# Syllabus for Integrated Master of Technology (Int. M. Tech.)
# Major: Chemical Engineering
# and Multidisciplinary Minor (MDM)

**(Under the National Education Policy 2020)**
**(NEP 2020)**
**in**
**(2023-2024)**

## Offered by

## INSTITUTE OF CHEMICAL TECHNOLOGY MUMBAI
## MARATHWADA CAMPUS, JALNA

(University Under Section-3 of UGC Act, 1956)

**Elite Status and Center for Excellence**

## Government of Maharashtra

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## A. Preamble

The Institute revamped the syllabi of various courses in 2023 as per National Education Policy 2020. All the courses are credit based and the evaluation are grade based. The credit system is a systematic way of describing an educational programme by attaching credits to its components. The definition of credits is based on student workload, learning outcomes and contact hours. It is a student-centric system based on the **student workload** required to achieve the objectives of a programme. Each theory course consists of lectures and tutorials. During tutorial session it is expected that the problem solving, case studies, relevant real-life applications, student presentations, home assignments, or projects (individual or group) are discussed in presence of the teacher. Teacher can have the freedom to interchange lectures / tutorials depending upon the need. Each laboratory course consists of practical hours and/or extra lecture hours depending upon the need. The Institute gives emphasis on continuous evaluation with considerable freedom to the teacher in deciding the mode of evaluation of the students. It is desirable to revise the syllabi of various courses every 5-6 years. Accordingly, the syllabus for Integrated Master of Technology (Int. M. Tech.) program is being revised. The revised syllabus comes into effect for first year students from the academic year 2023-24.

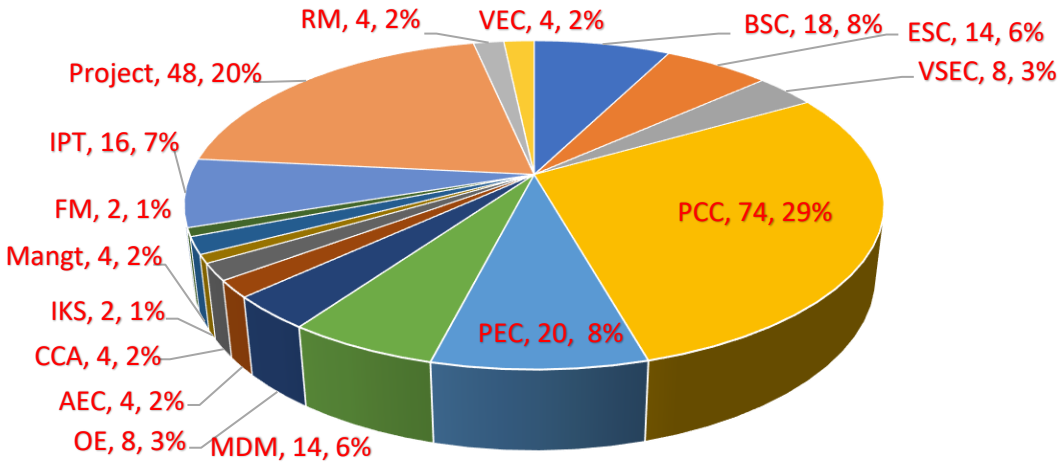



***Figure 1. Distribution of various course types (in percentage) for the programme as per the guidelines of NEP 2020. This distribution does not include Honours courses having 18 credits in total.***

Detailed discussions were conducted by the joint syllabus revision committee consisting of representative from both ICT Marathwada and ICT-IOC Campuses, and Department of Chemical Engineering, ICT Mumbai, and the following Programme Education Objectives (PEO), Programme Outcomes (PO) and Graduate Attributes (GA) were agreed upon. The revised syllabus is in line with the PEO, PO, and GA as noted below.

## B. Programme Education Objectives (PEOs)

| | |
|---|---|
| **PEO1** | Create awareness amongst students about the social/industrial demands and role of chemical engineer in the society. |
| **PEO2** | Incorporate a culture of research and Innovation by providing students with latest facilities. |
| **PEO3** | Provide a platform to the students to interact with leading teachers, scientists, and industry practitioners. |
| **PEO4** | Multi-faceted development of students through co-curricular and extra-curricular activities, participation in various events |
| **PEO5** | Build technical and managerial capabilities amongst students to meet the needs of society and industry. |

## C. Programme Outcome (POs)

| | | |
|---|---|---|
| **PO1** | **Engineering knowledge** | Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems. |
| **PO2** | **Problem analysis** | Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences |
| **PO3** | **Design/ development of solutions** | Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations |
| **PO4** | **Conduct investigations of complex problems** | Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. |
| **PO5** | **Modern tool usage** | Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations |
| **PO6** | **The engineer and society** | Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice. |
| **PO7** | **Environment and sustainability** | Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development |
| **PO8** | **Ethics** | Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice |
| **PO9** | **Individual and teamwork** | Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings. |
| **PO10** | **Communication** | Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| **PO11** | **Project management and finance** | Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments |
| **PO12** | **Life-long learning** | Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change. |

## D. Programme Specific Outcome (PSOs)

The graduates will be able to:

| | | |
|---|---|---|
| **PSO1** | **Factual Knowledge** | Understand terminology, basic concepts of science, mathematics, and fundamentals of engineering particularly in Chemical Engineering |

| | | |
|---|---|---|
| **PSO2** | **Conceptual Knowledge** | Comprehend theories or models, choose appropriate model, equipment, or process to meet the specified needs considering feasibility, safety, health hazards, societal, economic, environmental or sustainability factors as well as critically analyze relationships between these factors |
| **PSO3** | **Procedural Knowledge** | Investigate, conduct experiments, research, or model as per standards, collect and analyze information based on field visits, analysis, and interpretation of data to prepare the valid technical reports. |
| **PSO4** | **Metacognitive Knowledge** | Apply Chemical Engineering knowledge in various sectors of industry, environment, life, and society, as well as develop solutions to complex problems applying principles and knowledge gained throughout the program or to develop new knowledge or methodologies through research |
| **PSO5** | **Industrial and Societal Perspective** | Cater to the needs of chemical industry, research organizations and academic institutes. set-up their own ventures and generate employment, promote awareness in society about Chemical Engineering profession. |

## E. Graduate Attributes (GAs)

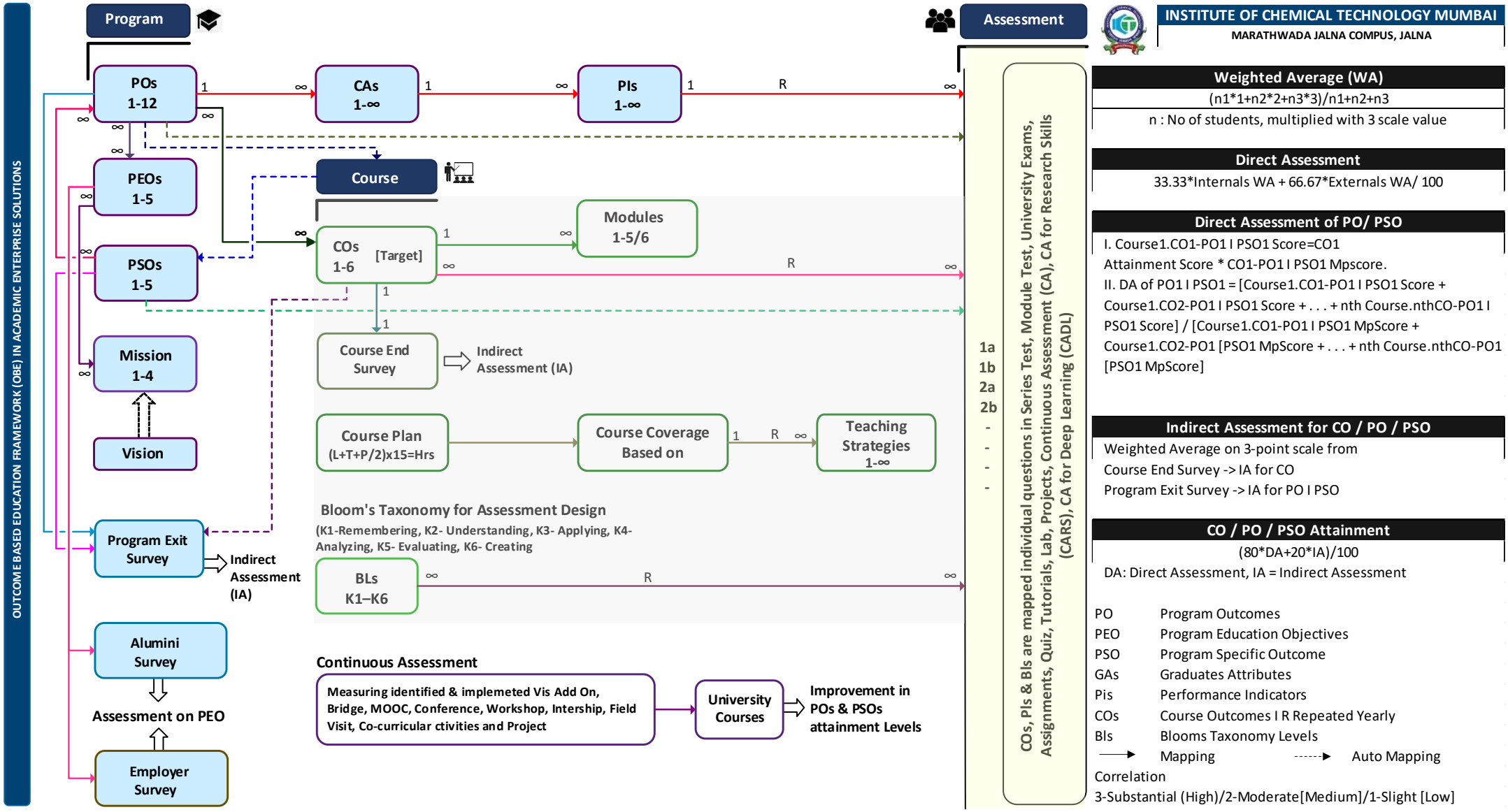
1. Problem analysis and solving skills.
2. Familiar with usage of modern tools, techniques
3. Communication Skills
4. Capacity to analyze new concepts.
5. Capacity to analyze and interpret experimental data Capacity to analyze business trends.
6. Capacity to design, optimize and operate equipment and plants safely, economically, and effectively.
7. Design and Development of solutions to industrial and societal needs.
8. Skills related to Project Management and Economics
9. Skills to analyze scientific literature including patents.
10. Ethics

## F. Vision

To be a vibrant educational institute with innovative programs and research culture in the field of chemical and allied sciences.

## G. Mission

1. Produce trained engineers and problem solver research fellows.
2. Develop science and technologies of global standards having relevance to India as well as to local Industry from Marathwada region.
3. Develop entrepreneurship and provide incubation centres for encouraging Start-ups in Marathwada region.
4. Catalyse the process of generating wealth from knowledge creating bridge among industry, agriculture, environment, and society.


OUTCOME BASED EDUCATION FRAMEWORK (OBE) IN ACADEMIC ENTERPRISE SOLUTIONS
Program
Assessment
INSTITUTE OF CHEMICAL TECHNOLOGY MUMBAI
MARATHWADA JALNA COMPUS, JALNA
POs 1-12
CAs 1-∞
PIs 1-∞
PEOs 1-5
PSOs 1-5
Mission 1-4
Vision
Course
COs 1-6 [Target]
Modules 1-5/6
Course End Survey
Indirect Assessment (IA)
Course Plan (L+T+P/2)x15=Hrs
Course Coverage Based on
Teaching Strategies 1-∞
Bloom's Taxonomy for Assessment Design
(K1-Remembering, K2- Understanding, K3- Applying, K4-Analyzing, K5- Evaluating, K6- Creating
BLs K1–K6
Program Exit Survey
Indirect Assessment (IA)
Alumini Survey
Assessment on PEO
Employer Survey
Continuous Assessment
Measuring identified & implemeted Vis Add On, Bridge, MOOC, Conference, Workshop, Intership, Field Visit, Co-curricular ctivities and Project
University Courses
Improvement in POs & PSOs attainment Levels
1a
1b
2a
2b
COs, PIs & BIs are mapped individual questions in Series Test, Module Test, University Exams, Assignments, Quiz, Tutorials, Lab, Projects, Continuous Assessment (CA), CA for Research Skills (CARS), CA for Deep Learning (CADL)
Weighted Average (WA)
(n1*1+n2*2+n3*3)/n1+n2+n3
n : No of students, multiplied with 3 scale value
Direct Assessment
33.33*Internals WA + 66.67*Externals WA/ 100
Direct Assessment of PO/ PSO
I. Course1.CO1-PO1 I PSO1 Score=CO1 Attainment Score * CO1-PO1 I PSO1 Mpscore.
II. DA of PO1 I PSO1 = [Course1.CO1-PO1 I PSO1 Score + Course1.CO2-PO1 I PSO1 Score + . . . + nth Course.nthCO-PO1 I PSO1 Score] / [Course1.CO1-PO1 I PSO1 MpScore + Course1.CO2-PO1 [PSO1 MpScore + . . . + nth Course.nthCO-PO1 [PSO1 MpScore]
Indirect Assessment for CO / PO / PSO
Weighted Average on 3-point scale from
Course End Survey -> IA for CO
Program Exit Survey -> IA for PO I PSO
CO / PO / PSO Attainment
(80*DA+20*IA)/100
DA: Direct Assessment, IA = Indirect Assessment
PO Program Outcomes
PEO Program Education Objectives
PSO Program Specific Outcome
GAs Graduates Attributes
Pis Performance Indicators
COs Course Outcomes I R Repeated Yearly
Bls Blooms Taxonomy Levels
Mapping
Auto Mapping
Correlation
3-Substantial (High)/2-Moderate[Medium]/1-Slight [Low]

## H. Syllabus Structure for Int. M. Tech.

**Semester I**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CHT4151 | Applied Chemistry | BSC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CHP4151 | Applied Chemistry Lab | BSC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| MAT4151 | Mathematics - I | BSC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| PHT4151 | Applied Physics | BSC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| PHP4151 | Applied Physics Lab | BSC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| EST4151 | Structural Mechanics | ESC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| ESP4151 | Structural Mechanics Lab | ESC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| ESP4152 | Engineering Graphics with Computer Aided Modelling | VSEC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUP4151 | Communication Skills- English | AEC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | 2 | 0 | 0 | 4 | | | | |
| | **Total** | | **22** | **09** | **1** | **24** | | | | |

**Semester II**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CHT4152 | Applied Chemistry II | BSC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| MAT4152 | Mathematics: II | BSC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| EST4153 | Electrical Engineering and Basic Electronics | ESC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| ESP4153 | Electrical Engineering and Basic Electronics Lab | ESC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| EST4152 | Mechanical Engineering | ESC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| EST4154 | Introduction to Chemical Engineering | ESC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CEP4151 | Material Balance and Energy Balance Calculations | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| ESP4154 | Engineering Applications of Digital computers | VSEC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUTXXXX | MOOC- Indian Knowledge System | IKS | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | 2 | 0 | 0 | 4 | | | | |
| | **Total** | | **24** | **14** | **2** | **16** | | | | |

Note: Universal Human Values (UHV) an audit course to be taken in inter-semester break after Semester-II to be taken as MOOC course.

** Students will undertake these co-curricular activities such as sports / Fine Arts / Yoga / Music / Literature etc administered through various clubs under Technological Association approved by Dean, Students Affairs.

