. |
| **Course Description** | Introduction to the fundamental aspects of mass transfer and their importance in chemical engineering processes are covered in this course. Calculations and phase diagrams in distillation, extraction, and absorption are taught in the course. |
| **Course Content** | Fick’s law of diffusion, Molecular diffusion, Gas- and liquid- phase diffusion coefficients; Mass transfer in convective system; Types and correlations for mass transfer coefficients; Eddy diffusion; Mass transfer theories; Equilibrium; Raoult’s and Henry’s law; Inter-phase mass transfer; Overall mass transfer coefficient; Contacting equipment – gas-liquid; Type of contacting equipment: plate, tray, bubble column, packed column, agitated vessel, spray tower; Design of packed tower; Flooding in packed towers; Equilibrium in gas-liquid systems; Gas absorption and stripping; Selection of solvent; Number of stages in a tray tower; Height equivalent to a theoretical plate; Distillation: Vapor-liquid equilibrium; Enthalpy-concentration plots; Flash vaporization; Batch distillation; Steam distillation; Continuous fractionation; McCabe-Thiele and Ponchon-Savarit methods; Liquid-liquid extraction (LLE); Solvent selection; Equipment for LLE; Solid-liquid extraction/leaching: rate, solid-liquid contacting strategy, equipment. |
| **Learning Outcome** | Identify, quantify and calculate various parameters relevant to simple mass transfer operations.  Describe various equipment working on mass transfer principles.  Design the basic equipment required for separation processes that are based on mass transfer principles. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination. |

**Text Books:**

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill, 3rd Ed., 1980.
2. E. L. Cussler, Diffusion- Mass Transfer in Fluid Systems, Cambridge University Press, 1997.
3. B. K. Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning Private Limited, 2009.

**Reference Books:**

1. W. McCabe, J. Smith, P. Harriott, Unit Operations of Chemical Engineering. McGraw-Hill, 7th Ed., 2021.

2. C. J. Geankoplis, A. A. Hersel, D. H. Lepek. Transport Processes & Separation Process Principles, Pearson Education Limited, 5th Ed., 2013.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 |  | X | X |
| PLO3 |  | X | X |

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| --- | --- |
| **Course Number** | **CB2203** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Fundamentals of Biochemical Engineering** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To enhance skills in the areas of biochemical processes, to provide the fundamental background of biological systems, biochemical engineering.  To make a better understanding of the microbial world and their growth.  To make an expert of enzymes in kinetic analysis of biochemical reactions, apply the basic concepts of thermodynamics, mass and energy balances, reaction kinetics, and reactor design for biochemical processes. |
| **Course Description** | This course contains the basic concepts of biochemical products, the kinetics of enzymatic and microbial-related reactions, design and principles of bioreactors, types and principles of fermenters, and transport phenomena related to bioprocess systems. |
| **Course Content** | Introduction: definition and scope of biochemical engineering; Enzymes; Vitamins; Single-cell protein microbiology; Biocatalysts; Model reactions; Kinetics of enzyme catalyzed reactions; Kinetic models (structured and unstructured) of microbial growth and product formation; Fermenter types: Modeling of batch and continuous fermenter; Design and analysis of bioreactor; Mixing phenomena in bioreactors; Sterilization equipment; Batch and continuous sterilize design; Transport phenomena in bioprocess systems: gas-liquid mass transfer in cellular systems, bubble aeration and mechanical agitation, calculation of power consumption, correlation between oxygen transfer coefficient and operating variables, estimation of KLa in the fermentation process, factors affecting volumetric oxygen transfer, rheology of fermentation fluids; Biochemical product recovery and separation: membrane separation process (reverse osmosis, dialysis, ultrafiltration, chromatographic methods). |
| **Learning Outcome** | The students are expected to understand the basic importance and need for biochemical engineering and also the difference between bioprocesses and chemical processes.  Ability to understand growth patterns and kinetics of microbe.  Acquire knowledge of enzyme-catalyzed reaction and inhibition mechanisms. |
| **Assessment Method** | Assignments, Literature review, Simulation, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. J.E. Bailey, D.F. Ollis, Biochemical Engineering Fundamentals, McGraw- Hill, 2nd Ed., 1986.
2. S N Mukhopadhyay, Process Biotechnology Fundamentals, Viva Books Private Limited, 2nd Ed., 2001.
3. Debabrata Das, Debayan Das, Biochemical Engineering, Jenny Stanford, 1st Ed., 2019.

**Reference Books:**

1. P. M. Doran, Bioprocess Engineering Principles, Academic Press, 2nd Ed., 2013.
2. D. G. Rao, Introduction to Biochemical Engineering. Tata McGraw-Hill, 1st Ed 2005.
3. J. Nilsen, J. Villadsen, Bioreaction Engineering Principles, Plenum Press, 1994.
4. M. L. Shuler, F. Kargi, Bioprocess Engineering, Prentice Hall, 2nd Ed., 1992.
5. P. F. Stanbury, A. Whitekar, Principles of Fermentation Technology, The Pergamon Press, 1984.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X |  |
| PLO3 | X |  | X |

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| --- | --- |
| **Course Number** | **CB2204** |
| **Course Credit**  **(L-T-P-C)** | **3-0-2-4** |
| **Course Title** | **Process Dynamics and Control** |
| **Learning Mode** | Lectures and practical |
| **Learning Objectives** | To study the different type of physical processes and its dynamics.  To learn about the various components of a control system and the type of disturbances.  To familiarize with different process instruments such as flow measurement, level measurement, temperature measurement, pressure measurement etc. |
| **Course Description** | This course introduces different kinds of control systems and identifies the suitable controller parameter for a stable system. |
| **Course Content** | The fundamental concepts of measurement and transduction; Quantification of pressure, temperature, level, flow, and composition; Sensors; Laplace Transform; System dynamics; Dynamic behavior; Linear systems; Systems of various orders, including first, second, and higher orders; Transfer function; Time constant; Gain; Standard inputs; Set point; Disturbance; Closed and open loop control; Block diagram; Feedback and feed forward configurations; Controllers and final control element; Effects of controller action on process response; Concept of stability, Routh test; Root locus; Poles and zeros; Zigler-Nichols approach; Experimental determination of process model; Frequency response: Design of controllers, Bode stability criterion; Advanced control strategies: cascade control, ratio control and feed forward control designs. |
| **Learning Outcome** | Mathematical modeling of different process systems and its dynamic behavior under various disturbances.  Examine the stability of a control system using various methods.  Identify the optimum parameters for the design of a controller. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination. |

**Text Books:**

1. D. E. Seborg, T. F. Edgar, D. A. Mellichamp, F. J. Doyle III, Process Dynamics and Control, 4th Ed., Wiley, 2016.

2. G. Stephanopoulos, Chemical Process Control: An Introduction to Theory and Practice, PTR Prentice Hall Inc., 2008.

**Reference Books:**

1. W. L. Luyben, Process Modelling, Simulation and Control for Chemical Engineers, Sub Ed., McGraw Hill, 1989.

2. D. R. Coughanowr, S.E. LeBlanc, Process systems analysis and control, 3rd Ed. McGraw-Hill, 2009.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X |  | X |
| PLO3 | X | X | X |

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| --- | --- |
| **Course Number** | **CB2205** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Chemical Reaction Engineering-I** |
| **Learning Mode** | Classroom Lectures |
| **Learning Objectives** | To learn about basics about type of reactions, contacting patterns, and different reactors. |
| **Course Description** | The course teaches the concepts of reaction rate, stoichiometry and equilibrium to the analysis of chemical reacting systems, derivation of rate expressions from reaction mechanisms and equilibrium or steady state assumptions, design of chemical reactors via synthesis of chemical kinetics, transport phenomena, and mass and energy balance. |
| **Course Content** | Introduction; Types of chemical reactions; Elementary and non-elementary homogeneous reactions; Order and molecularity of reactions; Arrhenius Equation and effect of temperature; Constant and varying volume batch reactor; Interpretation of batch reactor data; Reaction rate; Determination of rate constant and half-life; Differential and integral methods; Parallel and series reaction; Batch reactor; Plug-flow or tubular reactor; Continuous stirred tank reactor (CSTR); Performance equations; Recycle reactors; Design of parallel reactions and distribution of products; Autocatalytic reactions; Temperature and pressure effects for single and multiple reactions. |
| **Learning Outcomes** | Ability to read and analyze chemical reaction data, and generate rate expressions.  Designing experiments involving chemical reactions with multiple reactants and products, recycle reactors.  Develop skills to choose the right reactor among single, multiple, recycle reactor, etc. for isothermal/ non-isothermal/ adiabatic reactions. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination. |

**Text Books:**

1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall, 4th Ed., 2008.

2. O. Levenspiel, Chemical Reaction Engineering, Wiley Eastern, 3rd Ed., 2003.

**Reference Books:**

1. J. M. Smith, Chemical Engineering Kinetics, McGraw Hill, 3rd Ed., 1980.

2. L. D. Schmidt, The Engineering of Chemical Reactions, Oxford University Press, 1998.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  | X | X |

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| **Sl. No.** | **Subject Code** | **SEMESTER V** | **L** | **T** | **P** | **C** |
| 1. | CB3101 | Mass Transfer-II | 3 | 0 | 3 | 4.5 |
| 2. | CB3102 | Chemical Process Technology | 3 | 0 | 0 | 3 |
| 3. | CB3103 | Process Equipment Design | 1 | 2 | 0 | 3 |
| 4. | CB3104 | Chemical Reaction Engineering-II | 3 | 0 | 2 | 4 |
| 5. | CB3105 | Chemical Process Modeling and Simulation | 2 | 0 | 3 | 3.5 |
| 6. | XX31PQ | IDE-II | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **15** | **2** | **8** | **21** |

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| --- | --- |
| **Course Number** | **CB3101** |
| **Course Credit**  **(L-T-P-C)** | **3-0-3-4.5** |
| **Course Title** | **Mass Transfer-II** |
| **Pre-requisite** | CB2202 (Mass Transfer-I) |
| **Learning Mode** | Lectures and practical |
| **Learning Objectives** | To learn specific application of the basic concepts of mass transfer Operations.  To select appropriate operating conditions for unit operations involving mass transfer.  To calculate yield and efficiency parameters for unit operations involving mass transfer. |
| **Course Description** | Engineering calculations related to mass transfer operations such as humidification, drying, crystallization, adsorption, and membrane separations are taught in this course. Relevant examples and numerical help the students to relate the theory to industrial applications. |
| **Course Content** | Humidification and Dehumidification: terms, definitions, psychrometric chart; Cooling towers: design of tower, tower height; Crystallization: solid-liquid equilibrium, crystal nucleation and growth, particle size distribution, crystallization equipment design; Drying of solids: drying rate curve, equilibrium, rate calculations; Drying equipment: classification, selection and design; Adsorption: characteristics, properties, and selection of adsorbents, adsorption isotherms, equipment for adsorption; Pressure swing adsorption; Chromatographic technique; Ion exchange; Membrane separation techniques: materials, types, preparation, and characterization of membranes; Membrane modules; Dialysis; Reverse osmosis; Micro-, ultra, and nano-filtration; Pervaporation; Multi-component distillation: key components, approximate design technique. |
| **Learning Outcome** | Identify mass transfer operations occurring in processes such as humidification, drying, crystallization, adsorption, and membrane separation processes.  Quantify and calculate various parameters relevant to the above listed operations.  Describe various equipment for the above processes. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill, 3rd Ed., 1980.