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CEP4171 | IPT (4-6 months): Only for student opting for exit at certificate Level (Year 1) | IPT | 8 | 0 | 0 | 40 | | | | |
| | **Total** | | **8** | | | **40** | | | | |

**Semester III**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4251 | Fluid Flow | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4252 | Heat Transfer | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| EST4155 | Engineering Thermodynamics | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4253 | Industrial Chemistry and Reaction Engineering | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CEP4251 | Chemical Engineering Lab-I | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths) | OE | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| XXP | From Basic Sciences (Chemistry/ Physics/Biology / Maths) | OE | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| HUPXXXX | Modern Indian Language (Marathi / Hindi or Any other language will be chosen) | AEC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUT4156 | Basic Principles of Finance & Economics | Management | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CET4257 | Environmental Sciences | VEC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| | **Total** | | **26** | **18** | **4** | **8** | | | | |

**Semester IV**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4254 | Chemical Engineering Operations | PCC | 4 | 2 | 2 | 0 | 20 | 30 | 50 | 100 |
| CET4255 | Process Safety | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4256 | Instrumentation and Process Dynamics | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| XXP | From sciences and/or any other Engineering Discipline | MDM | 2 | 0 | 0 | 2 | 0 | 50 | 50 | 100 |
| XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CEP4252 | Chemical Engineering Lab-II | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUT4157 | Industrial Management | Management | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| ESP4157 | Digital Computation in Emerging areas (AI/ML/DA) | VEC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| HUP4158 | Community Projects | Field Project | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CETxxxx | Chemical Engineering Elective: I | PEC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| | **Total** | | **26** | **13** | **5** | **14** | | | | |

# Students will undertake community projects as individual or group related to study of societal technological activities through various organization such as Lions club, Teach India, Marathi Vidnyan Parishad, CSR projects outsourced by various industries, ISR activities administered through Technological Association approved by the Dean, Student Affairs.

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CEP4272 | IPT (4-6 months): Only for student opting for exit at Diploma Level (Year 2) | IPT | 8 | | | 40 | | | | |
| | **Total** | | **8** | | | **40** | | | | |

**Semester V**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4351 | Chemical Reaction Engineering | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4352 | Momentum Transfer | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4353 | Chemical Engineering Thermodynamics | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CEP4253 | Chemical Engineering Lab: III | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CEP4255 | Process Simulation Lab: I | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CETxxxx | Chemical Engineering Elective-II | PEC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CETxxxx | Chemical Engineering Elective-III | PEC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| XXP | From sciences and/or any other Engineering Discipline | MDM | 2 | 0 | 0 | 2 | 0 | 50 | 50 | 100 |
| CETxxxx | Honors Course -1/Research-1 | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| | **Total** | | **28** | **15** | **7** | **10** | | | | |

**Semester VI**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4362 | Honors Course 2/Research-2 | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4354 | Chemical Process Control | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4356 | Separation Processes | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4357 | Heat Transfer Equipment design | PCC | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CETxxxx | Chemical Engineering Elective-IV | PEC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4363 | Honours Course-3/Research-3 | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| XXT | From Sciences and/or any other Engineering Discipline | MDM | 2 | 1 | 1 | 0 | 20 | 30 | 50 | 100 |
| CEP4256 | Process Simulation Lab-II | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CEP4254 | Chemical Engineering Lab-IV | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CET4358 | Chemical Project Economics | PCC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CET4373 | IPT (after Semester VI exams for Eight weeks) | IPT | 4 | 0 | 0 | 0 | | | | |
| | **Total** | | **30** | **15** | **7** | **8** | | | | |

**Semester VII**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4451 | Chemical Process Development and Engineering | PCC | 3 | 2 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4452 | Chemical Industrial Management | PCC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CETxxxx | Chemical Engineering Elective V | PEC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| CEP4451 | Chemical Process Equipment Design and drawing | PCC | 2 | 0 | 0 | 4 | 0 | 50 | 50 | 100 |
| CETxxxx | Honours Course-4/Research-4 | PCC | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CETxxxx | Honours Course-5/Research-5 | PCC | 4 | 3 | 1 | 0 | 20 | 30 | 50 | 100 |
| XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 2 | 0 | 0 | 20 | 30 | 50 | 100 |
| CEP4452 | Literature Review | RM | 2 | 1 | 0 | 2 | 0 | 50 | 50 | 100 |
| CEP4453 | Design and Analysis of Experiments | RM | 2 | 1 | 0 | 2 | 0 | 50 | 50 | 100 |
| CEP4461 | Design Project - I | Project | 4 | 0 | 0 | 8 | | | | |
| | **Total** | | **27** | **16** | **3** | **16** | | | | |

**Semester VIII**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CEP4474 | IPT (4-6 months) | IPT | 12 | 0 | 0 | 40 | | | | |
| | **Total** | | **12** | | | **40** | | | | |

**Semester IX**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CET4551 | Advanced Transport Phenomena | PCC | 3 | 2 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4552 | Advanced Separation Processes | PCC | 3 | 2 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4553 | Advanced Reaction Engineering | PCC | 3 | 2 | 1 | 0 | 20 | 30 | 50 | 100 |
| CET4554 | Advanced Mass transfer | PCC | 3 | 2 | 1 | 0 | 20 | 30 | 50 | 100 |
| CEP4563 | Thesis | Research | 10 | 0 | 0 | 40 | | | | |
| | **Total** | | **22** | **8** | **4** | **40** | | | | |

**Semester X**

| Course Code | Subjects | Course Type | Credits | Hrs/Week | | | Marks for various Exams | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | C. A. | M. S. | E. S. | Total |
| CEP4564 | Thesis | Research | 22 | 0 | 0 | 40 | | | | |
| | **Total** | | **22** | | | **40** | | | | |

BSC: Basic Science Course
ESC: Engineering Science Course
PCC: Program Core Course
PEC: Program Elective Course
MDM: Multi-disciplinary Minor: Different discipline of engineering or different faculty altogether
OE: Open Elective: To be chosen Compulsorily from faculty other than major discipline
VSEC: Vocational and Skill Enhancement Course: Hands on training corresponding to major/minor
AEC: Ability Enhancement Course: English 2 credit, Modern Indian Language 2 credit
IKS: Indian Knowledge System: Indian Architecture/ Maths/ Medicine/ Technologies
VEC: Value Education Course: e.g. Understanding India, Environmental Science, Education, Digital and Tech solution
RM: Research Methodology
CCA: Co-curricular activities: Health and wellness/ Yoga/ Sports/ Cultural activities/ NSS/ NCC/ Applied visual performing arts

**Bachelor's Eng./ Tech. Honor's Degree**

The Bachelor of Chemical Engineering Honours Degree programme with a multi-disciplinary degree Minor degree enables a student to take up five-six additional courses of 18 to 20 credits in the Chemical Engineering and allied disciplines distributed over semesters III to VIII. The decision regarding the distribution of these 18-20 credits over these semesters will be taken by Academic Authorities of University.

**Eligibility for Int. M. Tech. with Honors or Research Degree program:**

Eligibility for admission to the Bachelor of Chemical Engineering with Double Minor/ Honors /Research shall be a Minimum CGPA of 7.5 after the Fourth semester for Bachelor of Chemical Engineering Degre as per UGC guidelines:

**Honors Courses: (ICT Marathwada Campus will recommend Honors courses to be taken by the students. These could typically be the following.**

Honors - I: Biochemical Engineering
Honors - II: Multiphase Reaction Engineering
Honors - III: Mathematical Methods & Optimization in Chemical Engineering
Honors - IV: Refinery Science and Engineering
Honors - V: Catalytic Science and Engineering
Honors: VI: Statistical Thermodynamics

**Bachelor's Eng./ Tech. Honours with Research Degree in Chemical Engineering**

Under Bachelor of Technology (Major: Chemical Engineering) with Research Degree in chemical Engineering with a Multidisciplinary Minor degree, the students will work on a research project or dissertation for additional 18 credits in the Third and Fourth years in Chemical Engineering and allied subjects. The decision regarding the distribution of 18 credits for Research Project in Semesters VII and VIII of the Fourth Year will be taken by Academic Authorities of University.

**Multidisciplinary Minor Degree will be offered to the Chemical Engineering students in**

(a) Food Technology
(b) Pharmaceutical Chemistry & Technology
(c) Lipid Engineering
(d) Polymer and Materials Engineering
(e) Energy Technology
(f) Petroleum and Petrochemicals Technology
(g) Material Physics
(h) Chemical Sciences

## EXIT Options

Based on the National Education Policy guidelines, the students have an option of exiting at each level of their four-year program. Student will get certificate after 1st year, diploma after second year and BSc (Tech/Eng) after third year.

| Sr. No. | Exit Year | Activity to be completed for the option of an exit | Credits | Duration (No. of Weeks) |
|---|---|---|---|---|
| 1 | 1st Year (After Semester II) | 8 Credit course workshop or chemistry lab (after Semester II) | 8 | 8 weeks |
| 2 | 2nd Year (After Semester IV) | Certificate Course in Practice of Chemical Engineering (CCPCE) | 8 | 8 weeks |
| 3 | 3rd Year (After Semester VI) | In-plant training | 8 | 8 weeks |

The exit paths for the program were discussed and resolved to be as follows:

| Exit Option (Semesters) | Nomenclature of Exit Outcome |
|---|---|
| Year 1 (2 Semesters) | Certificate (Chemical Engineering) |
| Year 2 (4 Semesters + IPT) | Diploma (Chemical Engineering) |
| Year 3 (6 Semesters + IPT) | B. Sc. (Chemical Engineering) |
| Year 4 (8 Semester + IPT) | • B. Tech. (Major: Chemical Engineering, MDM minors)<br>• B. Tech. with Honors and Minor (Major: Chemical Engineering, MDM minors) with option for 1 year M. Tech. Degree |
| Year 5 (10 Semesters) | • M. Tech. (Major: Chemical Engineering, MDM minors), one year [+ B. Tech. with Honors and Minor (Major: Chemical Engineering, MDM minors) with option for 1 year M. Tech. Degree] |

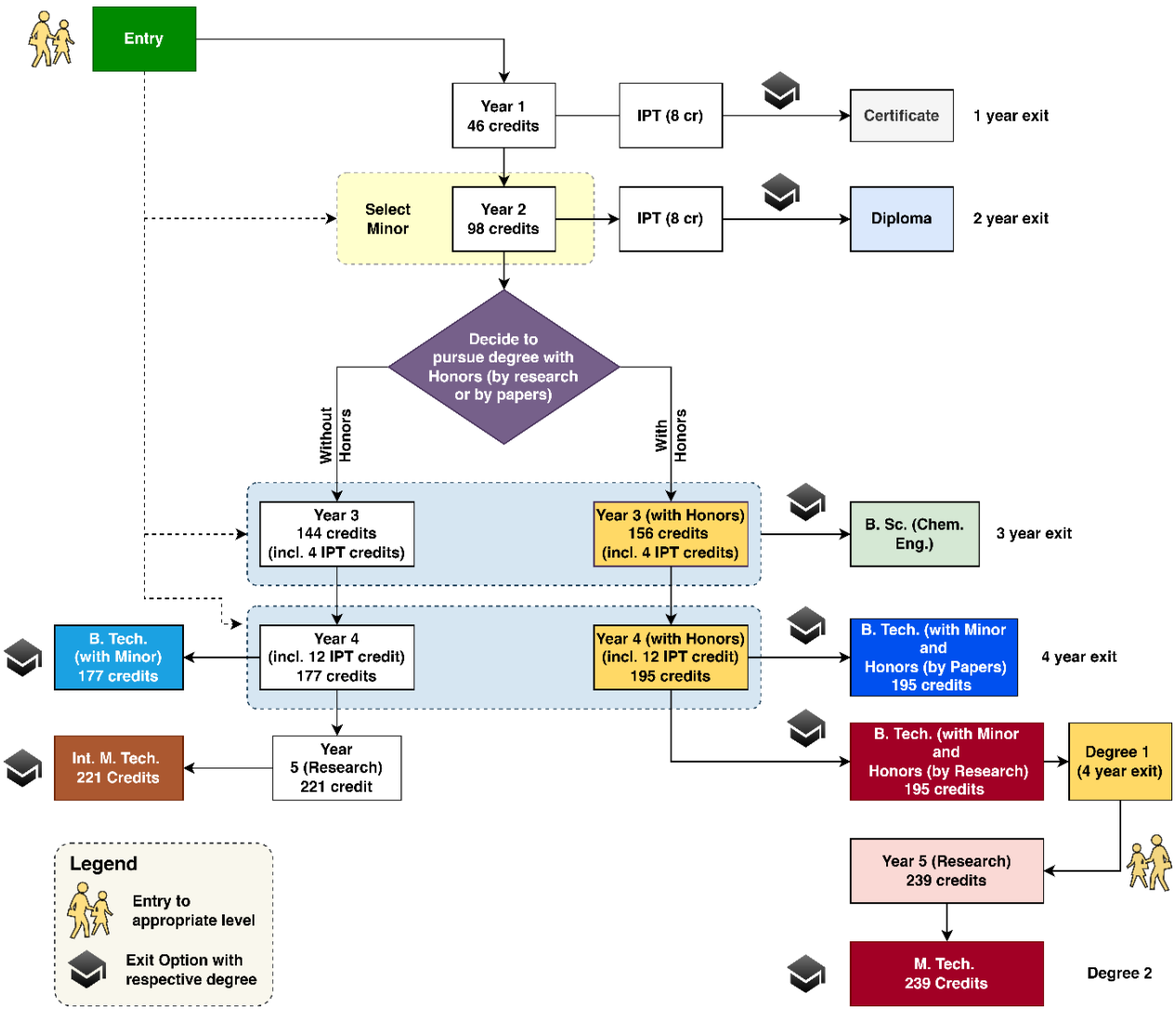



*Figure 2. A map of options available for entry to Integrated Master of Technology in Chemical Engineering.*

## I. Summary of Mapping of Subject Course Outcomes (COs) with Programme Outcomes (POs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| **First Year** | | | | | | | | | | | | | | | |
| I | CHT4151 | Applied Chemistry | BSC | 3 | 2 | 1 | 1 | 2 | - | - | - | - | 1 | 1 | 1 |
| | CHP4151 | Applied Chemistry Lab | BSC | 3 | 3 | 1 | 2 | 2 | 1 | - | - | - | 2 | 2 | 1 |
| | MAT4151 | Mathematics-I | BSC | 3 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | 1 | 1 |
| | PHT4151 | Applied Physics | BSC | 3 | 3 | 2 | 1 | 1 | 1 | - | 1 | - | 1 | 1 | 1 |
| | PHP4151 | Applied Physics Lab | BSC | 3 | 1 | 1 | 2 | 1 | - | - | - | - | 1 | - | - |
| | EST4151 | Structural Mechanics | ESC | 3 | 2 | 2 | 1 | 1 | 2 | 1 | - | - | 2 | - | - |
| | ESP4151 | Structural Mechanics Lab | ESC | 3 | 1 | 1 | - | - | - | - | - | - | 1 | - | - |
| | ESP4152 | Engineering Graphics with Computer Aided Modelling | VSEC | 2 | 1 | 1 | 1 | 2 | - | 1 | - | - | 1 | 1 | 1 |
| | HUP4151 | Communication Skills- English | AEC | - | - | 2 | 1 | 1 | 1 | - | - | - | 3 | 1 | - |
| | HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | - | - | - | - | - | - | - | 3 | 3 | - | 3 | - |
| II | CHT4152 | Applied Chemistry II | BSC | 3 | 2 | 1 | 1 | 2 | - | - | - | - | 2 | 2 | - |
| | MAT4152 | Mathematics: II | BSC | 3 | 2 | 1 | 2 | 2 | 1 | - | - | - | - | 1 | 1 |
| | EST4153 | Electrical Engineering and Basic Electronics | ESC | 3 | 2 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 1 | - |
| | ESP4153 | Electrical Engineering and Basic Electronics Lab | ESC | 3 | 2 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | - | - |
| | EST4152 | Mechanical Engineering | ESC | 3 | 2 | 1 | 1 | 1 | 2 | 2 | - | - | - | - | - |
| | EST4154 | Introduction to Chemical Engineering | ESC | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | - | 2 | 1 | 1 |
| | CEP4151 | Material Balance and Energy Balance Calculations | PCC | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 |
| | ESP4154 | Engineering Applications of Digital computers | VSEC | - | 2 | 2 | 2 | 2 | 1 | - | 1 | - | 1 | - | 1 |
| | HUTXXXX | MOOC- Indian Knowledge System | IKS | - | - | - | - | - | 2 | 1 | 3 | 1 | 3 | - | - |
| | HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | - | - | - | - | - | - | - | 3 | 3 | - | 3 | - |
| **Second Year** | | | | | | | | | | | | | | | |
| III | CET4251 | Fluid Flow | PCC | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | - | 1 | 2 | 1 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CET4252 | Heat Transfer | PCC | - | 3 | 1 | 2 | 2 | 1 | 2 | 1 | - | 1 | 1 | 1 |
| | EST4155 | Engineering Thermodynamics | PCC | 3 | 3 | - | 2 | 1 | 1 | 1 | 1 | - | 1 | 1 | - |
| | CET4253 | Industrial Chemistry and Reaction Engineering | PCC | 3 | 2 | 1 | 2 | 2 | 1 | 1 | - | - | 1 | 1 | 2 |
| | CEP4251 | Chemical Engineering Lab-I | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 1 | - | - | - | 2 | 3 | - | 1 | 2 | 1 | 1 |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths) | OE | 3 | 1 | - | 1 | - | 2 | 2 | - | 2 | 1 | - | - |
| | XXP | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 1 | - | 2 | - | 2 | 2 | - | 2 | 1 | - | - |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 1 | - | 1 | - | 2 | 2 | - | 2 | 1 | | |
| | HUPXXXX | Modern Indian Language - (Marathi / Hindi or Any other language will be chosen) | AEC | - | - | - | - | - | - | - | - | - | 3 | - | - |
| | HUT4156 | Basic Principles of Finance & Economics | Management | - | 1 | 3 | 2 | - | 1 | 1 | - | - | 1 | 1 | 1 |
| | CET4257 | Environmental Sciences | VEC | 1 | 1 | 1 | 2 | 1 | - | 1 | - | 2 | 1 | 1 | 1 |
| IV | CET4254 | Chemical Engineering Operations | PCC | 3 | 3 | 3 | 3 | - | 1 | 3 | - | - | 2 | 2 | 1 |
| | CET4255 | Process Safety | PCC | 3 | 3 | 3 | 3 | - | 1 | 3 | - | - | 1 | 1 | - |
| | CET4256 | Instrumentation and Process Dynamics | PCC | 3 | 2 | 2 | 2 | 2 | 2 | 1 | - | - | 2 | 2 | - |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | 1 | 3 | 2 | 1 | 2 | 1 | 2 | 2 |
| | XXP | From sciences and/or any other Engineering Discipline | MDM | 3 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 2 | 1 | 2 | 2 |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 1 | - | 2 | - | 2 | 2 | - | 2 | 1 | - | - |
| | CEP4252 | Chemical Engineering Lab-II | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| | HUT4157 | Industrial Management | Management | 2 | 3 | 3 | 2 | 2 | 1 | - | - | 2 | 1 | 3 | 1 |
| | ESP5157 | Digital Computation in Emerging areas (AI/ML/DA) | VEC | - | - | - | - | - | 3 | - | 1 | - | 2 | 2 | - |
| | HUP4158 | Community Projects | Field Project | - | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 2 | 3 | 3 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CETxxxx | Chemical Engineering Elective: I | PEC | 2 | 3 | 3 | 2 | 2 | 1 | 1 | - | - | 1 | 1 | 1 |
| **Third Year** | | | | | | | | | | | | | | | |
| V | CET4351 | Chemical Reaction Engineering | PCC | 3 | 2 | 2 | 1 | 2 | 2 | 3 | - | - | 1 | 1 | - |
| | CET4352 | Momentum Transfer | PCC | 3 | 2 | 2 | 2 | 1 | 2 | 2 | - | - | 1 | 1 | - |
| | CET4353 | Chemical Engineering Thermodynamics | PCC | 3 | 2 | 1 | 2 | 1 | 2 | 1 | - | - | - | 2 | - |
| | CEP4253 | Chemical Engineering Lab: III | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| | CEP4255 | Process Simulation Lab: I | PCC | 2 | 2 | 2 | 1 | 1 | 1 | - | 2 | - | - | 2 | - |
| | CETxxxx | Chemical Engineering Elective-II | PEC | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 3 | - | 2 | - |
| | CETxxxx | Chemical Engineering Elective-III | PEC | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 3 | - | 2 | - |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 2 | 1 | 2 | 2 |
| | XXP | From sciences and/or any other Engineering Discipline | MDM | 3 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 2 | 1 | 2 | 2 |
| | CETxxxx | Honors Course -1/Research-1 | PCC | 3 | 2 | 3 | 2 | 2 | 1 | 3 | - | - | 2 | 2 | - |
| VI | CETxxxx | Honors Course 2/Research-2 | PCC | 3 | 2 | 1 | 2 | 2 | 2 | 2 | - | - | 2 | 2 | - |
| | CET4354 | Chemical Process Control | PCC | 3 | 2 | 2 | 1 | 2 | 2 | 1 | - | 1 | - | 3 | - |
| | CET4356 | Separation Processes | PCC | 3 | 2 | 2 | 1 | 2 | 2 | 2 | - | - | 1 | 2 | - |
| | CET4357 | Heat Transfer Equipment design | PCC | 3 | 2 | 2 | 1 | 2 | 2 | 2 | - | - | 1 | 1 | - |
| | CETxxxx | Chemical Engineering Elective-IV | PEC | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 3 | - | 2 | - |
| | CET4363 | Honours Course-3/Research-3 | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 2 | - | - | 1 | 2 | - |
| | XXT | From Sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 3 | 2 | 1 | 2 | 2 | 3 | 3 | 3 | 3 | 2 |
| | CEP4256 | Process Simulation Lab-II | VSEC | 2 | 2 | 2 | 1 | 1 | 1 | - | 2 | - | - | 2 | - |
| | CEP4254 | Chemical Engineering Lab-IV | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| | CET4358 | Chemical Project Economics | PCC | 3 | 1 | 2 | 1 | 2 | 3 | 2 | - | - | 1 | 2 | 1 |
| | CET4373 | IPT (after Semester VI exams for Eight weeks) | IPT | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 2 |
| **Fourth Year** | | | | | | | | | | | | | | | |
| VII | CET4451 | Chemical Process Development and Engineering | PCC | 3 | 1 | 2 | 1 | 2 | 1 | 2 | - | - | 3 | 2 | 1 |
| | CET4452 | Chemical Industrial Management | PCC | - | - | 2 | 1 | - | 1 | - | 3 | 1 | 2 | 2 | 2 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CETxxxx | Chemical Engineering Elective V | PEC | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 3 | - | 2 | - |
| | CEP4451 | Chemical Process Equipment Design and drawing | PCC | 3 | 1 | 1 | 1 | 2 | 3 | 3 | - | - | 2 | 2 | 2 |
| | CETxxxx | Honours Course-4/Research-4 | PCC | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 1 | 1 | 2 | - |
| | CETxxxx | Honours Course-5/Research-5 | PCC | 2 | 3 | 2 | 2 | 3 | 2 | 3 | - | - | 1 | 2 | - |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 1 | 1 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |
| | CEP4452 | Literature Review | RM | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | - | 3 | 2 | - |
| | CEP4453 | Design and Analysis of Experiments | RM | 3 | 1 | 1 | 1 | 2 | 2 | 2 | - | - | 3 | 1 | - |
| | CEP4461 | Design Project - I | Project | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 3 | 2 | - |
| VIII | CEP4474 | IPT (4-6 months) | IPT | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 2 |
| **Fifth Year** | | | | | | | | | | | | | | | |
| IX | CET4551 | Advanced Transport Phenomena | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 2 | - |
| | CET4552 | Advanced Separation Processes | PCC | 2 | 3 | 2 | 2 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| | CET4553 | Advanced Reaction Engineering | PCC | 3 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 1 | 1 | - |
| | CET4554 | Advanced Mass transfer | PCC | 3 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | 1 | - |
| | CEP4563 | Thesis | Research | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |
| X | CEP4564 | Thesis | Research | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |

## J. Summary of Mapping of Honors Course Outcomes (COs) with Programme Outcomes (POs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| **Honors Syllabus** | | | | | | | | | | | | | | | |
| V | Honors Syllabus | Biochemical Engineering | PCC | 3 | 2 | 3 | 2 | 2 | 1 | 3 | - | - | 2 | 2 | - |
| VI | | Multiphase Reaction Engineering | PCC | 3 | 2 | 1 | 2 | 2 | 2 | 2 | - | - | 2 | 2 | - |
| VI | | Mathematical Methods & Optimization in Chemical Engineering | PCC | 3 | 2 | 2 | 2 | 2 | 1 | 2 | - | - | 1 | 2 | - |
| VII | | Refinery Science and Engineering | PCC | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 1 | 1 | 2 | - |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VII | Catalytic Science and Engineering | PCC | 2 | 3 | 2 | 2 | 3 | 2 | 3 | - | - | 1 | 2 | - |
| VII | Statistical Thermodynamics | PCC | 2 | 1 | 2 | 1 | 2 | 2 | 1 | - | - | 1 | 1 | - |

## K. Summary of Mapping of Elective Course Outcomes (COs) with Programme Outcomes (POs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| **Elective Course** | | | | | | | | | | | | | | | |
| V | CET 2769E | Process Intensification | PEC | 2 | 3 | 3 | 2 | 2 | 1 | 1 | - | - | 1 | 1 | 1 |
| V | CET2161 | Chemical Safety and Risk Management | PEC | 3 | 2 | 2 | 1 | - | 2 | 3 | 1 | 2 | 2 | - | - |

## L. Summary of Mapping of Subject Course Outcomes (COs) with Programme Specific Outcomes (PSOs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| | | **First Year** | | | | | | |
| I | CHT4151 | Applied Chemistry | BSC | 2 | 2 | 3 | 2 | 1 |
| | CHP4151 | Applied Chemistry Lab | BSC | 3 | 2 | 1 | 1 | 1 |
| | MAT4151 | Mathematics-I | BSC | 3 | 2 | 3 | 3 | 1 |
| | PHT4151 | Applied Physics | BSC | 2 | 3 | 2 | 2 | 1 |
| | PHP4151 | Applied Physics Lab | BSC | 3 | 3 | 2 | 1 | 1 |
| | EST4151 | Structural Mechanics | ESC | 3 | 2 | 2 | 2 | 1 |
| | ESP4151 | Structural Mechanics Lab | ESC | 3 | 2 | 1 | 1 | - |
| | ESP4152 | Engineering Graphics with Computer Aided Modelling | VSEC | 3 | 2 | 1 | 2 | 1 |
| | HUP4151 | Communication Skills- English | AEC | 2 | 2 | 3 | 1 | - |
| | HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | 3 | - | - | - | - |
| II | CHT4152 | Applied Chemistry II | BSC | 2 | 2 | 2 | 1 | - |
| | MAT4152 | Mathematics: II | BSC | 3 | 2 | 2 | 1 | 1 |
| | EST4153 | Electrical Engineering and Basic Electronics | ESC | 3 | 2 | 2 | 1 | 1 |
| | ESP4153 | Electrical Engineering and Basic Electronics Lab | ESC | 2 | 1 | 1 | 1 | - |
| | EST4152 | Mechanical Engineering | ESC | 3 | 2 | 1 | 1 | 1 |
| | EST4154 | Introduction to Chemical Engineering | ESC | 3 | 3 | 2 | 2 | 1 |
| | CEP4151 | Material Balance and Energy Balance Calculations | PCC | 2 | 2 | 2 | 1 | 1 |
| | ESP4154 | Engineering Applications of Digital computers | VSEC | 2 | 2 | 1 | 1 | 1 |
| | HUTXXXX | MOOC- Indian Knowledge System | IKS | 3 | 2 | - | - | - |
| | HUPXXXX | OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS | CCA | 3 | - | - | - | - |
| | | **Second Year** | | | | | | |
| III | CET4251 | Fluid Flow | PCC | 2 | 2 | 2 | 2 | 1 |
| | CET4252 | Heat Transfer | PCC | 3 | 2 | 3 | 3 | 1 |
| | EST4155 | Engineering Thermodynamics | PCC | 2 | 3 | 2 | 2 | 1 |
| | CET4253 | Industrial Chemistry and Reaction Engineering | PCC | 2 | 3 | 2 | 2 | 1 |
| | CEP4251 | Chemical Engineering Lab-I | PCC | 1 | 2 | 1 | 2 | 2 |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 3 | 3 | 2 | 1 |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths) | OE | 3 | 2 | 1 | - | - |
| | XXP | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 2 | 1 | - | - |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 2 | 1 | - | - |
| | HUPXXXX | Communication Skills-Marathi (Any other language will be using MOOCS) | AEC | 2 | - | - | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HUT4156 | Basic Principles of Finance & Economics | Management | 3 | 3 | 2 | 1 | 1 |
| | CET4257 | Environmental Sciences | VEC | 2 | 3 | 3 | 1 | - |
| IV | CET4254 | Chemical Engineering Operations | PCC | 3 | 3 | 2 | 1 | 1 |
| | CET4255 | Process Safety | PCC | 2 | 2 | 2 | 1 | 1 |
| | CET4256 | Instrumentation and Process Dynamics | PCC | 3 | 2 | 1 | 1 | 1 |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | - |
| | XXP | From sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | 1 |
| | XXT | From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science) | OE | 3 | 2 | 1 | - | - |
| | CEP4252 | Chemical Engineering Lab-II | PCC | 1 | 2 | 1 | 2 | 2 |
| | HUT4157 | Industrial Management | Management | 2 | 2 | 2 | 1 | 3 |
| | ESP4157 | Digital Computation in Emerging areas (AI/ML/DA) | VEC | 2 | - | - | - | - |
| | HUP4158 | Community Projects | Field Project | 3 | 2 | 2 | 2 | 3 |
| | CETxxxx | Chemical Engineering Elective: I | PEC | 3 | 2 | 3 | 3 | 2 |
| **Third Year** | | | | | | | | |
| V | CET4351 | Chemical Reaction Engineering | PCC | 2 | 2 | 3 | 3 | 1 |
| | CET4352 | Momentum Transfer | PCC | 3 | 2 | 2 | 1 | 1 |
| | CET4353 | Chemical Engineering Thermodynamics | PCC | 2 | 3 | 2 | 2 | 1 |
| | CEP4253 | Chemical Engineering Lab: III | PCC | 1 | 2 | 1 | 2 | 2 |
| | CEP4255 | Process Simulation Lab: I | PCC | 2 | 2 | 3 | 3 | 1 |
| | CETxxxx | Chemical Engineering Elective-II | PEC | 2 | 3 | 3 | 2 | 1 |
| | CETxxxx | Chemical Engineering Elective-III | PEC | 2 | 3 | 3 | 2 | 1 |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | 1 |
| | XXP | From sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | 1 |
| | CETxxxx | Honors Course -1/Research-1 | PCC | 2 | 2 | 3 | 3 | 2 |
| VI | CETxxxx | Honors Course 2/Research-2 | PCC | 2 | 2 | 3 | 3 | 2 |
| | CET4354 | Chemical Process Control | PCC | 2 | 2 | 3 | 3 | 1 |
| | CET4356 | Separation Processes | PCC | 2 | 2 | 1 | 2 | 1 |
| | CET4357 | Heat Transfer Equipment design | PCC | 2 | 1 | 2 | 2 | 1 |
| | CETxxxx | Chemical Engineering Elective-IV | PEC | 2 | 3 | 3 | 2 | 1 |
| | CETxxxx | Honours Course-3/Research-3 | PCC | 2 | 3 | 3 | 3 | 2 |
| | XXT | From Sciences and/or any other Engineering Discipline | MDM | 3 | 2 | 1 | 2 | 1 |
| | CEP4256 | Process Simulation Lab-II | VSEC | 1 | 2 | 3 | 3 | 1 |
| | CEP4254 | Chemical Engineering Lab-IV | PCC | 2 | 1 | 2 | 2 | 2 |
| | CET4358 | Chemical Project Economics | PCC | 2 | 2 | 3 | 1 | 1 |
| | CET4373 | IPT (after Semester VI exams for Eight weeks) | IPT | 3 | 2 | 2 | 3 | 3 |
| **Fourth Year** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| VII | CET4451 | Chemical Process Development and Engineering | PCC | 2 | 2 | 3 | 3 | 2 |
| | CET4452 | Chemical Industrial Management | PCC | 2 | 3 | 2 | 1 | 1 |
| | CETxxxx | Chemical Engineering Elective V | PEC | 2 | 3 | 3 | 2 | 1 |
| | CEP4451 | Chemical Process Equipment Design and drawing | PCC | 3 | 2 | 3 | 2 | 2 |
| | CETxxxx | Honours Course-4/Research-4 | PCC | 2 | 2 | 2 | 2 | 1 |
| | CETxxxx | Honours Course-5/Research-5 | PCC | 3 | 1 | 2 | 2 | 1 |
| | XXT | From sciences and/or any other Engineering Discipline | MDM | 2 | 1 | 2 | 2 | 3 |
| | CEP4452 | Literature Review | RM | 3 | 2 | 2 | 2 | 1 |
| | CEP4453 | Design and Analysis of Experiments | RM | 3 | 2 | 2 | 2 | - |
| | CEP4461 | Design Project - I | Project | 2 | 2 | 2 | 3 | 2 |
| VIII | CEP4474 | IPT (4-6 months) | IPT | 2 | 2 | 3 | 3 | 2 |
| | | **Fifth Year** | | | | | | |
| IX | CET4551 | Advanced Transport Phenomena | PCC | 1 | 2 | 3 | 3 | 1 |
| | CET4552 | Advanced Separation Processes | PCC | 2 | 3 | 3 | 2 | 2 |
| | CET4553 | Advanced Reaction Engineering | PCC | 2 | 3 | 3 | 2 | 1 |
| | CET4554 | Advanced Mass transfer | PCC | 2 | 3 | 3 | 2 | 1 |
| | CEP4563 | Thesis | Research | 2 | 3 | 3 | 3 | 3 |
| X | CEP4564 | Thesis | Research | 2 | 3 | 3 | 3 | 3 |