2. B. K. Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning Private Limited, 2009.

**Reference Books:**

1. W. McCabe, J. Smith, P. Harriott, Unit Operations of Chemical Engineering. McGraw-Hill, 7th Ed., 2021.

2. C. J. Geankoplis, A. A. Hersel, D. H. Lepek. Transport Processes & Separation Process Principles, Pearson Education Limited, 5th Ed., 2013.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  |  | X |
| PLO3 |  | X | X |

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| --- | --- |
| **Course Number** | **CB3102** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Chemical Process Technology** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | To learn the process flow and instrumentation diagram.  To learn the production of different chemical products, fuels and other specialty chemicals.  To learn the related engineering challenges and their troubleshooting by selecting appropriate operating conditions including catalyst requirement for the synthesis/production of different useful products/chemicals. |
| **Course Description** | This course is mainly about learning the production process of different chemicals/materials/fuels/specialty chemicals; operating conditions including catalyst requirements and troubleshooting for different synthesis/production processes. |
| **Course Content** | Introduction and scope; A brief history and structure of the chemical industry (India and worldwide); Process flow and instrumentation diagrams: preparation, symbols; Introduction to the following Industries including the special features of design and operation; Fuels and industrial gases including Natural gas; Process for the conversion of biomass (biofuel and bio-based chemicals production); Petrochemical and downstream products; Polymer- production and processing; Fertilizer; Cement; Caustic chlorine; Coal based chemicals; Petroleum refining processes; Nitrogen and its derivatives; Sulphur and its derivatives, Phosphorus and its derivatives; Soaps and detergents; Glycerin; Sugar; Pulp and paper; Alcohol based chemicals; Specialty chemicals; Leather; Paint and pigments; Fermentation industries; Process intensification: introduction, structured catalytic reactors, reactive separation. |
| **Learning Outcome** | Familiarize with process flow and instrumentation diagrams including symbols.  Gaining design and operation knowledge related to the process industries.  Propose appropriate operating conditions including catalyst requirement for the synthesis/production of different useful products/chemicals. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. I.D. Mall, Chemical Process Technology, CBS Publishers and Distributors Pvt Ltd., 2024.

2. C.E. Dryden, Outlines of Chemical Technology, Edited and revised by M. Gopala Rao and Marshall Sitting, 3rd Ed., Affiliated East-West Press, 1997.

3. G.T. Austin, R.N. Shreve, Chemical Process Industries, 5th Ed., McGraw Hill, 1984.

**Reference Books:**

1. P.H. Groggins, Unit Processes in Organic Synthesis, 5th Ed., McGraw Hill, 2001.
2. J.A. Moulijn, M. Makkee, A.V Diepen, Chemical Process Technology, 2nd Ed., Wiley, 2015.
3. D.F. Kirk-Othmer, Encyclopedia of Chemical Technology, 5th Ed., Wiley Interscience, 2004.
4. J.H. Gary, G.E. Handwerk, Petroleum Refining: Technology and Economics, 1st Ed., Marcel Dekker, 2001**.**

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| --- | --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 | CLO4 |
| PLO1 | X |  |  |  |
| PLO2 |  | X | X | X |
| PLO3 |  |  | X | X |

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| --- | --- |
| **Course Number** | **CB3103** |
| **Course Credit**  **(L-T-P-C)** | **1-2-0-3** |
| **Course Title** | **Process Equipment Design** |
| **Pre-requisite** | CB2103 (Heat Transfer), CB2202 (Mass Transfer-I) |
| **Learning Mode** | Classroom lectures and tutorials |
| **Learning Objectives** | To build a preliminary understanding on mechanical design of process vessels used at various stages for the product development.  To familiarize the emergence of pressure/stresses and their importance in equipment design.  To study about different parts of pressure vessels and their structural optimization. |
| **Course Description** | In this course, the mechanical aspects of designing process equipment and their constructional parts have been covered using basic concepts of solid mechanics which is very useful for appropriate sizing and thickness calculations. |
| **Course Content** | Introduction; Design preliminaries- design pressure, maximum allowable working pressure, design temperature, design stress; Pressure vessels; Stress and strain; Poisson’s ratio; Thin and thick vessels; Open and closed vessels; Factor of safety; Corrosion allowance; Weld joint efficiency; Theories of failure; Design of cylindrical and spherical vessels under internal pressure; Heads and closures; Non-standard flanges; Process vessels and pipes under external pressure; Tall vessels; Design of supports for process vessels; Thick walled high pressure vessels; Mechanical and flow aspects in shell and tube heat exchanger; Air-cooled heat exchanger; Condensers and boilers; Tray/plate column design; Mechanical properties of materials; Material specifications; Equipment fabrication and testing. |
| **Learning Outcome** | Knowledge on various forms of stresses in pressure vessels and their relation.  Mechanical designing of different parts/components used in heat exchangers or in separation units such as nuts/bolts, flanges, heads, shell, etc.  Consideration and elementary sizing calculation on tall, horizontal/vertical vessels, and their constructional supports. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. B.C. Bhattacharya, Introduction to Chemical Equipment Design, Mechanical Aspects, CBS Publisher and Distributor, 1st Ed., 2012.
2. V.V. Mahajani, S.B. Umarji, Joshi’s Process Equipment Design, Macmillan India Ltd., 4th Ed., 2009.
3. G. Towler, R. Sinnott, Butterworth-Heinemann, Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 4th Ed., An Imprint of Elsevier Inc., 2005.

**Reference Books**:

1. S.M. Walas, Chemical Process Equipment: Selection and Design, Butterworth-Heinemann, 1999.
2. R. Sinnott, G. Towler**,** Chemical Engineering Design, 5th Ed, Elsevier, 2009.
3. M.S. Peters, K.D. Timmerhaus, R.E. West, Plant Design and Economics for Chemical Engineers, 5th Ed., McGraw Hill Education (India), 2003.
4. R.H. Perry, D.W. Green, Perry’s Chemical Engineer’s Handbook, 7th Ed., McGraw Hill, 1998.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X |  | X |
| PLO3 |  |  | X |

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| --- | --- |
| **Course Number** | **CB3104** |
| **Course Credit**  **(L-T-P-C)** | **3-0-2-4** |
| **Course Title** | **Chemical Reaction Engineering-II** |
| **Learning Mode** | Lectures |
| **Pre-requisite** | CB2205 (Chemical Reaction Engineering-I) |
| **Learning Objectives** | To learn about reaction kinetics for single, multiple, isothermal, non-isothermal reactions and reactor design procedures. |
| **Course Description** | This course describes the non-ideality in a reactor and also, covers the topics related to catalyzed reactions |
| **Course Content** | Non-ideality in non-ideal flow reactors; Residence time distribution (RTD) experiments and analysis; Micro-and macro-mixing in reactors; methods for generating E, F and C curves; Different parameters model (zero, one, two and three) including tanks-in-series model, segregation model and dispersion models; Diagnostic methods for analysis of flow patterns in the reactors; non-isothermal reactors; Non-catalytic fluid-solid reactions; Application of fluid bed reactors and their design consideration; Heterogeneous Catalysis; Catalysts deactivation and poisoning; Diffusion effects in catalysis; Design of fluid-solid catalytic reactors; Thermal effects and cases of runaway reaction and its analysis; Strategies for stable reactor operations; Design of multi-phase/heterogeneous reactors; packed bed reactors. |
| **Learning Outcome** | Ability to analyse chemical reactors and reaction systems.  Designing experiments involving chemical reactors, analysing and interpreting data.  Ability to solve problems of mass transfer with reaction in solid catalysed reactions.  Design and sizing of industrial scale reactors on the basis of kinetic data obtained at lab scale. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall, 4th Ed., 2008.

2. O. Levenspiel, Chemical Reaction Engineering, Wiley Eastern, 3rd Ed., 2003.

3. L. D Schmidt, The Engineering of Chemical Reactions, Oxford University Press, 1998

**Reference Books:**

1. J. M. Smith, Chemical Engineering Kinetics, McGraw Hill, 3rd Ed., 1980.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X |  | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB3105** |
| **Course Credit**  **(L-T-P-C)** | **2-0-3-3.5** |
| **Course Title** | **Chemical Process Modeling and Simulation** |
| **Learning Mode** | Lectures and practical |
| **Pre-requisite** | CB2205 (Chemical Reaction Engineering-I) |
| **Learning Objectives** | To learn the various principles or laws for modeling of various chemical engineering processes.  To familiarize with the different simulation and optimization techniques.  To learn and familiarize with standard process engineering software to solve various industrial problems. |
| **Course Description** | This course covers mathematical formulation of various chemical processes, introduces different simulation techniques to understand the dynamic behavior of a system. |
| **Course Content** | Mathematical modeling (physical and mathematical form); Techniques for expression of modeling (analytical and empirical); Linear and non-linear model; Various steps for model development; Conservation principle: mass, energy and momentum; Chemical kinetics; Process variable and state equation; Batch reactor; Continuous stirred tank reactor (CSTR); CSTRs in series; Non-isothermal CSTR; Vaporizer; Flash drum; Reactor with mass transfer; Ideal binary distillation column; Batch distillation; Heat exchange equipment: shell and tube heat exchanger, condenser, Heat balance, Heat transfer coefficient; Simulation: different techniques, information flow diagram; Simulation of models. |
| **Learning Outcome** | Formulate the mathematical modeling of different physical and chemical processes such as reactor, distillation column, flash drum, etc.  Simulate the chemical process to understand the dynamic behavior of the systems.  Identify the optimum system parameters. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. W. L. Luyben, Process Modelling, Simulation and Control for Chemical Engineers, McGraw Hill, 2nd Ed., 1999.

2. S. S. Rao, Engineering Optimization: Theory and practice, New Age Publishers, 3rd Ed., 2013.

3. A. K. Jana, Chemical Process Modelling and Computer Simulation, PHI Learning Pvt. Ltd., 2nd Ed., 2011.

**Reference Books:**

1. B. V. Babu, Process Plant Simulation, Oxford University Press, 2004.

2. A. Hussain, Gangaiah K., Optimisation Techniques for Chemical Engineers, Macmillan, 2001.

3. B. W. Bequette, Process Control: Modeling, Design and Simulation, Prentice Hall India, 2006.

4. K. Najim, Process Modeling and Control in Chemical Engineering, CRC Press, 1st Ed., 1989.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 | X |  |  |
| PLO3 |  | X | X |

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| --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Subject Code** | **SEMESTER VI** | **L** | **T** | **P** | **C** |
| 1. | CB3201 | Process Plant Design and Economics | 3 | 0 | 0 | 3 |
| 2. | CB3202 | Transport Phenomena | 3 | 1 | 0 | 4 |
| 3. | CB3203 | Numerical Methods in Chemical Engineering | 3 | 1 | 0 | 4 |
| 4. | CB3204 | AI/ML for Chemical Engineers | 1 | 0 | 4 | 3 |
| 5. | CB3205 | Chemical Plant Safety and Hazards | 3 | 0 | 0 | 3 |
| 6. | CB32XX | DE-I | 3 | 0 | 0 | 3 |
| **TOTAL** | | | **16** | **2** | **4** | **20** |

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| --- | --- |
| **Course Number** | **CB3201** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Process Plant Design and Economics** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | To learn design principles and economics as applied in various chemical engineering processes and operations.  To integrate all the knowledge gained in the chemical engineering course. curriculum and apply this understanding to solving real-life process problems. |
| **Course Description** | This course covers the basic concepts of various process parameters in engineering economics and plant design in developing a techno-economic process and plant design. |
| **Course Content** | Introduction to plant design; General design consideration, process design and development; Analysis of cost estimation: cash flow, production costs, capital investment, cost indexes; Estimation of capital investment and total product cost; Interest; Time value of money; Cash flow patterns; Taxes and fixed charges; Profitability standards; Methods for calculating profitability, Alternative investments, and replacement; Developing a conceptual design and finding the best; Input information; Batch versus continuous; Input-output structure and recycle structure of the flowsheet; Application of separation system; Application of heat exchanger network design principles; Cost diagrams and quick screening of process alternatives; Case study; Techno-economic feasibility and report writing. |
| **Learning Outcome** | Develop the ability to design new or improve existing processes and plants.  Develop a broad spectrum of knowledge and intellectual skill to design new or modified products that will benefit society. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination. |

**Text Books:**

1. J. Douglas, Conceptual Design of Chemical Processes, McGraw Hill, 1989.
2. M.S. Peters, K.D. Timmerhaus, R.E. West, Plant Design and Economics for Chemical Engineers, McGraw Hill Education, 5th Ed., 2003.