## M. Summary of Mapping of Honors Course Outcomes (COs) with Programme Specific Outcomes (PSOs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| | | **Honors Syllabus** | | | | | | |
| V | Honors Syllabus | Biochemical Engineering | PCC | 2 | 2 | 3 | 3 | 2 |
| VI | | Multiphase Reaction Engineering | PCC | 2 | 2 | 3 | 3 | 2 |
| VI | | Mathematical Methods & Optimization in Chemical Engineering | PCC | 2 | 3 | 3 | 3 | 2 |
| VII | | Refinery Science and Engineering | PCC | 2 | 2 | 2 | 2 | 1 |
| VII | | Catalytic Science and Engineering | PCC | 3 | 1 | 2 | 2 | 1 |
| VII | | Statistical Thermodynamics | PCC | 3 | 2 | 3 | 2 | 2 |

## N. Summary of Mapping of Elective Course Outcomes (COs) with Programme Specific Outcomes (PSOs))

| Sem | Course Code | Course Name | Course Type | Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| | | **Elective Course** | | | | | | |
| V | CET 2769E | Process Intensification | PEC | 3 | 2 | 3 | 3 | 2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| V | CET2161 | Chemical Safety and Risk Management | PEC | 3 | 2 | 2 | 1 | 1 |

# First Year

# Semester-I

| Semester I | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: CHT4151** | **Course Title: Applied Chemistry** | **Credits 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 30** | **2** | **0** | **0** |

| List of prerequisite courses | | |
|---|---|---|
| | Standard XII (Chemistry) | |

| List of courses where this course will be prerequisite | | |
|---|---|---|
| | Material Balance and Energy Calculations (CEP4151); Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Operation (CET4254), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451), Catalytic Science and Engineering (Hon.) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course aims to introduce the students to the concepts in IUPAC nomenclature, Organic Chemistry, and name reactions. The course content is designed to familiarize the students with various basic organic reactions such as sulfonation, halogenation, nitration etc. used chemical industry. The emphasis will be on relating the previously taught concepts of chemistry to real world examples.

| | Course contents (topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | **Organic Chemistry Nomenclature**: IUPAC nomenclature of organic compounds | **4** |
| 2 | **Structure activity relationship in organic molecules**: Use of bond length and bond energies to explain the reactivity of functional groups. Acidity & basicity values for organic molecules such as alkynes, alcohols, acids, ketones, amines. | **4** |
| 3 | **Aromatic electrophilic substitution:** Activating and deactivating functional groups on aromatic compounds, resonating structures, reactions such as Halogenation, Nitration, Friedel Crafts alkylation and acylation, sulfonation. | **10** |
| 4 | **Aromatic compounds:** Problems associated with SNAr reactions and how to overcome them. Mechanism for aromatic nucleophilic substitutions. | **8** |
| 5 | **Name reactions:** Aldol and related reactions, Henry reactions, Evens, and Mukaiyama reactions. Industrial importance of names reactions. | **4** |
| | **Total** | **30** |

| List of Textbooks/ Reference Books | | |
|---|---|---|
| 1 | Organic Chemistry, Paula Y. Bruice, Pearson Education | |
| 2 | Organic Chemistry – T. W. G Solomons, C. B. Fryhle, John Wiley and Sons | |
| 3 | Organic Chemistry, Clayden, Greeves, Warren, Oxford publication | |
| 4 | March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure 7 Edition (English, Paperback, Michael B. Smith) | |

| Course Outcomes (students will be able to….) | | |
|---|---|---|
| CO1 | Learn and understand how to write and name the organic compounds | K3 |
| CO2 | Understand reactions and structure activity relationship in organic molecules | K1 |
| CO3 | Understand the concept of nucleophilic and electrophilic substitution reactions | K3 |
| CO4 | Understand simple mechanisms of aromatic reactions | K4 |
| CO5 | Understanding the role and importance of name reactions and address the limitation and challenges of current protocols. | K4 + P |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Applied Chemistry: CHT4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | 1 | 1 | - | - | - | - | 2 | 1 | 1 |
| CO2 | - | 2 | 1 | 1 | 2 | - | - | - | - | 1 | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | 3 | 2 | 1 | 1 | - | - | - | - | - | 1 | - | - |
| CO4 | 3 | 2 | 1 | 1 | 2 | - | - | - | - | 1 | 1 | 1 |
| CO5 | 3 | 3 | 2 | 2 | 1 | - | - | - | - | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Applied Chemistry: CHT4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | - |
| CO2 | 2 | 1 | 2 | 1 | - |
| CO3 | 1 | 2 | 3 | 2 | 1 |
| CO4 | 2 | 2 | 3 | 2 | 1 |
| CO5 | 3 | 2 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: CHP4151** | **Course Title: Applied Chemistry Laboratory** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **0** | **0** | **4** |
| **List of Prerequisite Courses** | | | | | |
| | Standard XII Chemistry | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Applied Mathematics: II (MAT4151) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| 1. Introduce students to the basics of organic chemistry in terms of synthesis of important molecules and reaction monitoring through chromatographic techniques.<br>2. Introduce students to various techniques such as extraction, chromatography and crystallization for purification, and isolation of pure compounds.<br>3. Students will understand characterization methods to identify the structure of unknown compounds.<br>4. To develop skills to identify nature and type of different unknown compounds through qualitative analysis. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | 1. Organic Synthesis:<br>1.1. One-pot synthesis of organic compounds<br>1.2. Common synthetic method applied for the synthesis of pharmaceutical and biological importance molecules and optimization of reaction conditions while highlighting several green and sustainable principles.<br>1.3. Progress of the reactions monitoring by thin layer chromatography (TLC). | | 20 | | |
| 2 | 2. Separation and isolation of Final Products:<br>2.1 Purification of organic compounds, liquid-liquid, inorganic-organic, solid-liquid mixtures.<br>2.1 Purification of solid products by crystallization process<br>2.2. Purification of impure organic compounds by column chromatography | | 20 | | |
| 3 | 3. Identification of organic molecules based on physicochemical properties: Organic compounds contain different functional groups which undergo characteristic reactions:<br>3.1. Physical properties such as solubility and chemical reactivity in known reactions will also be used in the identification.<br>3.2. Identification of an organic compounds by physical constants methods (melting point and boiling point). | | 20 | | |
| | **Laboratory:** Any 12 experiments will be conducted<br>1. A solvent free approach for chalcone synthesis via aldol condensation and reaction progress monitoring through thin layer chromatography (TLC)<br>2. Isolation of aldol product (chalcone) by recrystallization and product analysis by TLC<br>3. Recrystallization and melting point determination of benzoic acid<br>4. Purification of catechol from its impure mixture using solvent extraction technique<br>5. Separation of organic compound (catechol) from solvent (ethyl acetate) by evaporation using rotary evaporator<br>6. Separation of organic compound by using silica gel column chromatography<br>7. Organic qualitative analysis and functional group determination of given unknown organic compound (Oxalic acid and Benzophenone)<br>8. Organic qualitative analysis and functional group determination of given unknown organic compound (Cinnamic acid and beta-Naphthol)<br>9. Organic qualitative analysis and functional group determination of given unknown organic compound (p-Nitroaniline and p-Toluidine)<br>10. Organic qualitative analysis and functional group determination of given unknown organic compound (Succinic acid)<br>11. Organic qualitative analysis of monosaccharide's containing "6-C" atoms (Glucose and Fructose)<br>12. To determine the functional groups in given organic compounds by Fourier Transform Infrared Spectroscopic (FTIR) analysis | | | | |

| | | |
|---|---|---|
| | **Total** | **60** |
| **List of Textbooks/ Additional Reading Material / Reference Books** | | |
| 1 | Vogel's Textbook of Practical Organic Chemistry by Brian S. Furniss, Anthony J. Hannaford, Peter W. G. Smith &Autin R. Tatchell: Fifth Edition | |
| 2 | Practical Organic Chemistry, by I.L. Finar | |
| 3 | Practical physical Chemistry: B. Viswanathan and P.S. Raghavan | |
| 4 | Practical physical Chemistry- Alexander Findlay | |
| **Course Outcomes (students will be able to….)** | | |
| | **Students will be able to** | |
| CO1 | Able to prepare condensation products via one-pot synthesis/solid phase synthesis | K3 |
| CO2 | Identify simple organic compounds systematically. | K1 |
| CO3 | Identify the various functional groups by simple tests. | K3 |
| CO4 | Identify structure of unknown compounds. | K4 |
| CO5 | Purify organic compounds based on their physical properties. | K4 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Applied Chemistry Laboratory: CHP4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | 1 | - | 2 | 1 | - | - | - | 1 | 2 | 1 |
| CO2 | 2 | 2 | 1 | 1 | 1 | - | - | - | - | 2 | 1 | - |
| CO3 | 3 | 2 | 1 | 2 | 2 | - | - | - | - | - | - | - |
| CO4 | 3 | 3 | 1 | 2 | 2 | 1 | - | - | - | 2 | 2 | 1 |
| CO5 | 2 | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Applied Chemistry Laboratory: CHP4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 1 | - |
| CO2 | 2 | 2 | 1 | - | - |
| CO3 | 3 | 2 | 1 | - | 1 |
| CO4 | 3 | 2 | 1 | 1 | 1 |
| CO5 | 2 | 3 | 2 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code:** **MAT4151** | **Course Title:** **Mathematics - I** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **4** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | HSC Standard Mathematics | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Applied Mathematics: II (MAT4152); Material and Energy Balance Calculations (CEP4151), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Process Simulation Lab - I and II (CEP4255 and CEP4256), Chemical Process Control (CET4354), Separation Processes + Membrane (CET4356), Heat Transfer Equipment design (CET4357), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Statistical Thermodynamics (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This is a basic Mathematics course. This knowledge will be required in almost all subjects later. This knowledge is also required for solving various mathematical equations that need to be solved in several chemical engineering courses such as MEBC, momentum transfer, reaction engineering, separation processes, thermodynamics, etc. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | **Calculus of one variable:** Review of Mean Value theorems, Higher order differentiation and Leibnitz Rule for the derivative, Taylor's and Maclaurin's theorems and applications to error estimates, convexity of functions, Local Maxima/Minima. | | 8 | | |
| 2 | **Multivariable calculus:** Functions of two or more variables, Limit and continuity, Partial differentiation, Directional derivatives, Total derivatives, Chain Rules of partial derivatives, Taylor's theorem for multivariable functions and its application to error calculations, Local and absolute Maxima/Minima | | 10 | | |
| 3 | **Integral Calculus:** Beta and Gamma functions, Differentiation under the integral sign, Multiple Integrals, Line and surface integrals and applications to Greens, Gauss-Divergence and Stokes theorem | | 12 | | |
| 4 | **Linear Algebra-I:** Systems of linear equations, matrices and Gauss elimination, Vectors in $\mathbb{R}^n$, notion of linear independence and dependence. Vector subspaces of $\mathbb{R}^n$, basis of a vector subspace., row space, null space, and column space, rank of a matrix. Determinants and rank of matrices. Abstract vector spaces, linear transformations, matrix of a linear transformation, change of basis and similarity, rank-nullity theorem, and its applications | | 8 | | |
| 5 | **Linear Algebra-II:** Inner product spaces, orthonormal bases, Gram-Schmidt orthogonalization process, Eigenvalues and eigenvectors, characteristic polynomials, eigenvalues of special matrices (orthogonal, unitary, Hermitian, symmetric, skew- symmetric, normal), Orthogonal projection and its application to least methods Diagonalization of matrices and its applications stochastic matrices, Matrix Factorization, Applications such as SVD, PCA etc. | | 8 | | |
| 6 | **Ordinary Differential Equations:** Review of first and second order ODEs (constant coefficient), Existence and Uniqueness theorems for first order ODEs. Higher order Linear ODE with constant and variable coefficient, Solutions of Initial and Boundary value problems, Solving initial value system of linear ordinary differential equations. | | 8 | | |
| 7 | **Ordinary Differential Equations -II:** Power series method of solving ODE's and special functions, Legendre Polynomials Bessel functions and applications. | | 6 | | |
| | **Total** | | **60** | | |
| **List of Textbooks / Reference Books** | | | | | |
| 1 | G. Strang, Linear Algebra and its Applications (4th Edition), Thomson (2006). | | | | |
| 2 | W. Keith Nicholson, Linear Algebra with Applications, Lyryx Learning Inc | | | | |
| 3 | Howard Anton, Elementary Linear Algebra, Wiley (2016) | | | | |
| 4 | Arnold J. Insel, Lawrence E. Spence, and Stephen H. Friedberg, Linear Algebra, Pearson | | | | |