**Reference Books:**

1. L.T. Biegler, I.E. Grossmann, A.W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall, 1997.
2. R. Smith, Chemical Process Design, McGraw Hill, 1995.
3. E.E. Ludwig, Applied Project Engineering, Gulf Publishing Company, 2nd Ed., 1988.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X | X |
| PLO3 |  |  |  |

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| --- | --- |
| **Course Number** | **CB3202** |
| **Course Credit**  **(L-T-P-C)** | **3-1-0-4** |
| **Course Title** | **Transport Phenomena** |
| **Learning Mode** | Lectures and Tutorials |
| **Prerequisite** | CB2102 (Fluid Mechanics), CB2103 (Heat Transfer), CB2202 (Mass Transfer-I) |
| **Learning Objectives** | To develop a correspondence among all the transport processes involving heat, mass, and momentum exchange.  To identify generalized fundamental equations dealing with all the basic laws of convective and diffusive transport of quantities and highlighting the analogy/relation among them. |
| **Course Description** | This course develops a relation among all the transport processes (momentum, heat, concentration) through a general transport equation and analogous relations. |
| **Course Content** | Introduction; Vector and tensor analysis; Gradient, divergence and curl; Shear stress and rate of deformation tensors; Material derivative; Continuum theory; Molecular transport mechanisms; Newton’s law of viscosity; Fourier’s law of heat conduction; Fick’s law of diffusion; Transport in laminar flow in one dimension; Reynolds transport theorem; Development of continuity (mass conservation) equation; Momentum conservation; Energy conservation; Scalar transport equation; Velocity, temperature and concentration profiles; Equations of change for isothermal, non-isothermal and multi-component systems. Equations of motion for free- and forced-convection (heat/mass); Development of boundary layer equations; Momentum, energy and mass transport in boundary layers with relevant analogies; Interphase and unsteady-state transport. |
| **Learning Outcome** | Understanding the role of vectors and tensors in transport processes.  Comprehensive derivation of conservation equations based on control volume and control mass formulation and their solution under steady/unsteady conditions.  In-depth knowledge on boundary layer formation, its significance, equations and solution. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination, End-semester examination. |

**Text Books:**

1. R.B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, Wiley, 2nd Ed., 2006.
2. F.P. Incropera, D.P. Dewitt, Fundamentals of Heat and Mass Transfer, John Wiley & Sons Inc., 5th Ed., 2010.

**Reference Books:**

1. P.J. Pritchard, R.W. Fox, A.T. McDonald, Introduction to Fluid Mechanics, John Wiley & Sons Inc., 8th Ed., 2011.
2. E.L. Cussler, Diffusion: Mass Transfer in Fluid Systems, Cambridge University Press, 3rd Ed., 2009.

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| --- | --- | --- |
|  | CLO1 | CLO2 |
| PLO1 | X | X |
| PLO2 |  | X |
| PLO3 | X |  |

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| --- | --- |
| **Course Number** | **CB3203** |
| **Course Credit**  **(L-T-P-C)** | **3-1-0-4** |
| **Course Title** | **Numerical Methods in Chemical Engineering** |
| **Learning Mode** | Classroom Lectures and Tutorials |
| **Learning Objectives** | Familiarization with various mathematical models and numerical techniques.  Integration of mathematical modeling with computational tools.  Formulation of real-life problems associated with heat and mass transfer, fluid mechanics and chemical reaction engineering. |
| **Course Description** | This course introduces the various numerical methods for solving different mathematical problems and how to formulate chemical engineering problems and apply them to solve them computationally. |
| **Course Content** | Solution of simultaneous linear equations; Matrix representation; Cramer’s rule; Gauss elimination; Matrix inversion; LU decomposition; Non-linear equations- Bisection method, Regular-Falsi method, Newton-Raphson method, Fixed-point iteration method; Eigen values and eigen vectors of matrices: Jacobi method, Power methods; Statistical analysis of data: curve fitting, approximation of functions; Interpolation: finite difference operators, difference tables, Newton's forward/backward difference, Lagrange interpolation, Newton’s divided difference interpolation; Numerical integration: Trapezoidal and Simpson's rules for integration; Differentiation using forward/backward/central difference formula; Ordinary differential equations - initial and boundary value problems: Euler method, Euler modified method, Runge-Kutta methods; Partial differential equations; Error and stability analysis in numerical computing; Implementation of numerical methods through programming. |
| **Learning Outcome** | Solving a variety of complex mathematical problems.  Developing confidence in problem-solving capability using various computational tools.  Modeling of real-world chemical engineering problems and solving them using numerical techniques. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. S. C. Chapra, R. P. Canale, Numerical Methods for Engineers, Tata-McGraw-Hill, 7th Ed., 2015.

2. S. K. Gupta, Numerical Methods for Engineers, New Age International, 1st Ed., 2001.

**Reference Books:**

1. A. Constantinides, Applied Numerical Methods with Personal Computers, McGraw-Hill, 1st Ed., 1987.

2. F. Gerald, P. O. Wheatley, Applied Numerical Methods, Pearson Education, 7th Ed., 2003.

3. R.M. Somasundaram, R. M. Chandrasekaran, Numerical Methods with C++ Programming, Prentice-Hall of India, 1st Ed., 2005.

4. W.H. Press, S.A. Teukolsky, W.T. Vellerling, B.P. Flannery, Numerical Recipes in FORTRAN: The Art of Scientific Programming, Cambridge University Press, 2nd Ed., 1992.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 |  | X | X |
| PLO3 |  | X | X |

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| --- | --- |
| Course Number | **CB3204** |
| Course Credit  (L-T-P-C) | **1-0-4-3** |
| Course Title | **AI/ML for Chemical Engineers** |
| Learning Mode | Classroom lectures and practical |
| Learning Objectives | Deliver background on AI in chemical engineering and allied systems.  To learn about artificial intelligence basics and applications.  To learn about AI/ML application for prediction/classification in chemical engineering problems. |
| Course Description | This course gives the overview of artificial intelligence and machine learning algorithms in the context of chemical engineering problems. |
| Course Content | Introduction to artificial intelligence: history, definition and scope, scope in chemical engineering; Knowledge: knowledge representation, heuristic knowledge, rule-based knowledge; Decision trees; Object oriented programming; Artificial neural networks: types, training methods, uses, data fitting; Application of AI in modeling: AI in chemical process modeling, AI in optimization of chemical process, Application of neural networks in chemical process control; Modelling real-world processes: Deep and shallow knowledge integrated with approximate reasoning in a diagnostic expert system; Application of AI techniques in fault detection and diagnosis of chemical engineering; Case studies; AI in chemical engineering: recent trends; Development in large scale systems of self-organizing intelligent agents, Introduction to IIoT. |
| Learning Outcome | Gain fundamental understanding of the application of AI in chemical and allied engineering.  Learn to develop AI model equations, approaches for chemical and allied engineering systems.  Learn to write basic codes of AI for simple systems. |
| Assessment Method | Assignments, Literature review, Simulations, Quiz, Mid-semester examination and End-semester examination. |

**Text Books**

1. T. E. Quantrille, Y. A. Liu. Artificial Intelligence in Chemical Engineering, Elsevier, 2012.
2. M. L. Mavrovouniotis, Artificial Intelligence in Process Engineering, Academic Press, 1990.

**Reference Books**

1. V. Venkatasubramanian, The Promise of Artificial Intelligence in Chemical Engineering: Is It Here, Finally? AIChE, Vol. 65, 2019.
2. M. Gopal, Applied Machine Learning, McGraw-Hill Education, 2018.
3. K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
4. A. Smola, S. V. N. Vishwanathan, Introduction to Machine Learning, Cambridge University, UK, 2008.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X | X |
| PLO3 | X | X | X |

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| **Course Number** | **CB3205** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Chemical Plant Safety and Hazards** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To conduct assessments and to produce safe operational working procedures in industries and research laboratories.  To apply the principles and approach of inherently safer design to reduce and eliminate hazards, lowering the risk of new or currently operating chemical plants.  To plan emergency procedures and disaster management. |
| **Course Description** | The course helps students learn and analyze different risks associated with chemical process plants. This course will also help students understand how to work in emergencies. |
| **Course Content** | Engineering ethics, accidents, loss statistics, acceptable risk, and inherent safety; Identification, classification, and assessments of various hazards and safety audits; Reactivity, instability, and explosiveness of materials; Hazard indices, hazard assessment and operability (HAZOP); Case studies; Seven significant disasters; Consequences analysis: Discharge model, flash and evaporation, and dispersion models; Explosion and fires: Unconfined vapor cloud explosion and flash fires, physical explosion, BLEVE and fireball, confined explosion, pool fire & jet fire; Effect models: Toxic gas effects, thermal effects, explosion effects, evasive actions; Risk estimates: Risk indices, individual and societal risks; Emergency planning and disaster management plan; Emergency work planning, and procedures; Disaster management planes. |
| **Learning Outcome** | Students will be able to identify the typical sources of risk in process plants by hazard identification and examination of case studies and to perform chemical process safety analysis on a proposed process. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examinations, and End-semester examination |

**Text Books:**

1. D.A. Crowl, J. F. Louvar, Chemical Process Safety, Fundamentals with Applications, 2nd Ed, Prentice Hall, 2002.
2. F. Crawley, Malcolm Preston, Brian Tyler, HAZOP Guide to Best Practice, 2nd Edition, IChemE, 2008.
3. J.W. Vincoli, J. Hoboken, Basic Guide to System Safety, Wiley & Sons, Inc., New Jersey, 2014.

**Reference Books**:

1. A.M. Flynn, L. Theodore, M. Dekker, Health, Safety and Accident Management in the Chemical Process Industries, Inc. NW, 2002.
2. *AIChE,* Guidelines for Chemical Process Quantitative Risk Analysis. 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2000.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X |  | X |
| PLO3 |  | X | X |

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| --- | --- | --- | --- | --- | --- | --- |
| **Elective - DE-I** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB3206 | Catalysis Science and Engineering | 3 | 0 | 0 | 3 |
| 2. | CB3207 | Biopharmaceutical Downstream Processing | 3 | 0 | 0 | 3 |
| 3. | CB3208 | Material Science and Engineering | 3 | 0 | 0 | 3 |
| 4. | CB3209 | Introduction to Microfluidics Technology | 3 | 0 | 0 | 3 |

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| **Course Number** | **CB3206** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Catalysis Science and Engineering** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | Provides students with basic concepts regarding the design, operation, and process related to the use of catalysis, basic characterization techniques, and reaction engineering |
| **Course Description** | This course contains the basic understanding of heterogeneous and homogeneous catalysis. Also, various characterization techniques and the underlying working principle. |
| **Course Content** | Fundamentals of solid catalysts and their relevant characterization techniques (such as surface area analyzer, X- ray diffraction, FTIR, Raman, XPS, electron microscopy, thermal analysis) for estimation of chemical and physical properties; Synthesis methods of catalysts; Types of catalytic reactors and effect of external and internal transport resistances; Catalyst deactivation; Study of different industrial catalysts such as for Steam Reforming and Petroleum Refining; Environmental Catalysis; Hydrogenation and oxidation catalysis, Homogeneous catalysis: Enzyme catalysis, Zeolites catalysts; Polymerization catalysts; Carbon nanotubes; Nano metal or metal oxide catalysts; Phase transfer catalysts; Design of catalysis- supported and non-supported; Molecular Modeling. |
| **Learning Outcome** | Able to analyze the basic principles and techniques of catalytic reaction engineering |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. R.J. Farrauto, C.H. Bartholomew, Fundamentals of Industrial Catalytic Processes, Blackie Academic & Professional, 2nd Ed., 1997.