| | | |
|---|---|---|
| 5 | E. Kreyszig, Advanced Engineering Mathematics (8th Edition), John Wiley (1999). (Officially prescribed) | |
| 6 | S. R. K. Iyengar, R. K. Jain, Advanced Engineering Mathematics Narosa. | |
| 7 | Marsden, J.E., Tromba, Anthony, Weinstein, Alan, Basic Multivariable Calculus. | |
| **Course Outcomes (students will be able to….)** | | |
| CO1 | Understand the notion of differentiability and apply these concepts to find maxima and minima of functions of one and several variables | K4 |
| CO2 | Understand different techniques for evaluating single and multiple integrals and apply them compute surface and volume integrals. | K4 |
| CO3 | Demonstrate their understanding on different concepts in vector spaces in solving computational problems related to matrices and determinants, such as solving systems of linear equations, etc. | K3 |
| CO4 | Understand the computational and geometrical concepts related to eigenvalues and eigenvectors and apply them to solve computational problems arising from chemical engineering | K3 |
| CO5 | Build mathematical models governed by differential equations to formulate chemical engineering problems and solve the equation using appropriate analytical techniques | K6 |
| CO6 | Solve ordinary differential equations using power series method and understand the utility and applications of various orthogonal functions in different chemical engineering problems | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Mathematics - I: MAT4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 2 | - | - | 2 | - | - | 1 | 2 | 1 |
| CO2 | 3 | 1 | 1 | 1 | 1 | - | 2 | - | - | 2 | 1 | 1 |
| CO3 | 3 | 1 | 2 | 1 | 1 | - | 1 | - | - | 2 | - | 1 |
| CO4 | 3 | 2 | 1 | 2 | 1 | - | - | - | - | 1 | 1 | 1 |
| CO5 | 3 | 2 | 2 | 2 | 1 | 1 | - | - | - | 1 | 2 | 1 |
| CO6 | 3 | 1 | 2 | 1 | 2 | 2 | 2 | - | - | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Mathematics - I: MAT4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 1 | - |
| CO2 | 3 | 2 | 2 | 1 | - |
| CO3 | 2 | 2 | 2 | 1 | - |
| CO4 | 2 | 1 | 3 | 3 | 1 |
| CO5 | 1 | 2 | 3 | 3 | 2 |
| CO6 | 1 | 2 | 3 | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: PHT4151** | **Course Title: Applied Physics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Standard XI and XII Physics course; Standard XII Chemistry course | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Applied Physics Laboratory (PHP 4151); Materials Science Minor program courses (Sem-III, IV, V, VI, VII, VIII) (Code); Open Elective courses from Physics Department (Sem-II, IV, V) (PST4251 and PST4252); Material and Energy Balance Calculations (CEP4151), Instrumentation and Process Dynamics (CET4256), Momentum Transfer (CET4352), Process Simulation Lab - I and II (CEP4255 and CEP4256) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Materials and their properties play a key role in the field of chemical engineering and technology. The Applied Physics course will provide the students with the necessary fundamentals to develop a broad understanding of various aspects related to materials, and thereby equip them with the ability to apply it wherever required in their course of study. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| | *Solid State Physics* | | | | |
| 1 | Crystal Structure of Solids: A revision of concepts of a lattice, a basis, unit cell, different crystal systems (SC, BCC, FCC, HCP), co-ordination number and packing fractions. Single crystalline, Polycrystalline, and Amorphous materials. | | 3 | | |
| 2 | Crystallographic planes and directions: concept of Miller indices and its determination, examples; calculation of inter-planar spacing in terms of Miller indices. | | 3 | | |
| 3 | Determination of crystal structure using X-rays: Bragg's law of X-ray diffraction, types of diffractometers, Indexing diffraction peaks and calculation of various lattice parameters and crystallite size | | 4 | | |
| 4 | Energy band in solids and classification of solids, the concept of Fermi level and Fermi distribution function, Intrinsic and extrinsic semiconductors, Transport properties of semiconductors: Conductivity in semiconductors and its dependence of carrier concentration and mobility. | | 5 | | |
| | *Electric and Magnetic properties of materials* | | | | |
| 1 | Revision of the laws of electrostatics and magnetostatics with illustrative examples. Introduction to the gradient, divergence, and curl operators. The current density vector and the continuity equation. | | 4 | | |
| 2 | Dielectrics: the concept of free and bound charges, polarization, introduction to the electric displacement and polarization vectors, dielectric constant, and electric susceptibility. Gauss's law in presence of dielectrics, Claussius-Mossotti equation. | | 6 | | |
| 3 | Magnetism: The Langevin theory of Diamagnetism and Paramagnetism: deriving the magnetic susceptibility and Curie's law. An introduction to the Weiss theory of paramagnetism and ferromagnetism. | | 5 | | |
| | **Total** | | **30** | | |
| **List of Textbooks/Reference books** | | | | | |
| 1 | Fundamentals of Physics - Halliday, Resnick, Walker - 6th Edition - John Wiley | | | | |
| 2 | Sears and Zeemansky's University Physics - Young and Freedman - 12th Edition - Pearson Education | | | | |
| 3 | A Textbook of Engineering Physics - M N Avadhanulu, P G Kshirsagar, TVS Arun Murthy - 11th Edition - S. Chand Publishers | | | | |
| 4 | Solid State Physics - S. O. Pillai - 10th Edition - New Age Publishers | | | | |
| 5 | Solid State Physics - A. J. Dekker - MacMillan India | | | | |
| 6 | Engineering Physics - V Rajendran - 6th Edition - McGraw Hill Publishers | | | | |
| 7 | Electricity and Magnetism - Edward Purcell and David Morin - 3rd Edition - Cambridge University Press | | | | |
| 8 | Electricity And Magnetism - R. Murugeshan - 3rd Edition - S Chand Publishers | | | | |
| 9 | Introduction to Electrodynamics - David Griffiths - 3rd Edition: Pearson Education | | | | |

| Course Outcomes (students will be able to….) | | |
|---|---|---|
| CO1 | Understand structures of solids and semiconductors, apply Bragg's law. | K2 |
| CO2 | Apply Bernoulli equation in simple pipe flows. | K3 |
| CO3 | Calculate resolving power of optical instruments. | K5 |
| CO4 | Describe principles of optical fibre communication. | K2 |
| CO5 | Introduced to the principles of lasers, types of lasers and applications. | K2 |
| CO6 | Understand application of acoustic cavitation of Chemical Engineering Processes | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Applied Physics - I: PHT4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | - | - | - | - | - | 2 | 1 | - |
| CO2 | 3 | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - |
| CO3 | 2 | - | - | - | 2 | - | - | - | - | - | - | - |
| CO4 | 1 | 3 | 2 | 2 | - | 1 | - | - | - | 1 | - | 1 |
| CO5 | 3 | 2 | 2 | 1 | 1 | - | - | - | - | 1 | 1 | - |
| CO6 | 3 | 2 | 2 | 1 | 1 | - | - | 1 | - | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Applied Physics - I: PHT4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 3 | 2 | 2 | 1 | - |
| CO3 | 1 | 2 | 3 | 2 | 1 |
| CO4 | 2 | 3 | 3 | 3 | - |
| CO5 | 2 | 3 | 2 | 2 | - |
| CO6 | 2 | 3 | 3 | 3 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: PHP4151** | **Course Title: Applied Physics Laboratory** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **0** | **0** | **4** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | 10+2th Physics; Applied Physics (PHT 4151) | |
| **List of Courses where this course will be prerequisite** | | |
| | Electrical properties of polymers (SYT4353), Engineering Physics (PST 4251), Materials Characterization Laboratory (SYP4352), Introduction to Nanophysics and Applications (SYT4355), Engineering Properties of Materials (SYT4352) | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| The hands-on experience gained by the students in the Applied Physics laboratory course will equip them with basic experimental skills related to measurement of various important physical quantities. These skills will act as a useful foundation for other laboratory and theory courses in their area of specialization. | | |
| | **Course Contents (List of Experiments)** | |
| 1. | Determination of Co-efficient of Viscosity by Poiseuille's method | 4 |
| 2. | Thermistor characteristics | 4 |
| 3. | Determination of compressibility of liquids using an ultrasonic interferometer | 4 |
| 4. | Durometer testing of given sample | 4 |
| 5. | Photoelectric effect: Determination of h/e | 4 |
| 6. | Hall effect- Determination of carrier type and concentration in a semiconductor | 4 |
| 7. | Newton's rings: Determination of wavelength of light | 4 |
| 8. | Study Laser Diffraction: using diffraction grating | 4 |
| 9. | Determine surface tension of liquid using capillary rise method | 4 |
| 10. | e/m ratio of electron by Thompson method | 4 |
| 11. | Study IV Characteristics of pn-junction diode | 4 |
| 12. | Study the transistor characterization in different mode | 4 |
| 13. | To determine of fermi energy of copper | 4 |
| 14. | Study of cathode ray oscilloscope (CRO) | 4 |
| 15. | Determine the RI of given liquid | 4 |
| | **Total** | **60** |
| **List of Textbooks/Reference books** | | |
| 1 | Fundamentals of Physics - Halliday, Resnick, Walker - 6th Edition - John Wiley | |
| 2 | Sears and Zeemansky's University Physics - Young and Freedman - Pearson Education | |
| 4 | Engineering Physics - V Rajendran - 6th Edition - McGraw Hill Publishers | |
| 5 | Concepts of Modern Physics - A. Beiser, McGraw-Hill. | |
| 6 | Ultrasonics: Methods and Applications - J. Blitz, Butterworth. | |
| 7 | Optics - Ajoy Ghatak - 7th Edition - McGraw Hill | |
| 8 | Fundamentals of Optics - F. Jenkins and H. White - 4th Edition McGraw Hill | |
| 9 | ICT Physics Laboratory Manual (supplied to students) | |
| **Course Outcomes (students will be able to….)** | | |
| | **Students will be able to** | |
| CO1 | Understand monochromatic light source and its applications. | K3 |
| CO2 | Understand engineering applications of lasers | K2 |
| CO3 | Measure thermal conductivity, photoelectric current, effect of magnetic field on electric current and its applications | K3 |
| CO4 | Analyze and estimate the experimental data | K5 |

| | | |
|---|---|---|
| CO5 | Evaluate the experimental value by analysing the experimental data | K5 |
| CO6 | Prepare and write the report | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Applied Physics Laboratory: PHP4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | - | 1 | - | - | - | - | 1 | - | - |
| CO2 | 3 | 1 | 2 | - | 1 | - | - | - | - | 1 | - | - |
| CO3 | 2 | 1 | 1 | 2 | 1 | - | - | - | - | - | - | - |
| CO4 | 3 | 1 | 1 | 2 | 1 | - | - | - | - | 1 | - | - |
| CO5 | 3 | 2 | 2 | - | - | - | - | - | - | - | - | - |
| CO6 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Applied Physics Laboratory: PHP4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 2 | 2 | 1 | - | - |
| CO3 | 2 | 3 | 2 | 2 | 1 |
| CO4 | 3 | 3 | 2 | 1 | 1 |
| CO5 | 3 | 2 | 1 | - | - |
| CO6 | 2 | 1 | 2 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code: EST4151** | **Course Title: Structural Mechanics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Engineering Mathematics (MAT4151); Materials in Engineering | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Process Equipment Design and Drawing (CEP4451); Material Technology | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This subject will help students to understand use of basics of Applied Mechanics and Strength of Materials. In engineering equipment and structures, which different types of forces are to be considered and how to quantify them? What are different conditions of equilibrium? How to apply equilibrium condition to analyse the problems? Importance of centre of gravity and moment of Inertia in Engineering Design. Advantages and disadvantages of various geometric sections available for engineering design. Study of different types of stresses and strains occurring in various components of the structure. Understanding and calculating Shear force and Bending moment in the beams with simple and complex loading. Determination of Bending stresses and shear stresses in the beams. Evaluation of slopes and deflections in the beams with simple and complex loading. This is the foundation course for a good Design Engineer. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Concepts of forces, their types, Resolution of forces, Composition of forces, Steps in Engineering Design, Different types supports and free body diagram. | | 3 | | |
| 2 | Equilibrium of rigid bodies - Conditions of equilibrium. Determinant and indeterminate structures. Equilibrium of beams, trusses, and frames problems on analysis of beams and truss. | | 5 | | |
| 3 | Concept of moment of Inertia (Second moment of area) its use. Parallel axis theorem. Problems of finding centroid and moment of Inertia of single figures, composite figures. Perpendicular axis theorem, Polar M.I., Radius of gyration. | | 4 | | |
| 4 | Shear Force and Bending Moment - Basic concept, S.F. and B.M. diagram for cantilever, simply supported beams (with or without overhang). Problems with concentrated and U.D. loads. | | 5 | | |
| 5 | Stresses and Strains - Tensile and compressive stresses, strains, modulus of elasticity, modulus of rigidity, bulk modulus. Relation between elastic constants. Lateral strain, Poisson's ratio, volumetric strain. Thermal stresses and strains. Problems based on stresses and strains. Stresses and Strains Relationship and Strain Deformation relationship. | | 4 | | |
| 6 | Theory of Bending - Assumptions in derivation of basic equation, Basic equation, section modulus, bending stress distribution. Advantages of various geometric sections from bending consideration. | | 3 | | |
| 7 | Problems on shear stress - Concept, Derivation of basic formula. Shear stress distribution for standard shapes. Problems of Shear stress distribution. Conditions under which shear stress is the governing criteria of design. | | 3 | | |
| 8 | Slope and Deflection of beams - Basic concept, Slope and Deflection of cantilever and simply supported beams under standard loading. Macaulay's method. Simple problems of finding slopes and deflections. | | 3 | | |
| | **Total** | | **30** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Engineering Mechanics Vol I Statics by B. N. Thadani, Publisher Wenall Book Corporation | | | | |
| 2 | Introduction to Mechanics of Solids by Egor Popov, Prentice Hall of India Pvt. Ltd | | | | |
| 3 | Mechanics of Materials by Ferdinand Beer and E. Russel Johnston, Tata McGraw Hill Publishing Co. Ltd. | | | | |
| 4 | Fundamentals of applied Mechanics by Dadhe, Jamdar and Walavalkar, Sarita Prakashan Pune | | | | |
| 5 | Engineering Mechanics by S. Timoshenko and D. H. Young, McGraw Hill Publications | | | | |
| 6 | Strength of Materials by Ferdinand Singer and Andrew Pytel, Harper Colins Publishers | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Understand the use of basic concepts of Resolution and composition of forces. | | K2 | | |
| CO2 | Analysis of the beams, truss or any engineering component by applying conditions of equilibrium. | | K2 | | |

| | | |
|---|---|---|
| CO3 | Understand the advantages and disadvantages of various geometric sections used in engineering design. | K2 |
| CO4 | Understand the different stresses and strains occurring in components of structure various standard loadings and in case of any complicated loading. | K2 |
| CO5 | Determination of shear stress, bending stresses in the beams with simple and complex loading. | K4 |
| CO6 | Understand how to calculate the deformations such as axial, normal deflections under different loading conditions. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Structural Mechanics: EST4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 2 | 1 | 2 | - | - | - | 1 | - | - |
| CO2 | 3 | 2 | 1 | - | 1 | 1 | - | - | - | - | - | - |
| CO3 | 2 | 1 | 2 | 1 | - | 1 | - | - | - | 1 | - | - |
| CO4 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | - | - | 1 | - | - |
| CO5 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | - | - | 2 | - | - |
| CO6 | 2 | 1 | - | 1 | 1 | 1 | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Structural Mechanics: EST4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 3 | 2 | 1 | - | - |
| CO3 | 3 | 2 | 2 | 1 | - |
| CO4 | 3 | 2 | 1 | 2 | - |
| CO5 | 1 | 2 | 2 | 3 | 1 |
| CO6 | 2 | 2 | - | 3 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code: ESP4151** | **Course Title: Structural Mechanics Laboratory** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **0** | **0** | **2** |
| **List of Prerequisite Courses** | | | | | |
| | XIIth Standard Physics, Mathematics, Applied Mathematics I and II (MAT4151-52), Structural Mechanics (EST4151) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Equipment design and Drawing I and II (CEP4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This subject will help students to understand the basics of Applied Mechanics and Strength of Materials. In engineering equipment different types of forces are to be considered and how to quantify them. What are different conditions of equilibrium and how to apply them analyze the problems. Importance of center of gravity and moment of Inertia in Engineering Design. Study of different types of stresses and strains occurring in various components of the structure. Advantages and disadvantages of various geometric sections available for engineering design. This is the foundation course for a good Design Engineer. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | **Suitable number of experiments from the above list will be performed (Minimum 5):** | | 4 | | |
| 2 | To study simple lifting machine and determine Law of Machine for (Screw Jack and Differential wheel and axle). | | 4 | | |
| 3 | To study graphical methods of analysis. | | 4 | | |
| 4 | To study the Universal testing machine and tests. (Demonstration) | | 4 | | |
| 5 | To study Non-destructive testing methods in Engineering | | 4 | | |
| 6 | Demonstration of Smith Hammer test, Ultrasonic pulse velocity test | | 4 | | |
| 7 | To study corrosion of reinforcement. (Demonstration) | | 6 | | |
| 8 | To study properties of cement composites and its applications. | | 6 | | |
| 9 | To study effect of performance enhancing admixtures and additives for cement composites. | | 4 | | |
| 10 | To study methods of manufacturing for Fiber Reinforced Polymer Composites | | 6 | | |
| 11 | To study various materials used for flooring. | | 6 | | |
| 12 | To study various materials used for Pipes for different engineering applications. | | 4 | | |
| | **Total** | | **60** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Engineering Mechanics Vol I Statics by B. N. Thadani, Publisher Wenall Book Corporation | | | | |
| 2 | Introduction to Mechanics of Solids by Egor Popov, Prentice Hall of India Pvt. Ltd | | | | |
| 3 | Mechanics of Materials by Ferdinand Beer and E. Russel Johnston, Tata McGraw Hill | | | | |
| 4 | Fundamentals of applied Mechanics by Dadhe, Jamdar and Walavalkar, Sarita Prakashan Pune | | | | |
| 5 | Engineering Mechanics by S. Timoshenko and D. H. Young, McGraw Hill Publications | | | | |
| 6 | Strength of Materials by Ferdinand Singer and Andrew Pytel, Harper Colins Publishers | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Further understanding of the concepts in the Theory course of Structural Mechanics | | K2 | | |
| CO2 | Understand structural mechanics principles | | K3 | | |
| CO3 | Measure stress, strain, testing, reinforcement and its applications | | K4 | | |
| CO4 | Analyze and estimate the experimental data | | K4 | | |
| CO5 | Evaluate the experimental value by analyzing the experimental data | | K5 | | |
| CO6 | Prepare and write the report | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Structural Mechanics Laboratory: ESP4151<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 1 | - | - | - | - | - | - | 1 | - | - |
| CO2 | 3 | 1 | 2 | - | 1 | - | - | - | - | 1 | - | - |
| CO3 | 2 | 1 | 1 | 2 | 1 | - | - | - | - | - | - | - |
| CO4 | 3 | 1 | 1 | 2 | 1 | - | - | - | - | 1 | - | - |
| CO5 | 3 | 2 | 2 | - | - | - | - | - | - | - | - | - |
| CO6 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Structural Mechanics Laboratory: ESP4151<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 1 | 1 | - |
| CO2 | 3 | 2 | 1 | 1 | - |
| CO3 | 2 | 3 | 2 | 2 | 1 |
| CO4 | 3 | 3 | 2 | 1 | 1 |
| CO5 | 3 | 2 | 1 | - | - |
| CO6 | 2 | 1 | 2 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **VSEC** | **Course Code: ESP4152** | **Course Title: Engineering Graphics and Computer Aided Drafting (CAD)** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **0** | **0** | **4** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Basic Geometry | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Engineering Graphics: II (ESP4152), Equipment Design and Drawing (CEP4451), Structural Mechanics (EST4151) | |