2. H.S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall, 4th Ed., 2008.

3. J.J. Carberry, Chemical and catalytic reaction Engineering, Dover Publications, 2001.

**References Books:**

1. J.M. Smith, Chemical Engineering Kinetics, McGraw Hill, 3rd Ed., 1980.

2. D.M. Ruthven, Principle of adsorption & adsorption processes, John Wiley & sons, 1st Ed., 1984.

3. C.H. Bartholomew, R. J. Farrauto, Fundamentals of Industrial Catalytic Processes, Wiley- VCH, 2nd Ed., 1997.

4. B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Catalysis: Principles & Applications, Narosa Publishing House, 2002.

5. J.M. Thomas, W.J. Thomas, Principles and Practice of Heterogeneous Catalysis, VCH, 2nd Ed., 1997.

6. L.D. Schmidt, The Engineering of Chemical Reactions, Oxford University Press, 1998.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB3207** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Biopharmaceutical Downstream Processing** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To learn theory and design of liquid chromatography step.  Learning application of basic concepts of mass transfer principles in liquid chromatography separation process.  Learning of quality-by-design (QbD) based preparative chromatography process development. |
| **Course Description** | Syllabus addresses preparative chromatography for industrial separation and purification of proteins and explains the physicochemical phenomena involved in the liquid chromatography step. Presents Quality-by-Design (QbD) model-based approaches for chromatography process development initiated by FDA regulatory authorities. |
| **Course Content** | Introduction to biomolecules; Analytical characterization of therapeutic biomolecules: high performance liquid chromatography, mass spectrophotometry, capillary electrophoresis, near infrared spectroscopy, UV spectroscopy; Unit operations in therapeutic protein production: Upstream and downstream processing; Preparative liquid chromatography; and Modes: affinity, reverse-phase, size exclusion, ion-exchange, hydrophobic interaction, multimodal chromatography; Stages in operation of liquid chromatography step; Zone movement in chromatography column; Height equivalent to Theoretical Plate (HETP); Mode of operation: Linear Gradient Elution (LGE) and Flow-through mode chromatography; Stationary phase properties characterization; Binding of protein to stationary phase: distribution coefficient and binding sites; Chromatography process development: one-factor-at-a-time (OFAT), design of experiments (DoE), high throughput process development (HTPD) plate study; Quality-by-design (QbD) model based approaches; Process chromatography: process development and optimization, scale-up, and intensification. |
| **Learning Outcome** | Identifying the applications of different modes of liquid chromatography in therapeutic protein purification.  Learning upstream and downstream unit operations and QbD based chromatography modeling involved in manufacture of therapeutic proteins |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. G. Guiochon, A. Felinger, D. G. Shirazi, A. M. Katti, Fundamentals of Preparative and Non-Linear Chromatography, 2nd Ed., Elsevier, 2006.
2. A. Staby, A. S. Rathore, S. Ahuja, Preparative Chromatography for Separation of Proteins. John Wiley & Sons, 2017.

**Reference books:**

1. G. Carta, A. Jungbauer, Protein chromatography: Process Development and Scale-up, John Wiley & Sons, 2020.
2. A. S. Rathore, A. Velayudhan, Scale-up and Optimization in Preparative Chromatography, Taylor & Francis, 2002.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X | X |
| PLO3 |  |  | X |

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| --- | --- |
| **Course Number** | **CB3208** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Material Science and Engineering** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To build an understanding on the basic models of elementary structures, material classification, and material properties.  Analyze phase diagrams of binary and multi-component mixtures.  Evaluate material properties and their failure mechanisms to identify potential applications. |
| **Course Description** | The course will provide basic understanding of the concepts of material science, and to identify materials suitable for various engineering applications based on their properties. |
| **Course Content** | Structure of atoms; Rutherford and Bohr’s models; Bonding in solids; Types of solids; Crystal systems; Bravais lattices; Miller indices; Crystal defects; Determination of crystal structure; Properties of engineering materials; Mechanical properties and methods of measurements; Poisson’s ratio; Stress-strain relation; True stress and true strain; Technological properties; Phase diagrams and transformations; Iron and iron carbide phase diagrams; Eutectic systems; Solid solutions; Heat treatment of metals and alloys; Non-ferrous metals and alloys; Alloys for specialized applications: High temperature; Nuclear applications; Corrosion resistance; Types and application of non-metallic materials: Ceramics; Polymers; Composite materials; Material failure: Fracture; Griffith theory; Crack propagation; Fatigue; Creep curves; Thermal, electrical, optical and magnetic properties of material; Materials for chemical industries: equipment, catalysts, adsorbents, membranes; Novel materials: 2D materials, nanomaterials. |
| **Learning Outcome** | Explain material selection based on various properties and their requirements.  Evaluate suitability of different materials for specific engineering applications. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. W. D. Callister, D. G. Rethwisch, Callister’s Material Science and Engineering, Wiley Publishers, 10th Ed., 2019.
2. V. Raghavan, Materials Science and Engienering: A First Course, PHI Learning, 6th Ed., 2015.

**Reference Books:**

1. B.S. Mitchell, An Introduction to Materials Engineering and Science for Chemical and Materials Engineers, Wiley- Interscience, 1st Ed., 2003.
2. S. Zhang, L. Li, A. Kumar, Materials Characterisation Techniques, CRC press, 2008.
3. J. Roesler, H. Harders, M. Baeker, Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites, Springer-Verlag, 2007.
4. R. J Young, P. A. Lovell, Introduction to Polymers, CRC Press, 3rd Ed., 2011.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  |  | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB3209** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Introduction to Microfluidics Technology** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To develop the skills and techniques for handling the systems in micro- and nanoscale.  To develop the fundamental knowledge on various microfabrication techniques.  To gain required skills for the designing of fluidic circuits for various biomedical applications. |
| **Course Description** | This course gives basic understanding on:  Principles of incompressible fluid mechanics and challenges, slip effects, lubrication theory, and electrokinetic phenomena at the micro and nanoscale.  Biomedical applications illustrating fabrication techniques and experimental methods. |
| **Course Content** | Introduction; Fundamentals: scaling laws, microfluidics vs. macrofluidics; Micro-scale fluid mechanics: dynamics at small scales, interfacial phenomena and surface effects in microchannels; Intermolecular forces: surface tension, wetting, contact angle; Governing equations at small scale: low Reynolds number flows, Electrokinetic phenomena; Continuum approach and deviations: Knudsen number and transition to non-continuum flows, slip boundary; Constitutive relations: rheological models, thermal effects; Low-Reynolds flows: characteristics, Stokes drag, transition; Couette and Poiseuille flows in microchannels, Capillary flows; Lab-on-Chip: concepts, sensing and detection technologies in healthcare, environment, and point-of-care diagnostics; Electrokinetics; Microfabrication techniques: oxidation, photolithography, spin coating, etching, wafer bonding, polymer microfabrication on PMMA/PDMS substrates, micromolding, and hot embossing; Bio-microfluidics: drug delivery systems, point-of-care devices, bio-sensing technologies. |
| **Learning Outcome** | Understand microfluidics technology and lab-on-a-chip systems.  Master basic fluid mechanics at small scales.  Know basic multi-physics for microfluidic applications.  Apply standard fabrication technologies for microfluidics. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination |

**Text Books:**

1. N.T. Nguyen, S.T. Werely, Fundamentals and Applications of Microfluidics, Artech house Inc., 2002.
2. P. Tabeling, Introduction to Microfluidics, Oxford University Press Inc., 2005.
3. S. Chakraborty, Microfluidics and Microfabrication, Springer, 2010.

**Reference Books:**

1. S. Colin, Microfluidics, John Wiley & Sons, 2009.
2. M.J. Madou, Fundamentals of Microfabrication, CRC press, 2002.
3. H. Bruus, Theoretical Microfluidics, Oxford University Press Inc., 2008.
4. B.J. Kirby, Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  |  | X |

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| **Sl. No.** | **Subject Code** | **SEMESTER VII** | **L** | **T** | **P** | **C** |
| 1. | CB41PQ | DE-II | 3 | 0 | 0 | 3 |
| 2. | CB41PQ | DE-III | 3 | 0 | 0 | 3 |
| 3. | XX41PQ | IDE-III | 3 | 0 | 0 | 3 |
| 4. | HS31XX | HSS Elective-II | 3 | 0 | 0 | 3 |
| 5. | CB4198 | Summer Internship\* | 0 | 0 | 12 | 3 |
| 6. | CB4199 | Project – I | 0 | 0 | 12 | 6 |
| **TOTAL** | | | **12** | **0** | **24** | **21** |

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| **Elective - DE-II** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4101 | Industrial Pollution Control | 3 | 0 | 0 | 3 |
| 2. | CB4102 | Introduction to Computational Biology | 3 | 0 | 0 | 3 |
| 3. | CB4103 | Molecular Modeling and Simulation | 3 | 0 | 0 | 3 |

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| **Course Number** | **CB4101** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Industrial Pollution Control** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To acquire a basic knowledge about various types of industrial pollutants, and their impact on the ecosystem.  To provide the opportunity for students to understand the principles of industrial pollution control technologies to minimize pollution. |
| **Course Description** | The subject gives a brief description of the principles and mechanisms of pollutant removal, the processes, and design of conventional as well as advanced technologies applied in treatment and control. |
| **Course Content** | Introduction: industrial pollution, characterization of effluents, environmental norms and regulations; Air pollution: types, sources, standards and limits, Atmospheric dispersion- Lapse rate; Plume and classification of plume; Dispersion models; Ground and elevated sources with and without reflection; Calculation for plume rise; Gaseous emission control by absorption and adsorption; Particulate pollutants control by mechanical separation and electrostatic precipitation; Design and efficiency of cyclones; Electrostatic precipitators; Fabric filters and scrubbers; Automobile emission control; Water Pollution: Sources; Pollution laws and limits; Classification of industrial wastewaters; Pretreatment and primary treatment techniques; Physical and chemical processes of water treatment; Anaerobic and aerobic treatment methods; trickling filter; Activated sludge process; Aeration systems; Sludge separation disposal; Solid waste pollution: Sources; Composition; Properties of solid wastes; Collection; Handling and storage of solid wastes; Various methods for processing of solid waste (Land-filling technique, Trench, Ramp methods, etc.). |
| **Learning Outcomes** | To understand strategies, legal requirements, and appropriate mitigation and treatment technologies for industrial pollution control.  To comprehend the process design of selected treatment technologies.  To explain the principles of physical, chemical, and biological treatment processes. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, and End-semester examination |

**Text Books:**

1. G. M Masters, W. P. Ela, Introduction to Environmental Engineering and Science, Pearson, 3rd Ed., 2015.
2. P. A. Vesilind, S. M. Morgan, Introduction to Environmental Engineering, Nelson Engineering, 2nd Ed., 2003.
3. N. D. Nevers, Air Pollution Control Engineering, McGraw-Hill, 1994.