**Description of relevance of this course in the Int. M. Tech. Program**

A student of Chemical Engineering is required to know the various processes and the equipment used to carry out the processes. Some of the elementary processes like filtration, size reduction, evaporation, condensation, crystallization etc., are common to all engineers and technologists. These and many other processes require machines and equipment. One should be familiar with the design, manufacturing, working, and maintenance of such machines and equipment. The subject of "drawing" is a medium through which one can learn all such matters, because the "drawings" are used to represent objects and processes on paper. Through the drawings, a lot of accurate information is conveyed which will not be practicable through a spoken word or a written text. Drawing is a language used by engineers and technologists. This course is required in many subjects as well as later in the professional career.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | **Orthographic projections:**<br>Basics of Engineering drawing, Different lines in the drawing and their applications, Methods of projection, Different planes of projection, first and third angle of projections of drawing, four quadrants and concept of orthographic projections. | 12 |
| 2 | **Sectional views and Missing views:**<br>Need for the drawing sectional views, concept of sectioning and section lines, sectional drawings of different solids and machine components, auxiliary planes, and views.<br>Concept of recognizing missing views and their interpretation, drawing of missing views from given orthographic drawings. | 08 |
| 3 | **Projections, Sections, Development of surfaces and Interpenetration of solids:**<br>Introduction to basic shapes of Solids, Projections of Solids in different planes as per the given conditions, Sectional planes for cutting solids and respective drawings,<br>Concept of surface development of respective solids, Development of surfaces of cylinders, prisms, pyramids, cones etc.<br>Interpenetration of two or more solids and their respective drawings | 12 |
| 4 | **Introduction to Computer Aided Drafting (CAD):**<br>Basic introduction to CAD software, 2D and 3D drawings, drawing modification and dimensioning, different components of an engineering drawing in the industry. | 08 |
| 5 | **Isometric projections using CAD:**<br>Concept of isometric views, isometric projections and isometric scale, Iso metric projections of different solids and machine components using CAD software. | 08 |
| 6 | **Assembly drawing using CAD:**<br>Basics of Assembly drawing, preparation of 3d components and assembling on CAD software, labelling and table creation for bill of materials | 12 |
| | **Total** | **60** |

| List of Textbooks/ Reference Books | |
|---|---|
| 1 | Engineering Drawing by N.D.Bhat |
| 2 | Engineering Drawing by N.H.Dubey |
| 3 | CAD/CAM: Theory and Practice by Ibrahim Zeid and R Sivasubramanian |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Students will be able to read Drawing | K2 |
| CO2 | Can understand Different drawing views and its interpretation. | K2 |

| | | |
|---|---|---|
| CO3 | Can draw 3d drawing on a CAD software | K3 |
| CO4 | Assembly of different machine parts and its working. | K3 |
| CO5 | Estimate and evaluate the computer data with modeling | K5 |
| CO6 | Create the file and data reporting | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Engineering Graphics and Computer Aided Drafting (CAD): ESP4152**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | - | 2 | 1 | 2 | - | - | - | - | - | 1 | 1 |
| CO2 | 2 | 1 | 1 | 2 | 1 | - | - | - | - | 1 | 1 | 1 |
| CO3 | 2 | 1 | 1 | 1 | 1 | - | 1 | - | - | - | 2 | 1 |
| CO4 | 1 | - | 1 | 1 | 2 | - | - | - | - | - | 1 | - |
| CO5 | 2 | 1 | 1 | 1 | 2 | - | 1 | - | - | 1 | 1 | 1 |
| CO6 | 3 | 1 | 2 | 2 | 1 | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Engineering Graphics and Computer Aided Drafting (CAD): ESP4152**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 3 | 2 | 1 | - | - |
| CO3 | 2 | 1 | - | 2 | 1 |
| CO4 | 2 | 1 | 2 | 3 | 1 |
| CO5 | 3 | 2 | 1 | 2 | 1 |
| CO6 | 3 | 2 | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **AEC** | **Course Code: HUP4151** | **Course Title: Communication Skills - English** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 30** | **0** | **0** | **4** |
| **List of Prerequisite Courses** | | | | | |
| | Basic English Language of the XII Grade Level | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This is an important course for the effective functioning of an Engineer. Communication skills are required in all courses. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Communication as a way of life<br>Process of communication and its elements<br>Functions of communication and importance in future careers<br>Essentials of good communication | | 6 | | |
| 2 | The communication cycle -<br>The 5-step communication cycle:<br>Idea formation<br>Message encoding.<br>Message transmission.<br>Decoding<br>Feedback | | 4 | | |
| 3 | Factors affecting effective communication.<br>Planning for effective communication<br>Modes of communication | | 3 | | |
| 4 | Non-verbal communication<br>Gestures<br>Facial expressions<br>Posture and movement.<br>Paralinguistics<br>Eye contact<br>Image management | | 4 | | |
| 5 | Presentation skills<br>What makes good presentation?<br>Presenting the message<br>Presenting oneself<br>Visual Communication | | 8 | | |
| 6 | Introduction to research study<br>Introduction to databases<br>Introduction to citation and referencing styles.<br>How to conduct literature review<br>Preparation of a report based on literature review | | 5 | | |
| | **Total** | | **30** | | |
| **List of Text Books** | | | | | |
| 1 | THE SCIENCE OF EFFECTIVE COMMUNICATION: Improve Your Social Skills and Small Talk, Develop Charisma and Learn How to Talk to Anyone- Ian Tuhovsky | | | | |
| 2 | The Quick and Easy Way to Effective Speaking- Dale Carnegie | | | | |
| **List of Additional Reading Material / Reference Books** | | | | | |
| 1 | The Hindu Businessline | | | | |
| 2 | National Newspapers' editorials | | | | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Student would be able to illustrate the 5-step communication process | K2 |
| CO2 | Student would be able to explain the end goal of communication | K2 |
| CO3 | Student would be able to explain barriers to clear communication | K2 |
| CO4 | Student would be able to articulate the role of visual communication within society and implement the creative process to express himself/herself. | K3 |
| CO5 | Student would be able to identify the most relevant textbooks, reviews, papers and journals | K4 |
| CO6 | Reporting and communicate the idea and thoughts | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Communication Skills - English: HUP4151**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | 3 | 1 | 1 | - | - | - | - | 2 | - | - |
| CO2 | - | - | 2 | 1 | - | - | - | - | - | 2 | 1 | - |
| CO3 | - | - | 3 | 1 | 1 | 1 | - | - | - | 2 | - | - |
| CO4 | - | - | 2 | 1 | 2 | 2 | - | - | - | 3 | - | - |
| CO5 | - | - | 2 | 1 | 1 | 1 | - | - | - | 3 | 1 | - |
| CO6 | - | - | 2 | 1 | 1 | 1 | - | - | - | 3 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Communication Skills - English: HUP4151**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 2 | 2 | 3 | - | - |
| CO3 | 2 | 3 | 3 | - | - |
| CO4 | 2 | 2 | 3 | 1 | - |
| CO5 | - | 2 | 3 | 2 | - |
| CO6 | 2 | 2 | 3 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| CCA | Course Code: HUP4152 | Course Title: OPEN Activity - Sports - I | Credits = 2 | | |
| | | | L | T | P |
| | Semester: I | Total contact hours: 60 | 0 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Students with Science 12th level preferable with Sports Background | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Not Applicable | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course aims to improve knowledge, skills, and different health practices related to selected sports disciplines and promote Health and wellness through Healthy Lifestyle.

**Evaluation of the students**
1. Minimum 80 % attendance is required. 50% marks will be given to regular attendance.
2. Evaluation through Skill Test/ Practical Record File: 50%.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1. | **Playfield Technology** – Marking and Construction of the playfields in the selected sports discipline | 2 |
| 2. | Rules and their interpretation in the selected sports discipline | 2 |
| 3. | **Basic Fitness, Training, and Assessment**<br>• General and specific warm-up and limbering down related to sport<br>• Training for Health-related fitness - Muscular Endurance, Muscular Strength, Flexibility, Body Composition. | 2 Hrs./Week |
| 4. | **Kabaddi/Badminton/Volleyball:** Basic skills/practices | 2 Hrs./Week |
| 5 | **Regular Practice** | 2 Hrs./Week |
| | **Total** | **60** |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | To understand the basic training and practices required in the selected sports discipline. | K2 |
| CO2 | To know the basic specifications of court/ground, and general rules and demonstrate the basic skills in the selected sports discipline. | K2 |
| CO3 | To develop a set of core skills in the selected sports discipline for overall growth and development | K3 |
| CO4 | To create a foundation for professionals in the selected sports discipline. | K3 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**OPEN Activity - Sports - I: HUP4152**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | - | - | - | - | - | 1 | 2 | - | - | - |
| CO2 | - | - | - | - | - | - | - | 1 | 3 | - | - | - |
| CO3 | - | - | - | - | - | - | - | 1 | 2 | - | - | - |
| CO4 | - | - | - | - | - | - | - | 1 | 3 | - | - | - |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

**OPEN Activity - Sports - I: HUP4152**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |

| | | | | | |
|---|---|---|---|---|---|
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| **CCA** | **Course Code:** **HUP4155** | **Course Title:** **OPEN Activity - Fine arts - I** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: I** | **Total contact hours: 60** | **0** | **0** | **4** |
| **List of Prerequisite Courses** | | | | | |
| | Basic Drawing Course, Primary Extracurricular Activities course | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Cultivation of arts is an integral part of the development of human beings since the arts are what make us most human, most complete as people. They offer us the experience of wholeness because they touch us at the deepest levels of mind and personality. They come into being not when we move beyond necessity but when we move to a deeper necessity, to the deeper human need to create order, beauty and meaning out of chaos. They are the expressions of deepest human urges, imperatives and aspirations | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | The Institute offers a range of courses in different art forms: music, dance, theatre, painting, and other art forms.<br>Students will be given an option to choose a particular art form and learn and practice it under an artist-instructor. At the end of the course, a student should be able to demonstrate basic proficiency in that particular art form. | | 60 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Gardner's Art Through the Ages: A Global History. (13th Ed.), ed. F.S. Kleiner, Ref. N5300. G25 2011 vol. 1-2 | | | | |
| 2 | The Grove Encyclopedia of Classical Art and Architecture. ed. Gordon Campbell. Ref. N5610. G76 2007 vol. 1-2 | | | | |
| 3 | Art and Music: A Student's Guide (Reclaiming the Christian Intellectual Tradition) | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Enhance perceptual and cognitive skills | | K3 | | |
| CO2 | Develop self-esteem, motivation, aesthetic awareness, cultural exposure | | K3 | | |
| CO3 | Be creative with improved emotional expression | | K3 | | |
| CO4 | Develop social harmony and appreciation of diversity. | | K3 | | |
| CO5 | Develop an understanding and sharing of culture, with social skills that enhance the awareness and respect of others | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **OPEN Activity - Fine arts - I: HUP4155**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | - | - | 1 | - | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| CO2 | - | - | 1 | - | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| CO3 | - | - | 1 | - | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| CO4 | - | - | 2 | - | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |
| CO5 | - | - | 2 | - | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| OPEN Activity - Fine arts - I: HUP4155<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| CO5 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester I | | | | | |
|---|---|---|---|---|---|
| CCA | Course Code: HUP4159 | Course Title: OPEN Activity - Yoga - I | Credits = 2 | | |
| | | | L | T | P |
| | Semester: I | Total contact hours: 60 | 0 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | It may be necessary to gather some basic information about the students, such as their age, marital status, academic schedules, and recreational activities, whether they have any sleep issues and stress because of any situation. It shall be better to know how the students deal with stress, and whether they have proper nutrition. We also might need information about any injuries past or current and any other medical condition that may interfere in the program. | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Applicable throughout professional and personal lives | |

**Description of relevance of this course in the Int. M. Tech. Program**

Yoga is not course but a journey. The benefits of Yoga are many. It brings in calmness of mind besides the physical fitness by doing Yoga Aasanas. Apart from flexibility developed by regular physical activities, it makes one aware of his own potential. Professional and personal lives are full of situations that can be stressful. Yoga helps the students to withstand the stress coming from the expectations and demands of their own lives.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | **Yoga**<br>The principles and foundations of yoga. Both concentrative and insight meditation techniques may be practiced for each session. Behavioural techniques of self-monitoring should also be practiced observing the stream of consciousness from the perspective of a vigilant but detached observer.<br>The students shall be trained to practice different models of mindfulness and meditation so as to elicit a state of deep physical and behavioural relaxation. They may work on selectively influencing or changing the symmetry in hemispheric brain activity. Positive addiction, meta-cognitive practices etc. are exercised to make the students experience the universal human capacity through spiritual experiences. The students may learn to turn-off or bypass the cognitive processing of usual daily preoccupations and concerns, allowing access to mindful, spiritual and meditative state of self-realization<br>The students shall keep a small journal to write down their own journey/progress on physical flexibility, strength building and most importantly, how they deal with stressful conditions. This record will form the paper assessment of the student.<br>Yoga helps to develop many mental skills like mindfulness, self-control, focus, and even self-compassion. It's mainly a physical practice. The students are taken through different movements and poses during the yoga sessions. | 40 |
| 2 | **Assessment:** The following assessments are recommended:<br>Regular attendance<br>**Paper Assessment:** A paper assessment may include assessing student's understanding of the basic philosophy of yoga<br>Verbal Assessment on the basis of his/her ability to assimilate the philosophy of yoga and practicing in daily life.<br>Mobility & Flexibility assessment is to assess the strength and flexibility, like twist. | 20 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Yoga Sutra of Patanjali, Ramakrishna Mission, Kolkata | |
| 2 | RN Jha, Science of Consciousness Psychotherapy and Yoga Practices, Vidyanidhi Prakashan, Delhi 2016 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Keep physically fit and mentally agile | K2 |
| CO2 | Manage stress in studies and later in life | K2 |
| CO3 | Coordinate body and mind together | K2 |
| CO4 | Understand own emotions and maintain healthy daily routine | K2 |

| | | |
|---|---|---|
| CO5 | Understand and apply the importance of Yoga and Self-development in personal life | K3 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**OPEN Activity - Yoga - I: HUP4159**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 1 | 2 | - | 1 | - | 1 | 2 | 2 | 1 | - | 2 |
| CO2 | - | 1 | 2 | - | 1 | - | 1 | 2 | 2 | 1 | - | 2 |
| CO3 | - | 1 | 2 | - | 1 | - | 1 | 2 | 2 | 1 | - | 2 |
| CO4 | - | 1 | 2 | - | 1 | - | 1 | 2 | 2 | 1 | - | 2 |
| CO5 | - | 2 | 2 | - | 1 | - | 2 | 2 | 3 | 2 | - | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**OPEN Activity - Yoga - I: HUP4159**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| CO5 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# First Year