**Reference Books:**

1. C. N. Swayer, P. L. Mcarty, C. F. Perkin, Chemistry for Environmental Engineering and Science, McGraw-Hill, 2003.
2. L. Theodore, Air Pollution Control Equipment Calculations, John Wiley & Sons, 2006.
3. B. Sportisse, Fundamentals of Air Pollution: From Process to Modelling, Springer, 2014.
4. S. J. Arceivala, S. R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, Tata McGraw-Hill, 2008.
5. D. Mara, Domestic Wastewater Treatment in Developing Countries, Earthscan, 2003.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 |  | X | X |
| PLO3 |  |  |  |

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| --- | --- |
| **Course Number** | **CB4102** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Introduction to Computational Biology** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | Develop knowledge and understanding of statistical biophysics, molecular modeling, molecular biophysics, and chemical biophysics. |
| **Course Description** | Thermodynamics and molecular-level description are essential to analyze bio-systems and to gain valuable insights. This course will cover different aspects to provide a comprehensive understanding to a biological engineer to design and develop a novel compound. |
| **Course Content** | Statistical thermodynamics- definition and application; Macrostates and microstates; Boltzmann distribution law; Partition function and its relation to thermodynamics; Ensemble and time average; Structure and thermodynamic properties of macromolecules**-** Structural properties of protein and its stability; Driving forces in protein folding; Force fields for macromolecules- covalent, ionic, electrostatic and Van der Walls interactions; Conformational search in macromolecules; Calculation of the entropy and the free energy in biological macromolecules;Introduction to molecular dynamics simulation- building realistic model for biological macromolecules, topology and parameter files, steps in molecular dynamics, periodic boundary conditions and property analysis;Drug design and development- structure and property, 3D structure visualization, pharmacokinetic properties, ligand-receptor binding affinity; Case studies- structure based drug designing and other biomolecular systems. |
| **Learning Outcome** | Students will be able to understand the classical and statistical aspects of bio-systems. This molecular-level knowledge will help in the modification and design of bio-systems. |

**Text Books:**

1. D. Frenkel, B. Smit, Understanding Molecular Simulation: From Algorithms to Applications, Academic Press, 2nd Ed., 2001.
2. M.E. Tuckerman, Statistical Mechanics: Theory and Molecular Simulation, OUP Oxford, 2010.
3. C.I. Branden, J. Tooze, Introduction to Protein Structure, Garland Science; 2nd Ed., 1999.

**Reference Books:**

1. D.C. Rapaport, The Art of Molecular Dynamics Simulation, Cambridge University Press, 2nd Ed., 2004.
2. D. Voet, J.G. Voet. Biochemistry, Wiley, 4th Ed., 2010.
3. A.M. Lesk, Introduction to Protein Architecture: The Structural Biology of Proteins, Oxford, 2000.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X | X |
| PLO3 |  |  |  |

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| --- | --- |
| **Course Number** | **CB4103** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Molecular Modeling and Simulation** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To learn the fundamental concept of atomistic simulation (Monte Carlo and Molecular Dynamics), and its applications.  To gain knowledge about the statistical thermodynamic to relate the macroscopic properties from molecular level information.  To familiarize with the various methodologies, simulation techniques, and different simulation packages to solve engineering problems and to optimize the processes. |
| **Course Description** | This course introduces different methods of molecular simulation to understand the structural and dynamical behavior of a system at nanoscale. |
| **Course Content** | Introduction;  Statistical thermodynamics:Concept of ensemble, Derivation of partition function; Molecularmodeling: Force fields; Short-range forces; Cutoff; Correction; Electrostatic forces; Molecular dynamics simulation:Verlet method; Leap-frog method; Velocity Verlet; Thermostats; Maxwell-Boltzmann distribution; Velocity rescaling; Nosé-Hoover method; Monte Carlo simulation**:**Metropolis method; Markov chains; Acceptance ratio; Different moves; Translation, Rotation, Volume change;Monte Carlo Simulation for simple LJ system;Equilibration and Production cycle; Boundary conditions;Molecular dynamic simulation for simple LJ system; Radial distribution function; Diffusion; Viscosity; Preparation and simulation of molecular systems such as water and alkanols. |
| **Learning Outcome** | Understanding on building of a system at atomic scale.  Modeling of a system using molecular interaction parameters.  Evaluate the various structural and dynamical properties of the systems. |
| **Assessment Method** | Assignments, Literature review, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. D. Frankel and B. Smit, Understanding Molecular Simulation: From algorithm to Applications, 2nd Ed, Elsevier, 2002.
2. M.P. Allen and D. J. Tildesley, Computer Simulation of Liquids (Reprint/Revised), Clarendon Press, 1989.
3. D. McQuarrie, Statistical Thermodynamics (Reprint/Revised), University Science Books, 1991.

**Reference Books:**

1. D.C. Rapaport, The Art of Molecular Dynamics Simulation, 2nd Edition, 2004.
2. D. Chandler, Introduction to Modern Statistical Mechanics, OUP USA, 1987.
3. Y.V.C Rao, Postulational and Statistical thermodynamics, Allied Publishers Pvt. Ltd., 1st edition, 1994.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO2 |
| PLO1 | X | X |  |
| PLO2 |  |  | X |
| PLO3 |  |  | X |

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| --- | --- | --- | --- | --- | --- | --- |
| **Elective - DE-III** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4104 | Electrochemical Energy Systems | 3 | 0 | 0 | 3 |
| 2. | CB4105 | Fertilizer Technology | 3 | 0 | 0 | 3 |
| 3. | CB4106 | Nanomaterials | 3 | 0 | 0 | 3 |
| 4. | CB4107 | Combustion Engineering and Technology | 3 | 0 | 0 | 3 |

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| --- | --- |
| **Course Number** | **CB4104** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Electrochemical Energy Systems** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To introduce the fundamental elements of electrochemistry and the principles of operation of electrochemical energy conversion and storage.  To focus on power storage in various types of batteries, their design, and potential/drawbacks. |
| **Course Description** | This course describes the basic principles of design and operation of electrochemical energy storage cells. The topics cover the mathematical models of electrochemical energy storage and conversion. Various issues, limitations, important terminology, and performance characteristics in batteries have also been taken care of. |
| **Course Content** | Fundamentals of electrochemistry; Transport equations; Characteristics; Primary and secondary batteries; Supercapacitors; Kinetics of electrochemical cells; Electromotive force (EMF); Redox potential; Faraday’s law; Nernst equation; Battery design and performance parameters; Voltage, capacity, and performance curve; C-rate, state of charge (SoC), depth of discharge (DoD), Ragone diagram; Lithium-batteries and electrode materials; Design of separator, electrolyte, current collector; Types and fabrication of lithium cells; Cell degradation; Solid-electrolyte interface (SEI); Self-discharge; Limitations of lithium-ion cells; Battery module, pack design and battery management system (BMS), Types of thermal management; Other commercial rechargeable batteries such as Li-air, Li-sulfur, Na-ion and future aspects; Redox flow batteries; Solid state batteries. |
| **Learning Outcome** | After the course the student will be able to:  Understand the thermodynamics in electrolyte solutions.  Understand the concept of the electrochemical cell and various electrochemical energy storage solutions.  Understand the most common electrochemical reactions measurement techniques. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination |

**Text Books:**

1. V.S. Bagotsky, A.M. Skundin, Y.M. Volfkovich, Electrochemical Power Sources: Batteries, Fuel cells, and Supercapacitors. John Wiley & Sons, 2015.
2. R. Job, Electrochemical Energy Storage: Physics and Chemistry of Batteries, De Gruyter, 2020.

**Reference Books:**

1. A.J. Bard, L.R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Ed., John Wiley and Sons. Inc. New York, 2000.
2. A. Braun, Electrochemical Energy Systems: Foundations, Energy Storage and Conversion, De Gruyter, 2019.

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| --- | --- | --- |
|  | CLO1 | CLO2 |
| PLO1 | X |  |
| PLO2 |  | X |
| PLO3 |  | X |

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| --- | --- |
| **Course Number** | **CB4105** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Fertilizer Technology** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To understand the basic concepts of fertilizer for agriculture and the manufacturing process.  Design of ammonia reactor and urea prilling tower.  Analyses and examines different fertilizers for different agricultural purposes. |
| **Course Description** | The course will introduce the basic concepts of fertilizer for agriculture and the manufacturing process. |
| **Course Content** | Definition of fertilizer; Nutrient requirements for paddy, wheat, sugarcane plants, vegetables, etc. A natural way of fixing nitrogen; Nitrogen cycle, Carbon cycle; Different nitrogen-fixing plants, bacteria, and algae. Role of C/N ratio in the growth of different plants; Organic manure; Production of ammonia: its feed preparation; Limitations of using different feed materials for hydrogen generation, reforming process, and reformer design; Partial oxidation process and partial oxidation reactor design; Removal of impurities from synthesis gas; CO removal and shift reactor design; CO2 removal methods; Design of CO2 absorber; NH3 synthesis loop design, and design considerations for different types of NH3 Reactors; Phosphate fertilizers: different methods of production; NPK: production and drying of NPK fertilizers, and bio-fertilizer; fertilizer coating; Urea production: special features of urea reactor, prilling tower design. |
| **Learning Outcome** | This program will enable the students to learn fertilizer manufacturing, including new/modified fertilizer products and new techniques, which will help in agricultural production. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination, and End-semester examination |

**Text Books:**

1. V. Sauchelli, Chemistry and Technology of Fertilizers, Reinhold Publications, 1960.
2. M. Gopala Rao Sitting Marshal, Dryden’s Outlines of Chemical Technology, Affiliated East West Press (Pvt) Ltd, 3rd Ed., New Delhi, 1997.
3. G.T. Austin, Shreve’s Chemical Process Industries, McGraw Hill publication, 5th Ed., New Delhi, 2017.

**Reference Books:**

1. A.F. Gustafson, Handbook of Fertilizers: Their Sources, Make-up Effects, and use, Agrobios publications, Jodhpur, 3rd Ed., 2012
2. V. Gowarikar, V.N.Krishnamurthy, Sudha Gowariker, Manik Dhanorkar, Kalyani Paranjape, The Fertilizer Encyclopaedia, John Wiley & Sons, 2008.
3. N.S. Subba Rao, Bio fertilizers in Agriculture, Oxford & IBH Publishing Company, 4th Ed. 2017

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  | X |
| PLO2 |  |  | X |
| PLO3 |  | X | X |

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| **Course Number** | **CB4106** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Nanomaterials** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To build an understanding on the use, advantages, and classification of nanomaterials.  Identify production and characterization techniques of nanomaterials. |
| **Course Description** | The course will provide basic understanding of the concepts of material science, and to identify materials suitable for various engineering applications based on their properties. |
| **Course Content** | Introduction to nanomaterials and nanostructures: definitions, history, classifications, Properties of nanomaterials and their size dependence: mechanical, thermal, electrical, magnetic, optical properties; Synthesis routes of nanomaterials: chemical, electrochemical, gas-phase, thin films, mechanical methods, sol-gel methods, nanolithography; Characterization of nanomaterials: size, SEM, TEM, Scanning tunneling microscopy; Atomic force microscopy; Spectroscopy techniques; X-ray diffraction; Applications: Chemical and biosensing; Catalysis; Fuel-cells and other energy related applications; Biological applications; Multiscale hierarchical structures and their applications; Nanomaterials and structures in nature. |
| **Learning Outcome** | Explain production and applications of nanomaterials and nanostructures.  Evaluate performance of nanomaterials. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. M. F. Ashby, P. Ferreira, D. L. Schodek, Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects, Butterworth-Heinemann, 2009.
2. F. J. Owens, C. P. Poole Jr., The physics and Chemistry of Nanosolids. John Wiley & Sons, 2008.
3. D. Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, John Wiley & Sons, 2nd Ed., 2013.

**Reference Books:**

1. Z. L. Wang, Y. Liu, Z. Zhang, Handbook of Nanophase and Nanostructured Materials: Materials Systems and Applications, Springer New York, Volume 4, 2003.
2. G. A. Ozin, A. C. Arsenault, L. Cademartiri, Nanochemistry: A Chemical Approach to Nanomaterials. Royal Society of Chemistry, 2015.
3. E. L. Wolf, Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience. John Wiley & Sons, 3rd Ed., 2015.

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| --- | --- | --- |
|  | CLO1 | CLO2 |
| PLO1 | X | X |
| PLO2 |  | X |
| PLO3 | X |  |

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| **Course Number** | **CB4107** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Combustion Engineering and Technology** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | To understand the nature of fuel based on its physico-chemical properties.  To learn fundamentals of thermochemistry of combustion process.  To evaluate calorific values of fuels and identify their application in various combustion technologies. |
| **Course Description** | This course describes the fundamentals of solid, liquid, and gaseous fuels. It covers their origins, classification, preparation processes, and key physico-chemical properties. The course explores the thermodynamics of combustion for various fuels and discusses their applications in combustion technologies. |
| **Course Content** | Introduction: history of fuels, types and properties; Definition and characteristics of solid fossil fuels: classification of coal, composition, basis; Coal mining; Different type of combustion techniques of coal; Coal gasification; Gaseous fuels: Natural gas and liquid petroleum gas; Producer gas; Hydrogen; Water gas; Acetylene; Other fuel gases; Combustion: Stoichiometry, thermodynamics; Nature and types of combustion processes: Mechanism and kinetics of combustion; Ignition temperature; Explosion range; Flash and fire points; Calorific value calculations of fuels; Adiabatic flame temperature calculation; Flame properties; Combustion burners and furnaces; Internal combustion engines. |
| **Learning Outcome** | Identifying types of different fuels and its properties.  Deep understanding of thermodynamics and kinetics of combustion processes.  Identify application of fuels in various combustion processes. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. R. A. Dave, Modern Petroleum Technology, John Wiley & Sons. Ltd., Upstream, 1, 6th Ed., 2002.
2. A. G. Lucas, Modern Petroleum Technology, John Wiley & Sons. Ltd., Downstream, 2, 6th Ed., 2002.
3. I. Glassman, Combustion, Elsevier 2nd Ed., 2012.

**Reference Books:**

1. J. Griswold, Fuels Combustion and Furnaces, Mc-Graw Hill Book Company Inc., 1st Ed., 1946.
2. S. Sarkar, Fuels and Combustion, Universities Press, 3rd Ed., 2009.
3. W.L. Nelson, Petroleum Refinery Engineering, Mc-Graw Hill Book Company, 4th Ed., 1968.
4. B.K. Bhaskar Rao, Modern Petroleum Refining Processes, Oxford & IBH Publishing Co. Pvt. Ltd., 4th Ed., 2003.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 |  | X | X |
| PLO3 |  | X |  |

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| **Sl. No.** | **Subject Code** | **SEMESTER VIII** | **L** | **T** | **P** | **C** |
| 1. | CB42XX | DE-IV | 3 | 0 | 0 | 3 |
| 2. | CB42XX | DE-V | 3 | 0 | 0 | 3 |
| 3. | CB42XX | DE-VI | 3 | 0 | 0 | 3 |
| 4. | CB4299 | Project – II | 0 | 0 | 16 | 8 |
| **TOTAL** | | | 9 | 0 | 16 | **17** |

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| --- | --- | --- | --- | --- | --- | --- |
| **Elective - DE-IV** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4201 | Membrane Separation | 3 | 0 | 0 | 3 |
| 2. | CB4202 | Energy Storage: Technologies and Applications | 3 | 0 | 0 | 3 |
| 3. | CB4203 | Process Integration | 3 | 0 | 0 | 3 |

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| **Course Number** | **CB4201** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Membrane Separation** |
| **Learning Mode** | Classroom lectures |
| **Pre-requisite** | CB2202 (Mass Transfer-I) |
| **Learning Objectives** | To identify applicability of membranes in different separation processes.  Compare different membrane techniques and examine their applicability for specific purpose.  Evaluate membrane separation processes for their suitability with regard to various conventional and novel separation techniques. |
| **Course Description** | The course will provide introduction to different types of membranes, their production and characterization, and various membrane-based technologies utilized in chemical and allied industries. |
| **Course Content** | Introduction to membrane processes; Classifications of membrane separation techniques; Polymer based membranes and their applications; Polymers used in membranes; Inorganic membranes and their applications; Techniques for preparation of membranes; Composite membranes- production and applications; Characterization of membranes; Transport in porous and non-porous membranes; Types and applications of osmotic membrane technologies; Microfiltration, Basic principles, modules, transport, and applications; Ultrafiltration; Nanofiltration; Other membrane techniques- electrodialysis, pervaporation, ion-exchange membranes, membrane distillation units, membrane crystallizers, membrane reactors; Membrane fouling; Concentration polarization; Membrane recycling. |
| **Learning Outcome** | Identifying the applications of membrane technology in separation processes.  Learning membrane production and characterization techniques.  Identify various applications of membranes, including novel separation techniques. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. R.W. Baker, Membrane Technology and Application, John Wiley and Sons Ltd., 2004.
2. S. Heinrich, Introduction to Membrane Science and Technology, John Wiley & Sons, 2011.
3. J. Mulder, M. Marcel, Basic Principles of Membrane Technology, Springer Netherlands, 2013.

**Reference Books:**

1. W. S. Ho, K. K. Sirkar, Membrane Handbook, Vol 1, Springer US, 2012.
2. E. Nagy, Basic Equations of Mass Transport Through a Membrane Layer, Elsevier, 2nd Ed., 2018.
3. K. Nath, Membrane Separation Processes, PHI Learning Pvt. Ltd., 2017.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB4202** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Energy Storage: Technologies and Applications** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To provide understanding on various energy storage methodologies, their potential and fundamental design aspects.  To discover the advantages of energy storage and learn how to make informed decisions on energy storage systems.  To provide a suitable and economic energy storage solution based on demand-supply. |
| **Course Description** | This course describes the various methods and applications of energy storage to achieve sustainable energy solutions. Different types of energy storage systems and their importance has been covered herein. |
| **Course Content** | Need; Scope; Basic concepts; General aspects of thermodynamics, Thermal energy storage: Sensible heat; Latent heat; Heat pumps; Phase change materials; Storage for renewable energy: Solar and wind; Reversible chemical reactions; Electromagnetic energy storage; Hydrogen storage; Flywheels; Compressed air; Pumped-hydro power; Electrochemical energy storage; Rechargeable batteries; Lead-acid battery; Electrodes in lithium systems; Electric vehicles, battery pack and thermal management; Sodium/potassium-ion; Lithium-air; Sulfur-air and zinc-air battery; Fuel cells and microbial fuel cells (MFCs); Super capacitors; Medium to large scale applications; Energy savings and smart grids; Hybrid storage systems; Recent advances and applications. |
| **Learning Outcome** | On successful completion of the course students will be able to:  Discuss the scientific principles underpinning the operation of energy storage systems.  Resolve the intermittency of renewable energy sources by utilizing problem solving skills in energy storage engineering and grid integration. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination |

**Text Books:**

1. I. Dincer, M.A. Rosen, Thermal Energy Storage: Systems and Applications, Wiley, 2nd Ed., 2011.
2. R.A. Huggins, Energy Storage, Springer, 2010.

**Reference Books:**

1. R. Zito, Energy Storage: A New Approach, Wiley, 2010.
2. A.F. Zobaa, Energy Storage: Technologies and Applications, InTech, 2023.
3. A. Thumann, D.P. Mehta, Handbook of Energy Engineering, CRC Press, 2008.
4. J.W. Twidell, A.D. Weir, Renewable Energy Resources, E & F N Spon, London, 1986.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 | X | X | X |
| PLO3 |  |  | X |

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| --- | --- |
| **Course Number** | **CB4203** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Process Integration** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To study major applications process integration in the industrial and research realms.  To review specific literature on mathematical models developed in process integration operations.  To learn energy integration, water integration principles for industrial problems |
| **Course Description** | This course will primarily concentrate on the advancement of mathematical models and methodologies for process integration, which are extensively employed in chemical engineering research and industry. The focus will be on establishing a connection between the knowledge base developed in the process integration course and real-world illustrations. |
| **Course Content** | Process Integration; Targeting for energy; Pinch analysis; Hot composite curves; Cold composite curves; Grand composite curves; Area, unit and cost targeting; Heat exchanger network design and evolution: Heat exchanger design, Pinch design method, Retrofit design; Mathematical optimization techniques: linear programming, mixed integer linear programming; Production planning; Inventory management; Process integration of different systems: Fired heater; Cogeneration and utility system; Solar thermal; Batch Process; Distillation column; Evaporators; Resource management; Water management; Limiting composite curves; Source composite curves; Resource allocation networks; Hydrogen management; Environmental management; Recent developments. |
| **Learning Outcome** | Energy integration, water integration, production planning and other resource integration aspects. |
| **Assessment Method** | Assignments, Literature review, Quiz, Mid-semester examination and End-semester examination. |

**Text Books:**

1. I.C. Kemp, Pinch Analysis and Process Integration-A User Guide on Process Integration for the Efficient Use of Energy, Elsevier, 2007.
2. U.V. Shenoy, Heat Exchanger Network Synthesis: Processes Optimization by Energy and Resource Analysis, Gulf Publishing Company, Houston, 1995.

**Reference Books:**

1. B.D. Linnhoff, W. Townsend, D. Boland, G.F. Hewitt, B.E.A. Thomas, A.R. Guy, R.H. Marsland, User Guide on Process Integration for the Efficient Use of Energy, The Institution of Chemical Engineers, Rugby, UK, 1982.
2. J.M. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, New York, 1988.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 | X |  | X |
| PLO3 |  | X | X |

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| --- | --- | --- | --- | --- | --- | --- |
| **Elective - DE-V** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4204 | Renewable Energy Sources | 3 | 0 | 0 | 3 |
| 2. | CB4205 | Advanced Separation Processes | 3 | 0 | 0 | 3 |
| 3. | CB4206 | Fluidization Engineering | 3 | 0 | 0 | 3 |

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| --- | --- |
| **Course Number** | **CB4204** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Renewable Energy Sources** |
| **Learning Mode** | Classroom Lectures |
| **Learning Objectives** | To provide understanding on various sources of renewable energy and their production and applications.  To discover the advantages of renewable energy sources and learn how to make decisions on alternative to conventional fossil fuels.  To provide suitable designs of various renewable energy plant installations based on feasibility. |
| **Course Description** | This course describes the various sources and applications of renewable energy to achieve the sustainable energy solutions. Various types of renewable energy plant designs and their productions are covered. |
| **Course Content** | Biofuels: classification of biofuels; Biomass production; Energy generation via fermentation, gasification, pyrolysis and combustion; Aerobic and anaerobic biogas generation processes; Feed stock; Bio-gas composition; Biogas plant design and principle of operation. Hydrogen Energy: Electrolytic and thermo-chemical hydrogen production; Metal hydrides and storage of hydrogen; Economics and technical feasibility. Solar Energy: Solar radiation, availability, measurement and estimation; Solar collectors (liquid flat- plate collector, air heater and concentrating collector) and thermal storage; Steady state operation; Photovoltaic solar cell; Hybrid systems; Solar distillation; Solar drying; Ocean thermal energy conversion; Geothermal; Tidal energy; Power generation through OTEC; Wind energy: Wind power plant design; Horizontal axis/vertical axis wind turbines. |
| **Learning Outcomes** | On successful completion of the course students will be able to:  Understand on various sources of renewable energy and their production and applications.  Discover the advantages of renewable energy sources and make decisions on alternative to conventional fossil fuels.  Provide suitable designs of various renewable energy plant installations based on feasibility. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination. |

**Text Books:**

1. M. V. R. Koteswara Rao, Energy Resources-Conventional and Non-Conventional, 2nd Ed., BS Publications, 2006.
2. B.H. Khan, Non-Conventional Energy Resources, 2nd Ed., Tata McGraw Hill, 2009.
3. C. S. Solanki, Renewable Energy Technologies: A Practical Guide for Beginners, Second Printing, PHI Learning Private Limited, 2009.

**Reference Books:**

1. D. Mukherjee, S. Chakrabarti, Fundamentals of Renewable Energy Systems, New Age International (P) Limited, 2005.
2. D. Merick, R. Marshall, Energy, Present and Future Options, Vol. I and II, John Wiley and Sons, 2001.

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|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  |  |
| PLO2 | X | X | X |
| PLO3 |  |  | X |

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| **Course Number** | **CB4205** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Advanced Separation Processes** |
| **Learning Mode** | Classroom lectures |
| **Pre-requisite** | CB2202 (Mass Transfer I) |
| **Learning Objectives** | To study major applications of mass transfer operations in the industrial and research realms.  To review specific literature on mathematical models developed in mass transfer operations. |
| **Course Description** | The course will focus on the development of mathematical models and techniques of mass transfer used in chemical engineering research and industry. Emphasis will be on connecting the knowledge base created in the undergraduate chemical engineering course on mass transfer with real world examples. The course will involve literature review and numerical simulation of specific mass transfer units. |
| **Course Content** | Introduction to diffusion; Lumped and distributed models; Equations for steady-state and unsteady state mass transfer operations in thin film; Semi-infinite falling film; Diffusion in porous media; Interphase mass transfer; Boundary layer theory; Two-film theory; Mass transfer with first order homogeneous reaction- steady and unsteady state diffusion; Mass transfer and reaction in packed bed; Enhanced distillation techniques– azeotropic, extractive, steam, and reactive distillations; Adsorption processes; Isotherms; Breakthrough curves; Thermal and pressure swing adsorption; Continuous adsorption processes; Chromatography and ion-exchange processes; Crystallization: Phase diagrams; Cooling; Evaporative; Anti-solvent crystallization; Impact of mixing and mass transfer on crystallization process; Population balance model to study crystal size distribution. |
| **Learning Outcome** | Development of numerical models for steady and unsteady-state mass transfer processes.  Analyze flow diagrams and processes of enhanced distillation processes.  Analyzing process parameters for separation processes such as adsorption and crystallization |
| **Assessment Method** | Assignments, Literature review, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. E.L. Cussler, Diffusion: Mass Transfer in Fluid Systems, Cambridge University Press, 3rd Ed., 2009.
2. J. D. Seader, E. J. Henley, D. K. Roper, Separation Process Principles: With Applications Using Process Simulators, John Wiley & Sons, 4th Ed., 2016.

**Reference Books:**

1. C. J. Geankoplis, A. A. Hersel, D. H. Lepek. Transport Processes and Separation Process Principles, Pearson Education Limited, 5th Ed., 2013.
2. B. K. Dutta, Principles of Mass Transfer and Separation Processes, PHI Learning Private Limited, 2009.

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| --- | --- | --- |
|  | CLO1 | CLO2 |
| PLO1 | X | X |
| PLO2 |  | X |
| PLO3 |  |  |

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| --- | --- |
| **Course Number** | **CB4206** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Fluidization Engineering** |
| **Learning Mode** | Classroom lectures |
| **Prerequisite** | CB2102 (Fluid Mechanics) |
| **Learning Objectives** | The aim of this course is to provide basic knowledge about fluidization and aerodynamics of gas-solid systems as well as mathematical tools that enable the simulation of basic fluidized systems.  To learn about characteristics of fluidization and their relation to design a fluidized system for newer applications. |
| **Course Description** | This course mainly covers the basic principles of fluidization phenomena and introduces the learner to the fundamental and practical aspects of basic fluidization operations for industrial application. |
| **Course Content** | Introduction to fluidization: definition and basic concepts, applications and significance in industrial processes, history and development; Principles of fluid mechanics relevant to fluidized beds; Fluid flow regimes (laminar, turbulent) in fluidized systems; Bed expansion and pressure drop calculations; Fluidized bed behavior: types of fluidized beds (bubbling, turbulent, circulating); Fluidization regimes (minimum fluidization velocity, transition velocity); Characteristics of particles and their influence on fluidization (Geldart groups); Heat and mass transfer in fluidized beds; Hydrodynamics of fluidized beds: flow regimes and hydrodynamic characteristics, particle mixing and segregation, bed stability; Particle technology in fluidization: particle size distribution and its effects, particle properties (shape, density) and their influence on fluidization, fluidized bed reactors and their applications; Design and operation: design considerations (bed height, diameter, distributor design); distributors, gas jets and pumping power; Solid movement, mixing, segregation and staging; Scale-up and modeling approaches; Case studies of industrial applications. |
| **Learning Outcome** | Students will be able to understand the importance of fluidization.  Students will be able to describe the various applications of fluidization and their types.  Students will be able to explain the mass and heat transfer processes occurring in various modes of fluidization. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination |

**Text Books:**

1. D. Kunii, O. Levenspiel, Fluidization Engineering, 2nd Ed., Butterworth-Heinemann Ltd., 1991.
2. L.G. Gibilaro, Fluidization‐dynamics, Butterworth‐Heinemann, 2001.

**Reference Books:**

1. W.C. Yang, Fluidization, Solids Handling, and Processing: Industrial Applications, Noyes Publishing, 1999.
2. J.R. Grace, X. Bi., N. Ellis, Essentials of Fluidization Technology, Wiley-VCH, 2020.
3. S.K. Majumder, Hydrodynamics and Transport Processes of Inverse Bubbly Flow, 1st Ed. Elsevier, Amsterdam, 2016.
4. D. Gidaspow, Multiphase Flow and Fluidization: Continuum and Kinetic Theory Description, Elsevier Science & Technology, 1993.

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| --- | --- | --- |
|  | CLO1 | CLO2 |
| PLO1 | X |  |
| PLO2 | X | X |
| PLO3 |  | X |

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| --- | --- | --- | --- | --- | --- | --- |
| **Elective - DE-VI** | | | | | | |
| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB4207 | Energy Management | 3 | 0 | 0 | 3 |
| 2. | CB4208 | Heterogeneous Catalysis: Fundamentals and Applications | 3 | 0 | 0 | 3 |
| 3. | CB4209 | Polymer Science and Technology | 3 | 0 | 0 | 3 |
| 4. | CB4210 | Petroleum Refinery Engineering | 3 | 0 | 0 | 3 |

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| **Course Number** | **CB4207** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Energy Management** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | To learn the various principles or techniques for modeling of various energy systems.  To familiarize with the different simulation and optimization techniques for energy management.  To learn rules for energy conservation. |
| **Course Description** | This course covers energy management aspects of various processes and introduces different techniques to understand these systems. |
| **Course Content** | Importance of energy management; Energy audit: method, analysis of plant data, energy balance, laws of thermodynamics, measurements, portable and on line instruments; Utility Systems: boiler -efficiency testing, excess air control, steam distribution & use- steam traps, condensate recovery, flash steam utilization; Thermal insulation; Electrical systems: Demand control, power factor correction, load scheduling/shifting; Motor drives- efficiency testing, energy efficient motors, motor speed control; Efficient windows; Energy conservation in pumps, Fans (flow control); Compressed air systems; Refrigeration & air conditioning systems; Waste heat recovery: heat pipes, heat pumps; Cogeneration - concept, options (steam/gas turbines/diesel engine based); selection criteria; control strategy; Heat exchanger networking- concept of pinch, target setting, problem table approach, composite curves; Demand side management; Production planning and management. |
| **Learning Outcome** | Energy management, planning and conservation aspects |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination and End-semester examination |

**Text Books:**

1. L. C. Witte, P. S. Schmidt, D. R. Brown, Industrial Energy Management and Utilization, Hemisphere Publ, Washington,1988.
2. I.G.C. Dryden, The Efficient Use of Energy, Butterworths, London, 1982.
3. D. Steve, W.C. Turner, Energy Management Handbook, Wiley, New York, 2004.

**Reference Books:**

1. Technology Menu for Efficient energy use- Motor drive systems, Prepared by National Productivity Council and Center for & Environmental Studies- Princeton Univ., 1993.
2. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X |  | X |
| PLO3 |  | X | X |

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| --- | --- |
| **Course Number** | **CB4208** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Heterogeneous Catalysis: Fundamentals and Applications** |
| **Learning Mode** | Classroom lectures |
| **Pre-requisite** | CB2205 (Chemical Reaction Engineering-I) |
| **Learning Objectives** | To understand the catalytic process and reaction engineering and their application in industrial processes  To learn about the characterization techniques for heterogeneous catalysts  Evaluate heat and mass transfer effects in heterogeneous catalysis. |
| **Course Description** | The course will introduce to the catalytic processes, and their industrial applications. The focus is to learn about the underlying heat and mass transfer resistances and their impact on the overall rate of product formation. Additionally, detailed characterization techniques are introduced. |
| **Course Content** | Introduction and understanding of catalytic reactions; Adsorption, inter-particle and intra-particle transport processes in porous and non-porous catalysts; Effect of heat and mass transfer resistance in heterogeneous catalytic reactions; Calculation of effective diffusivity and thermal conductivity in porous ctalysts; Synthesis of as-designed catalysts using methods such as sol-gel, precipitation, hydrothermal, mechanical milling etc.; Physical and chemical properties analysis of catalysts using methods such as BET surface area analyzer, X-ray diffraction, FTIR, X-ray photoelectron spectroscopy; Scanning and transmission electron microscopy; Understanding of other techniques such as Gas chromatograph; UV-Visible spectroscopy; Photoluminescence; Fundamentals of catalyst test and reactor types; Kinetics of catalyst deactivation; Emerging industrially relevant catalysts. |
| **Learning Outcome** | It will impart the concepts of catalytic reaction engineering and its application in industries. |
| **Assessment Method** | Assignments, Literature review, Quiz, Mid-semester examination, and End-semester examination |

**Text Books:**

1. B.W. Wojciechowski, N.M. Rice, Experimental Methods in Kinetic Studies, Elsevier, 2003.
2. L. D. Schmidt**,** The Engineering of Chemical Reactions, Oxford University Press, 2004.
3. D. K. Chakrabarty, B. Vishwanathan, Heterogeneous Catalysis, New Age Science Ltd, 1st Ed., 2007.

**Reference Books:**

1. M. A. Vennices, Kinetics of Catalytic Reactions, Springer, 1st Ed., 2005.
2. B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Catalysis: Principles & Applications, CRC Press, 1st Ed., 2002.
3. J.J. Carberry, Chemical and Catalytic Reaction Engineering, Dover Publications, 1st Ed., 2001.
4. I. Chorkendorff, J.W. Niemantsverdriet, Concept of Modern Catalysis and Kinetics, Wiley-VCH, 2nd Ed., 2003.
5. J. M. Thomas, W. J. Thomas, Principles and Practice of Heterogeneous Catalysis, Wiley-VCH, 2nd Ed., 1997.

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|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X | X |
| PLO2 | X |  | X |
| PLO3 | X | X | X |

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| **Course Number** | **CB4209** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Polymer Science and Technology** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | Develop the students to decisively think and analyze complex problems related to polymer processing and accordingly should be able to develop new formulations.  Prepare students to execute new ideas with the knowledge of polymer technology in the field of research and development. |
| **Course Description** | The course will provide basic understanding of the polymer science, their synthesis, classifications, rheology, mechanisms, and different types of polymer additives and their processing. |
| **Course Content** | Introduction to polymers: concepts and definitions, classification, chemical bonding and structure; Polymer properties: molecular weight, chemical structure and thermal transitions, phase behavior and thermodynamics; Polymer synthesis and polymerization: Synthesis of polymers, polymerization mechanisms and techniques; Viscoelasticity and rubber elasticity; Degradation and stability; Solution and mechanical properties; Degradation, stability, and environmental issues; Polymer additives and reinforcements; Polymer types and applications: blends, composites, thermoplastics, fibers, elastomers, thermosets, and specialty polymers; Unit operations in polymer processing; Advanced topics in polymer science: Rheology and analysis using non-Newtonian fluid models, applications of polymers in separations. |
| **Learning Outcome** | Students will be able to understand the relationships between polymer molecular weight, molecular weight distribution, and the properties of polymeric materials.  Students will demonstrate an ability to distinguish different polymerization reactions and their mechanisms/kinetics.  Students will be able to describe the viscoelastic behavior of polymers with respect to their chemical structures and molecular weights, and to construct a corresponding master curve from the experimental data. |
| **Assessment Method** | Assignments, Quiz, Mid-semester examination, End-semester examination |

**Text Books:**

1. P.J. Flory, Principles of Polymer Chemistry, Asian Books, 2006.
2. R.O. Ebewele, Polymer Science and Technology, CRC Press, 1st Ed., 2000.
3. J.R. Fried, Polymer Science & Technology, Prentice Hall of India, 3rd Ed., 2014.

**Reference Books:**

1. F.W. Billmeyer (Jr.), Textbook of Polymer Science, 3rd Ed., John Wiley & Sons, 2002.
2. P. Bahadur, N.V. Sastry, Principles of Polymer Science, Narosa Publishing House, 2002.
3. V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Polymer science, New Age International (P) Ltd., 2001.
4. M. Rubinstein, R.H. Colby, Polymer Physics, Oxford University Press, 2003.
5. N.K. Petchers, R.K. Gupta, A. Kumar, Fundamentals of Polymer Engineering, Marcel Dekker, 2nd Ed., 2003.

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|  | CLO1 | CLO2 |
| PLO1 | X |  |
| PLO2 | X | X |
| PLO3 |  | X |

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| **Course Number** | **CB4210** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Petroleum Refinery Engineering** |
| **Learning Mode** | Lectures |
| **Learning Objectives** | To build understanding on fundamentals of petroleum refining and processing from basic chemical engineering concepts.  Learning about crude oil and its thermo-physical properties and petroleum fractions.  Learning about unit operations and unit processes used to convert crude oil to finished petroleum products. |
| **Course Description** | The course provides fundamentals of petroleum refining introducing refinery engineering topics from basic concepts and unit operations and unit processes. |
| **Course Content** | Introduction: overview, importance, historical background andevolution of refining technology, Role of refineries in the petroleum industry; Petroleum properties and composition: Composition of crude oil; Classification and physico-chemical properties of petroleum; Analysis and characterization techniques for crude oil; Refining processes such as atmospheric and vacuum distillation, fractionation, cracking, reforming and isomerization; Conversion of petroleum gas into motor fuel, aviation fuel, lubricating oils and petroleum waxes; Chemicals and clay treatment of petroleum products; Hydrotreating; Desulfurization; Refining operations: dehydration, desalting, gas separation, separation of light gases (methane, ethane, propane), natural gas production and gas sweetening; Tube still heater design; Product profile of petrochemicals; Petrochemical feed stocks; Olefin and aromatic hydrocarbons production; Treatment and upgrading of olefinic C4 and C5 cuts; Chemicals from C1 compounds; Ethylene and its derivatives; Propylene and its derivatives; Butadiene and butene; BTX chemicals. |
| **Learning Outcome** | Understanding the petroleum refinery engineering concepts.  Quantification of thermos-physical properties of crude oils and petroleum fractions.  Understanding the unit operations and unit processes used to convert crude oil to finished products. |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examination, and End-semester examination |

**Text Books:**

1. B.K. Bhaskara Rao, Modern Petroleum Refining Processes, Oxford & IBH Publishing, 6th Ed., 2018.
2. W.L. Nelson, Petroleum Refinery Engineering, McGraw Hill, New York, 4th Ed., 1981.
3. K.H. Altgelt, M.M. Boduszynski, Composition and Analysis of Heavy Petroleum Fractions, Taylor & Francis, 1994.

**Reference Book:**

J.H. Gary, G.E. Handwork, M.J. Kaiser, Petroleum refining: Technology and Economics, CRC Press, 5th Ed., 2007.

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|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  | X |
| PLO2 |  | X |  |
| PLO3 |  | X | X |

**IDE floated by the Department** (not applicable for B. Tech. Chemical Engineering students)

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| **Sl. No.** | **Subject Code** | **Course** | **L** | **T** | **P** | **C** |
| 1. | CB2206 | Environmental Science and Engineering | 3 | 0 | 0 | 3 |
| 2. | CB3106 | Introduction to Sustainable Engineering | 3 | 0 | 0 | 3 |
| 3. | CB4108 | Bioprocess Engineering | 3 | 0 | 0 | 3 |

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| **Course Number** | **CB2206** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Environmental Science and Engineering** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | To impart knowledge of the environment and different types of pollution, causes, and preventive measures against various pollutions. |
| **Course Description** | This course presents a broad introduction to Environmental Engineering. A set of fundamental principles, which are based on scientific fundamentals such as chemistry, biology, physics, and mathematics will be discussed.  Applications including water quality engineering, air quality engineering, and hazardous waste management will be explained. |
| **Course Content** | Structure of environment; Pollution arises due to urbanization and industrialization; Mass and energy balance for environmental engineering systems; Accumulation of pollutants in air, water, and soil; Air pollution and its remediation: smog and fumigation, collection of particulate pollutants, analysis of air pollutants, control of particulate emission, various types of equipment to control air emissions; Water pollution and its remediation: origin of wastewater, types of water pollutants, adverse effects on the ecosystem, water pollution control equipment and instruments; Liquid and solid waste; Domestic and industrial waste; Dumping solid wastes: incineration, sanitary land field, collection, and disposal; Noise pollution: types, adverse effects of noise, permissible noise limits, measurement, and reduction of noise; Thermal pollution; Greenhouse effect; Acid precipitation; Ozone layer depletion; Life cycle analysis; Environmental quality objectives. |
| **Learning Outcome** | The students should be able to describe environmental challenges and identify solutions, evaluate design solution alternatives, describe the principles and methods of environmental impact assessment |
| **Assessment Method** | Assignments, Quizzes, Mid-semester examinations, and End-semester examination |

**Text Books:**

1. G. Masters, W. Ela, W. Ela, Introduction to Environmental Engineering and Science, Pearson, 3rd Ed., 2013.
2. P. A. Vesilind, S. M. Morgan, Introduction to Environmental Engineering, Thomson, 2004.
3. N. de Nevers, Air Pollution Control Engineering, McGraw-Hill, 1994.

**Reference Books:**

1. David Cornwell, Mackenzie Davis, Introduction to Environmental Engineering, McGraw‐Hill Education, 2012.
2. D L Russel, Practical Wastewater Treatment, John Wiley & Sons, 2006.
3. G. Kiely, Environmental Engineering, McGraw-Hill, 2006.
4. M. N. Rao, H. V. N. Rao, Air Pollution, Tata McGraw-Hill, New Delhi, 1993.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X |  | X |
| PLO2 |  | X | X |
| PLO3 |  | X | X |

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| --- | --- |
| **Course Number** | **CB3106** |
| **Course Credit**  **(L-T-P-C)** | **3-0-0-3** |
| **Course Title** | **Introduction to Sustainable Engineering** |
| **Learning Mode** | Classroom lectures |
| **Learning Objectives** | Identify the various emissions and environmental impacts associated with commercial and non-commercial projects/processes.  Calculate the carbon footprint of various products/processes.  Evaluate new technologies that can help to mitigate the impacts of climate change. |
| **Course Description** | The course will introduce the climate and the reason for its deviation from the base timeline, current environmental policies, and the methods to mitigate the adverse effects of climate change. |
| **Course Content** | Global agreements; Sustainability- concepts and pillars; Sustainable materials; Design, and Energy; 17 Sustainable goals; Life cycle analysis. Environmental impact assessment; Industrial ecology; Biomimicry in sustainable engineering designs; The atmosphere and its constituents; Atmospheric lifetime; Atmospheric trace constituents- Sulfur, nitrogen, carbon, and halogen containing compounds; Mercury; Greenhouse gasses- sources and effects; Properties of atmospheric aerosol; Stratospheric aerosol, cloud condensation Nuclei, sizes of Atmospheric particles, mineral dust, biomass burning; Tropospheric Chemistry of chlorofluorocarbon (CFC) with ozone; Introduction to Carbon Footprint. ISO 14064. |
| **Learning Outcome** | It will impart the concepts of climate change, its effect on the environment, and its possible prevention methodology. |
| **Assessment Method** | Assignments, Literature review, Simulation, Quiz, Mid-semester examination and End-semester examination |

**Text Books:**

1. J. H. Seinfeld, S.N. Pandis, Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd edition, Wiley, 2006.
2. W. E. Kelly, B. Luke, N. R. Wright, Engineering for Sustainable Communities: Principles and Practices, American Society of Civil Engineers, 2017.

**Reference books:**

1. H. Bao-Jie. D. Prasad, G. Pgnata, J. Jupesta, Climate Change and Environmental Sustainability, Advance in Science, Technology & Innovation, Springer, 2022.
2. E. Adams, J. Connor, J. Ochsendorf, R. Nicolin, Design for Sustainability. Fall, Massachusetts Institute of Technology: MIT OpenCourseWare, 2006.
3. T. Letcher, Managing Global Warming: An Interface of Technology and Human Issues, Academic Press, 2018.

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|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 | X | X |  |
| PLO3 | X | X | X |

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| Course Number | **CB4108** |
| Course Credit  (L-T-P-C) | **3-0-0-3** |
| Course Title | **Bioprocess Engineering** |
| Learning Mode | Classroom lectures |
| Learning Objectives | Provides students with basic concepts regarding the design, operation, process optimization of various bioreactors. and fermenters. |
| Course Description | This course deals with the basic unit operation in bioprocesses, microbial growth kinetics, principles of bioreactors, bioreactors systems, basic bioreactor design, bioprocess control, and downstream operations. |
| Course Content | Introduction to bioprocess engineering; Upstream and downstream operations; Mass and energy balances in microbial processes; Enzyme technology: kinetics of enzyme-catalyzed reactions, immobilization, large-scale production; Fermentation processes: introduction, types, process parameters, design of fermenters, industrial application; Microbial growth: growth kinetic models, microbial behaviour in bioreactors; Necessity and optimization of growth media (Placket-Burman design); Fermenter and media sterilization; Cell disintegration and product recovery; Microbial cells and products separation technology: centrifugation, filtration; Purification techniques: precipitation, ultrafiltration, chromatography, electrophoresis; Integrated bio-reaction and bio-separation processes: membrane bioreactors, extractive fermentation, bioprocess instrumentation. |
| Learning Outcome | Able to analyze the basic principles and techniques of bioprocess engineering |
| Assessment Method | Assignments, Literature review, Simulation, Quiz, Mid-semester examination and End-semester examination |

**Text/Reference Books**

1. J. E. Bailey, D. Olis, Biochemical Engineering Fundamentals, McGrew- Hill Book Co., 2010.

2. S. N. Mukhopadhyay, Process Biotechnology Fundamentals, Viva Books Private Limited, 2001.

3. A. T. Jackson, Process Engineering in Biotechnology, Prentice-Hall, 1991.

4. M. L. Shuler, Bioprocess Engineering Basic Concepts, Prentice Hall PTR, 2nd Ed., 2014.

5. D.G. Rao, Introduction to Biochemical Engineering, Tata McGraw-Hill, 2005.

6. M, Doble, A. Kumar, Biotreatment of Industrial Effluents, Elsevier, 2008.

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| --- | --- | --- | --- |
|  | CLO1 | CLO2 | CLO3 |
| PLO1 | X | X |  |
| PLO2 |  | X | X |
| PLO3 |  |  | X |