# Semester-II

| Semester II | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: CHT4152** | **Course Title: Applied Chemistry II** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Standard XII Chemistry, Applied Chemistry (CHT4151) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Material and Energy Balance Calculations (CEP4151), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Operation (CET4251), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451), Biochemical Engineering (Hon.), Catalytic Science and Engineering (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| To train the students about reaction kinetics, thermodynamics, electrochemistry, interfacial chemistry and catalysis, beyond +2 level. The course will enable the students to understand and apply the principles of thermodynamics, kinetics, electrochemistry, interfacial chemistry and catalysis for engineering applications. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | **Chemical Kinetics:** Review of rate of reaction, rate constant, effects of the following on rate of reaction: concentration, temperature. Derivation of rate expression for Second order reactions, Complex reactions: parallel, consecutive, reversible reaction. | | **8** | | |
| 2 | **Thermodynamics:**<br>a) Enthalpy and heat capacities, first law of thermodynamics and application, thermochemistry Hess lab<br>b) 2nd law of thermodynamics, Clausius inequality, entropy as a state function, entropy, entropy changes for reversible and irreversible processes, free energy, Gibbs Helmholtz equation, Maxwell's relations, effect of T and P on free energy | | **8** | | |
| 3 | **Surfaces and interfaces:** Surface/interfacial energy and surface/ interfacial tension. Measurement of surface tension, Contact angle, its measurement, adhesion, cohesion and wetting phenomena, adsorption. | | **3** | | |
| 4 | **Catalysis:** Homogeneous catalysis (specific and general acid catalysis), Heterogeneous catalysis, Kinetics of reactions on solid surfaces, Enzyme catalysis (Michelis Menten kinetics). | | **3** | | |
| 5 | **Electrochemistry:** Ionic Conductance, Ion mobility, Transport number, Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Ion atmosphere: asymmetric effect, relaxation effect, and electrophoretic effect, Wien effect, Debye Falkenhagen effect; Debye-Huckel limiting law-brief qualitative description. Application of conductance measurement, Conductometric titrations, Walden's rule., Basic concept of cell and cell contraction. | | **8** | | |
| | **Total** | | **30** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Physical Chemistry, Atkins, Peter W.; Paula, Julio de; Keeler, James. Oxford University Press. | | | | |
| 2 | Physical Chemistry, K.J. Laidler and J.M. Meiser, CBS Publishers | | | | |
| 3 | A Textbook of Physical Chemistry, K L Kapoor, McGraw Hill Education | | | | |
| 4 | Physical Chemistry by G.W Castellan, Narosa | | | | |
| 5 | Physical Chemistry by P. C. Rakshit, Sarat Book House | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Understand the kinetics, write rate expressions and predict mechanism of simple reactions based on kinetics. | | K3 | | |
| CO2 | Understand and remember the law of thermodynamics, apply the concept for engineering applications. | | K3 | | |
| CO3 | Understand and differentiate the surface and interfacial phenomena and determination of surface tension of some unknow solutions. | | K4 | | |
| CO4 | Understand electrochemical phenomena and application of analytical methods based on them. | | K4 | | |

| | | |
|---|---|---|
| CO5 | Learn the principles, kinetics, design, and applications of catalysis. | K4 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Applied Chemistry II: CHT4152**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 1 | 3 | 1 | - | 1 | 1 | 3 | - |
| CO2 | 3 | 1 | 1 | 1 | 1 | 3 | - | 1 | 1 | 1 | 2 | 3 |
| CO3 | 3 | 3 | 1 | - | 2 | 3 | 1 | 3 | 3 | 2 | - | 2 |
| CO4 | 2 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| CO5 | 3 | 3 | 1 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Applied Chemistry II: CHT4152**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 1 |
| CO2 | 3 | 1 | 1 | 1 | 1 |
| CO3 | 3 | 3 | 1 | 2 | 2 |
| CO4 | 2 | 3 | 1 | 1 | 2 |
| CO5 | 3 | 3 | 1 | 2 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **BSC** | **Course Code: MAT4152** | **Course Title: Mathematics: II** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 60** | **4** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | HSC Standard Mathematics, Applied Mathematics: I (MAT4151) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Material balance and Energy Balance Calculation (CEP4151), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Process Simulation Lab - I and II (CEP4255 and CEP4256), Chemical Process Control (CET4354), Separation Processes + Membrane (CET4356), Heat Transfer Equipment design (CET4357), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Statistical Thermodynamics (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This is a basic Mathematics course. This knowledge will be required in almost all subjects later on. This knowledge is required for solving various mathematical equations that need to be solved in several chemical engineering courses such as MEBC, momentum transfer, reaction engineering, separation processes, thermodynamics, etc. | | | | | |
| | **Course Contents (Topics and subtopics)** | | | | **Hours** |
| 1 | **Probability Theory and Sampling Distribution:** Review of probability, Random variables and cumulative distribution function; probability mass function and probability density function; Some common univariate distributions: Binomial, Poisson, Geometric and Uniform, exponential, Normal, Gamma, beta etc; Expectation and Moments (central and raw moments); Generating functions: moment generating function and characteristic function; Multiple random variables and Joint distribution; marginal distributions, independence; Covariance and Correlation; method of least squares and simple linear regression; nonlinear regression | | | | 15 |
| 2 | **Partial Differential Equations**: Introduction to Partial Differential Equations (PDE), Classification of higher order PDEs, Solution of PDEs using separation of variable techniques | | | | 10 |
| 3 | **Numerical Solution of System of Linear Equations:** Solutions of system of linear equations (Gauss-elimination, LU-decomposition etc.), Numerical solution set of linear algebraic equations: Jacobi, Gauss Siedel, and under / over relaxation method | | | | 5 |
| 4 | **Numerical Roots:** Numerical methods for solving non-linear algebraic / transcendental etc.: Newton's method, Secant and Regula Falsi | | | | 6 |
| 5 | **Interpolations:** Interpolation and extrapolation for equal and non-equal spaced data (Newtons Forward, Newtons backward and Lagrange), Numerical integration (trapezoidal rule, Simpson's Rule) | | | | 6 |
| 6 | **Numerical Solution IVP:** Numerical methods for solution of first and higher order ODEs (initial values and boundary value problems) using single step methods (RK, Euler's explicit and implicit methods), multi-step methods (predictor: corrector methods etc.) | | | | 8 |
| 7 | **Numerical Solutions of BVP and PDE:** Finite difference methods: Forward difference, Backward difference, and Central differences application of finite difference methods to Boundary value problem in ODE and PDE (parabolic, elliptic and hyperbolic) | | | | 10 |
| | **Total** | | | | **60** |
| **List of Textbooks / Reference Books** | | | | | |
| 1 | A First Course in Probability, Sheldon Ross, Pearson Prentice Hall, 9th Edition (2018) | | | | |
| 2 | W.W. Hines, D. C. Montgomery, D.M. Goldsman, John-Wiley, Probability and Statistics in Engineering, John Wiley & Sons (2008) | | | | |
| 3 | Alexander M. Mood, Duane C. Boes, and Franklin A. Graybill, Introduction to the Theory of Statistics, McGraw Hill; 3rd edition (1974). | | | | |
| 4 | An Introduction to Statistics with Python with Applications in the Life Sciences by Thomas Haslwanter, 2016, Springer | | | | |
| 5 | E. Kreyszig, Advanced Engineering Mathematics, 8th Ed., John Wiley (1999). | | | | |

| | | |
|---|---|---|
| 6 | S. R. K. Iyengar, R. K. Jain, Advanced Engineering Mathematics, Narosa | |
| 7 | Learning Statistics with R by Daniel Joseph Navarro, 2015 | |
| 8 | Sastry S. S., Introductory Methods of Numerical Analysis, 5th Ed., PHI (20120 | |
| 9 | M. K. Jain, S R K Iyengar and R K Jain, Numerical Methods: For Scientific and Engineering Computation, New Age International Publication (2003) | |
| 10 | Kenneth J Beers Numerical Methods for Chemical Engineering Application Using MATLAB (2007), Cambridge University Press | |
| 11 | Mark E. Davis, Numerical Methods and Modelling for Chemical Engineers, Dover Publications (2003) | |
| 12 | Sandip Mazumder, Numerical Methods for Partial Differential Equations (2015), Elsevier | |
| **Course Outcomes (students will be able to….)** | | |
| CO1 | Understand the concepts of various probability distributions and apply them to analyse various engineering problems and make inference about the system | K4 |
| CO2 | Understand the method of linear and nonlinear least squares method and apply it to choose appropriate mathematical functions for modelling real data sets, arising from chemical engineering applications | K4 |
| CO3 | classify higher of partial differential equation and solve parabolic equation using separation of variables. | K3 |
| CO4 | Understand the principles of various numerical approximation techniques and apply them to solve system of linear equations and nonlinear algebraic equations | K4 |
| CO5 | Approximate appropriate mathematical functions from equal an unequally spaced data and perform integration using various numerical methods | K4 |
| CO6 | Choose appropriate numerical techniques to solve initial and boundary value problems on ordinary and partial differential equations arising from various chemical engineering applications | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analysing, K5: Evaluating, K6: Creating | | |

**Mathematics - II: MAT4152**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | 2 | 1 | - | - | - | - | 1 | - |
| CO2 | 3 | 2 | 2 | - | 1 | 2 | - | - | - | - | 1 | 1 |
| CO3 | 3 | 2 | 1 | 1 | 2 | - | - | - | - | - | - | 1 |
| CO4 | 3 | 1 | - | 2 | 1 | - | - | - | - | - | 1 | - |
| CO5 | 2 | 3 | 1 | 2 | 1 | - | - | - | - | - | - | - |
| CO6 | 2 | 1 | 1 | 1 | - | 1 | - | - | - | - | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Mathematics - II: MAT4152**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 3 | 2 | 2 | - |
| CO2 | 2 | 2 | 2 | 1 | - |
| CO3 | 2 | 2 | 3 | 1 | - |
| CO4 | 1 | 2 | 2 | - | - |
| CO5 | 3 | 3 | 2 | 1 | 1 |
| CO6 | 2 | 3 | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code: EST4153** | **Course Title: Electrical Engineering and Basic Electronics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | XIIth Standard Physics and Mathematics courses, Applied Physics: II (PHT4151) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Process Control (CET4354), Chemical Engineering Laboratory (CEP4251), Energy lab-II | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Students will get an insight to the importance of Electrical Energy in Chemical Plants. The students will understand the basics of electricity, changing the voltage levels to match with the appliances through transformers. Students will acquire knowledge on the number systems and different logic gates with the fundamentals of digital electronics. They will get basic knowledge as regards to thyristor application in industries. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | **DC Circuits**: Circuit Components, Ohm's Law - Kirchhoff's Laws –Independent and Dependent Sources – Voltage divider rule and Current divider rule - Nodal Analysis, Mesh analysis with independent sources. | | 4 | | |
| 2 | **AC Circuits**: Average value, RMS Value, form factor and peak factor. A.C. through resistance, inductance and capacitance. Instantaneous power, real power, reactive power and apparent power, power factor. | | 4 | | |
| 3 | **Single Phase Transformers**: Necessity of transformer, Principle of operation, Types and construction of transformers, EMF equation, losses, definition of regulation and efficiency. | | 3 | | |
| 4 | **Digital Electronics**: Number system and codes: Binary, octal, hexadecimal and decimal Number systems and then inter conversion.<br>**Basic Logic gates:** AND, OR, NOT, NAND, NOR, Ex-OR, Ex-NOR and their truth tables. | | 3 | | |
| 5 | **Power Electronics devices**-Thyristor: Construction and Static I-V characteristics of Thyristors, Applications. | | 2 | | |
| | **Total** | | **30** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Edward Hughe "Electrical and Electronic Technology", 10th Edition, Pearson Education Asia, 2019. | | | | |
| 2 | Kothari DP and I.J Nagrath, "Basic Electrical and Electronics Engineering", Second Edition, McGraw Hill Education, 2020 | | | | |
| 3 | Chapman, "Electric Machinery Fundamentals", McGraw-Hill Higher Education. | | | | |
| 4 | William H. Gothmann, "Digital Electronics", second edition, PHI publishers. | | | | |
| 5 | M.D. Singh, K B Khanchandani, 'Power Electronics', second edition, TATA McGraw Hill. | | | | |
| 6 | Electronic devices and circuits by Boylstead, Nashelsky | | | | |
| 7 | Principles of Electronics by V.K.Mehta and Rohit Mehta | | | | |
| 8 | Electrical Technology by B.L.Theraja, A.K.Theraja Vol I,II,IV | | | | |
| 9 | A Anand Kumar, "Fundamentals of Digital Circuits", fourth edition, PHI publishers. | | | | |
| **Course Outcomes (students will be able to….)** | | | | | |
| CO1 | Apply the concept of D.C. electrical circuit to Solve the basic electrical circuits. | | K3 | | |
| CO2 | Apply the concept of A.C. electrical circuit to Solve the basic electrical circuits. | | K3 | | |
| CO3 | Understand the transformer working principle and its basic concepts. | | K3 | | |
| CO4 | Understand the concept of number systems and logic gates in digital electronics. | | K3 | | |
| CO5 | Apply the power electronics devices for industrial applications. | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Electrical Engineering and Basic Electronics: EST4153<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 1 | 1 | - | - | - | - | - | 1 | 1 | - |
| CO2 | 3 | 3 | 3 | 2 | 1 | - | - | - | 1 | 1 | - | - |
| CO3 | 3 | 1 | 2 | - | - | - | - | - | - | - | 1 | - |
| CO4 | 3 | 1 | 1 | 1 | 2 | 2 | - | - | - | 1 | 1 | - |
| CO5 | 3 | 2 | 3 | 2 | 1 | - | - | - | - | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Electrical Engineering and Basic Electronics: EST4153<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 3 | 2 | 2 | - |
| CO2 | 2 | 2 | 2 | 2 | - |
| CO3 | 2 | 3 | 2 | 1 | 1 |
| CO4 | 2 | 2 | 1 | - | - |
| CO5 | 3 | 2 | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code: ESP4153** | **Course Title: Electrical Engineering and Basic Electronics Laboratory** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 60** | **0** | **0** | **4** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | XIIth Standard Mathematics and Physics courses, Applied Physics I (PHT4151), Electrical Engineering and Electronics (EST4153) | |
| **List of Courses where this course will be prerequisite** | | |
| | Chemical Process Control (CET4354) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Students will get an insight into the importance of Electrical Energy in Chemical Plants. The students will understand the basics of electricity, and the selection of diverse types of drives for a given application process. They will get basic knowledge as regards to Power supplies, instrumentation amplifiers and thyristor application in industries.

| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
|---|---|---|
| 1 | **Electrical Engineering Experiments** | |
| | 1. To verify KCL and KVL | 4 |
| | 2. To verify Thevenin's theorem. | 4 |
| | 3. To verify Superposition theorem | 4 |
| | 4. To measure three phase power by using two wattmeter method | 3 |
| | 5. Study of RLC circuits | 3 |
| | 6. Load test on transformer | 3 |
| | 7. Load test on induction motor | 3 |
| | 8. Study of 3 phase circuits with Star connected load | 3 |
| | 9. Study of 3 phase circuits with Delta connected load | 3 |
| 2 | **Electronics Engineering Experiments** | |
| | 1. Study of C.R.O. and its applications. | 5 |
| | 2. Measurement of Earth resistance | 5 |
| | 3. Study of half wave, full wave and bridge rectifier circuits | 5 |
| | 4. Study of input and output characteristics of a transistor. | 5 |
| | 5. Study of operational amplifier circuits. | 5 |
| | 6. Basic Logic Gates (NOT, OR, AND, NOR, NAND): Characteristics Trainer | 5 |
| | **Total** | **60** |

| **List of Textbooks/ Reference Books** | | |
|---|---|---|
| 1 | Electrical Engineering Fundamentals by Vincent Deltoro | |
| 2 | Electronic devices and circuits by Boylstead, Nashelsky | |
| 3 | Electrical Machines by Nagrath, Kothari | |
| 4 | Electrical Machines by P.S. Bhimbra | |
| 5 | Electrical Technology by B. L. Theraja, A. K. Theraja vol I, II, IV | |

| **Course Outcomes (students will be able to…..)** | | |
|---|---|---|
| CO1 | Understand the basic concepts of D.C., single phase and three phase AC supply and circuits Solve basic electrical circuit problems | K2 |
| CO2 | Understand the basic concepts of transformers and motors used as various industrial drives. | K2 |
| CO3 | Understand the basic concepts of electronic devices and their applications in power supplies, amplification, and instrumentation | K2 |
| CO4 | Understand the basic concepts of Data acquisition, signal conditioning | K2 |
| CO5 | Estimating and evaluate the data | K5 |
| CO6 | Prepare the report and create the idea and thoughts | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Electrical Engineering and Basic Electronics Laboratory: ESP4153<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 1 | 1 | - | 1 | 1 | - | - | 1 | 1 | - |
| CO2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | - | - | - | 1 | - |
| CO3 | 1 | 2 | 1 | 1 | 1 | 1 | - | - | - | 1 | - | - |
| CO4 | 3 | - | - | 1 | - | - | 2 | - | - | - | - | - |
| CO5 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | - | - |
| CO6 | 2 | 1 | 2 | 1 | - | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Electrical Engineering and Basic Electronics Laboratory: ESP4153<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 1 | 2 | 1 | - |
| CO2 | 2 | 2 | 3 | 2 | - |
| CO3 | 2 | 1 | 1 | 1 | - |
| CO4 | 1 | 2 | 1 | 2 | - |
| CO5 | 2 | 1 | 1 | 1 | - |
| CO6 | 2 | 1 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code:** **EST4152** | **Course Title:** **Mechanical Engineering** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Physics (PHT4151), Applied Mathematics: I and II (MAT4151 and MAT4152) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Engineering Thermodynamics-I (CET4155), Material and Energy Balance Calculations (CEP4151), Chemical Process Design and Engineering (CEP4451), Process Safety (CET4255) Chemical Project Engineering and Economics (CET4358) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Students will be able to understand various equipment's like steam turbine, gas turbine, pumps, compressors, and power transmission system. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Introduction to Thermodynamics, First and Second law of thermodynamics. | | 4 | | |
| 2 | Properties of steam, T-S Diagram, Calculation of entropy, enthalpy, specific volume of steam, steam table, Dryness fraction, | | 4 | | |
| 3 | Introduction to Steam Power Plant, Rankine cycle, Reheat cycle, Regenerative cycle, Back Pressure Turbine, | | 6 | | |
| 4 | Steam Turbine, Classification, Calculation of Power Developed by Steam Turbine, Compounding of Steam Turbine | | 6 | | |
| 5 | Boilers, Classification, Study of various Boilers such as Babcock & Wilcox Boiler, Cochran Boiler, La-Mount Boiler, Benson Boiler, Boiler Mountings and Accessories, Boiler Performance, Measurement of Steam Quality | | 6 | | |
| 6 | Steam Nozzles, Diverse types of Steam Nozzles, Variation of area, velocity, and specific volume | | 2 | | |
| 7 | Elements of Steam condenser, several types of steam condenser, Condenser Efficiency | | 4 | | |
| 8 | Compressors, Classification of Compressors, Reciprocating Compressors, Single stage compressor and multistage compressor, P-V diagram, Application of Compressors, Rotary Compressors, Centrifugal and Axial compressors | | 4 | | |
| 9 | Pumps, Classification of Pumps, Reciprocating Pumps, Centrifugal Pumps, Axial Pumps, Gear Pumps, Maintenance of Pumps | | 4 | | |
| 10 | Refrigeration: COP of refrigerator and heat pumps, classification of refrigerants, Nomenclature, properties desired by refrigerants. Vapor compression refrigeration cycle. Methods of increasing COP of VCRS. Vapor absorption refrigeration systems. | | 6 | | |
| 11 | Internal combustion engines: Thermodynamic cycles such as otto, diesel and dual cycles. Methods of increasing thermal efficiency and performance of internal combustion engines | | 4 | | |
| 12 | Gas turbines: Constant pressure and constant volume gas turbines, open and closed cycle gas turbines. Methods of increasing thermal efficiency and specific work output of gas turbines. | | 4 | | |
| 13 | Transmission of power: Introduction to various drives such as belt, rope, chain, and gear drives. Introduction to mechanical elements such as keys, couplings, and bearings in power transmission. | | 6 | | |
| | **Total** | | **60** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Thermodynamics by P.K. Nag | | | | |
| 2 | Gas turbine theory by HiH Saravanamutoo | | | | |
| 3 | Refrigeration and air conditioning by C.P. Arora | | | | |
| 4 | Power plant by Morse | | | | |
| 5 | Heat Engines by P.L. Balani | | | | |
| 6 | Hydraulic Machines by Jagdish Lal | | | | |
| 7 | Theory of Machines by Rattan. S.S | | | | |
| **Course Outcomes (students will be able to….)** | | | | | |
| CO1 | Understand the first law and second law of thermodynamics with its implications. | | K2 | | |

| | | |
|---|---|---|
| CO2 | Describe the properties of steam and working of various steam boilers. | K2 |
| CO3 | Explain the working principles of power developing systems such as steam turbines, gas turbines and internal combustion engines. | K2 |
| CO4 | Describe the working principle of vapor compression and vapor absorption refrigeration systems. | K2 |
| CO5 | Discuss several types of power transmission systems and their typical applications. | K2 |
| CO6 | Explain the working principles of power absorbing devices such as pumps and compressors. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Mechanical Engineering: EST4152**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 2 | - | - | - | - | - | 1 | - | - |
| CO2 | 2 | 1 | 1 | 1 | - | 1 | - | - | - | - | - | - |
| CO3 | 3 | 1 | 1 | 1 | 1 | - | 2 | - | - | - | - | - |
| CO4 | 2 | 2 | 2 | - | 1 | - | 1 | - | - | - | - | - |
| CO5 | 1 | 2 | 1 | 1 | 2 | 2 | - | - | - | - | - | - |
| CO6 | - | 2 | 1 | 2 | - | - | 1 | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Mechanical Engineering: EST4152**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 3 | 3 | 2 | 1 | - |
| CO3 | 3 | 2 | 1 | 2 | - |
| CO4 | 2 | 1 | 2 | 1 | - |
| CO5 | 2 | 2 | 1 | 1 | - |
| CO6 | 2 | 1 | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **ESC** | **Course Code:** **EST4154** | **Course Title:** **Introduction to Chemical Engineering** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 30** | **2** | **0** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Standard X+XII (Chemistry, Physics, Mathematics) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Material and Energy Balance Calculations (CEP4151); Fluid Flow (CET4151); Heat Transfer (CET4252); Engineering Thermodynamics (EST4155); Industrial Chemistry and Reaction Engineering (CET4253); Environmental Science (CET4258); Chemical Engineering Operations (CET4254); Process Safety (CET4255); Instrumentation and Process Dynamics (CET4256); Chemical Reaction Engineering (CET4351); Momentum Transfer (CET4352); Chemical Process Control (CET4354); Separation Processes (CET4356); Chemical Process Development and Engineering (CET4451); Chemical Process Equipment Design and Drawing (CEP4451), Chemical Engineering Laboratory: I (CEP4251), Chemical Process Development and Engineering (CET4451) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Students will be able to understand role of chemical engineering and chemical engineering principle and operation along with design and economics.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Chemical Engineer and Chemical Engineering Profession | 4 |
| 2 | Indian Chemical Industry: (a) Petroleum and petrochemical industry (b) Pharmaceutical industry (c) Agrochemicals and Pesticides industry (d) Specialty Chemicals industry (e) Inorganic Chemicals … etc. | 8 |
| 3 | Chemical Engineering Principles: Chemical reaction engineering, separation processes, automation and process control | 4 |
| 4 | Overview of chemical process equipment: Reactors, Distillation, Absorption, Filters, Dryer and solid handling | 4 |
| 5 | Global trends of chemicals | 4 |
| 6 | Life cycle assessment and environmental impact | 4 |
| 7 | Modern Chemical Engineering Plants: Batch to Continuous processing | 2 |
| | **Total** | **30** |

| List of Textbooks | | |
|---|---|---|
| 1 | Introduction to Chemical Engineering: Tools for Today and Tomorrow: A First-Year Integrated Course 5th Edition (English, Paperback, Kenneth A. Solen, John N. Harb), Wiley, 2014 | |
| 2 | Introduction To Chemical Engineering (English, Paperback, S. Pushpavanam) | |
| 3 | Chemical Engineering: An Introduction (Cambri…(Paperback) by Morton Denn (Cambridge University Press) | |

| List of Additional Reading Material / Reference Books | | |
|---|---|---|
| 1 | Ministry of Commerce and Industry reports | |
| 2 | A History of The International Chemical Industry by Fred Aftalion | |

| Course Outcomes (students will be able to….) | | |
|---|---|---|
| | **Students will be able to** | |
| CO1 | Identify the role of chemical engineer in industry and society | K2 |
| CO2 | Understand the Unit process and Unit Operation in chemical Engineering | K2 |
| CO3 | Understand the design of industrial process and equipment | K2 |
| CO4 | Use some of the engineering basic calculations | K3 |
| CO5 | Perform basic process calculations | K3 |
| CO6 | Create and develop the idea and thought in problem solving in chemical engineering principles | |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Introduction to Chemical Engineering: EST4154<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 1 | 1 | - | - | 1 | - | 2 | 1 | 1 | 1 |
| CO2 | 2 | 1 | 1 | 2 | 2 | - | 1 | - | - | 2 | 2 | - |
| CO3 | 2 | 1 | 1 | 2 | 1 | 1 | - | 1 | - | 1 | 1 | - |
| CO4 | 2 | 2 | 1 | - | 1 | - | - | - | - | 2 | 1 | - |
| CO5 | 2 | 1 | - | - | 1 | - | 1 | - | - | 2 | 1 | 2 |
| CO6 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | - | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Introduction to Chemical Engineering: EST4154<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 3 | 2 | 1 | - |
| CO2 | 3 | 2 | 1 | 2 | - |
| CO3 | 2 | 1 | 1 | 1 | - |
| CO4 | 2 | 2 | - | 1 | - |
| CO5 | 1 | 3 | 2 | 3 | 1 |
| CO6 | 3 | 3 | 2 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CEP4151 | Course Title: Material Balance and Energy Balance Calculations | Credits = 2 | | |
| | | | L | T | P |
| | Semester: II | Total contact hours: 60 | 0 | 0 | 4 |
| List of Prerequisite Courses | | | | | |
| | XIIth Standard Mathematics, Chemistry, Physics, Applied Mathematics: I (MAT4151), Applied Chemistry: I (CHT4151 and CHT4152), Applied Physics: I (PHT4151); Introduction to Chemical Engineering (EST4154); Mechanical Engineering (EST4152) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Operation (CET 4254); Chemical Reaction Engineering (CET4351); Chemical Project Economics (CET4358), Chemical Engineering Laboratory I, II, III and IV (CEP4151, CEP4252, CEP4253 and CEP4254), Separation Processes (CET4356), Heat Transfer Equipment design (CET4357), Chemical Project Economics (CET4358), Chemical Process Development and Engineering (CET4451), Biochemical Engineering (Hon.), Refinery Science and Engineering (Hon.) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This is a basic Chemical Engineering Course. This knowledge will be required in ALL subjects later on. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Introduction to Chemical Engineering: Chemical Process Industries, Chemistry to Chemical Engineering, Revision of Units and Dimensions | | 4 | | |
| 2 | Mole concept, composition relationship and Stoichiometry, Behavior of gases and vapors | | 6 | | |
| 3 | Material balances for reacting and non-reacting chemical and biochemical systems including recycle, bypass and purge | | 20 | | |
| 4 | Introduction to psychrometry humidity and air-conditioning calculations. | | 10 | | |
| 5 | Introduction to Energy Balances, Energy Balances in systems with and without reactions | | 10 | | |
| 6 | Unsteady State Material and Energy Balances | | 6 | | |
| 7 | Material and Energy Balances for multistage processes and complete plants | | 4 | | |
| | Total | | 60 | | |
| List of Textbooks/ Reference Books | | | | | |
| 1 | Chemical Process Principles, Hougen O.A., Watson K. M. | | | | |
| 2 | Basic Principles and Calculations in Chemical Engineering, Himmelblau, | | | | |
| 3 | Stoichiometry, Bhatt B.I. and Vora S.M. | | | | |
| | | | | | |
| Course Outcomes (students will be able to….) | | | | | |
| CO1 | Students will be able to convert units of simple quantities from one set of units to another set of units | | K3 | | |
| CO2 | Students will be able to calculate quantities and /or compositions in various processes and process equipment such as reactors, filters, dryers, etc. | | K3 | | |
| CO3 | Students will be able to calculate energy usages, etc. in various processes and process equipment such as reactors, filters, dryers, etc. | | K3 | | |
| CO4 | Able to apply the mass and energy balance etc, in various application of chemical engineering principle. | | K4 | | |
| CO5 | Able to evaluate the calculate the final predicted results | | K5 | | |
| CO6 | Create and develop idea and thoughts in chemical engineering principles | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Material Balance and Energy Balance Calculations: CEP4151<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 1 | 1 | - | - | 1 | - | 2 | 1 | 1 | 1 |
| CO2 | 2 | 1 | 1 | 2 | 2 | - | 1 | - | - | 1 | 2 | - |
| CO3 | 2 | 1 | 1 | 2 | 1 | 1 | - | 1 | - | 2 | 1 | - |
| CO4 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 |
| CO5 | 3 | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - |
| CO6 | 2 | 3 | 1 | 2 | - | - | 1 | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Material Balance and Energy Balance Calculations: CEP4151<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 2 | 1 | 1 |
| CO2 | 2 | 2 | 2 | 2 | - |
| CO3 | 1 | 3 | 1 | 1 | - |
| CO4 | 2 | 2 | 2 | 1 | 1 |
| CO5 | 3 | 2 | 1 | - | - |
| CO6 | 2 | 3 | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **VSEC** | **Course Code: ESP4154** | **Course Title: Engineering Applications of Digital Computers** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 60** | **0** | **0** | **4** |

| List of Prerequisite Courses | | |
|---|---|---|
| | XIIth Standard Mathematics and Physics Courses, Applied Mathematics: I and II (MAT4151 and MAT4152) | |
| **List of Courses where this course will be prerequisite** | | |
| | Digital Computation in Emerging areas (AI/ML/DA) | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| Students will be able to understand engineering applications of digital computers and data interpretation and presentation. | | |
| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
| 1 | Spreadsheet calculations: Use of cells, formulas, table calculations, graphs, matrix operations, goal seek, solver, curve fitting, regression, statistical analysis, excel important formulas, visual basic programming | 20 |
| 2 | Any programming language (preferably python): Basics, array types, conditional statements, iterative loops, functions | 20 |
| 3 | Programming case studies involving solution of single non-linear equation (Equation of state such as Van der Waal, Peng Robinson, RKS, friction factor equation, Ergun equation, Estimation of Drag Coefficient etc) | 6 |
| 4 | Solution of ordinary differential equations (IVP and BVP) | 8 |
| 5 | Data visualization (2D plots, 3D plots, contours, surface plots) | 6 |
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Microsoft Office help | |
| 2 | Python: The Complete Reference, Martin Brown | |
| 3 | Unit Operations of Chemical Engineering, McCabe, Smith and Harriott (for case studies) | |
| **Course Outcomes (students will be able to….)** | | |
| CO1 | Students would be able to carry out Spreadsheet calculations for chemical engineering problems | K3 |
| CO2 | Students would be able to develop programming logic and code it in software | K4 |
| CO3 | Student would be able to apply the software skill in making code | K4 |
| CO4 | Student would be able to analyze the result using data solving | K4 |
| CO5 | Student would be able to evaluate result using formulae in computer | K5 |
| CO6 | Student would be able to create and write the program | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Engineering Applications of Digital Computers: ESP4154**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | - | 1 | 2 | - | - | 1 | - | 1 | - | - |
| CO2 | - | 2 | 2 | 1 | 1 | 1 | - | - | - | 1 | - | - |
| CO3 | - | 2 | 2 | 2 | 2 | 1 | - | 1 | - | 1 | - | 1 |
| CO4 | - | 1 | 2 | - | - | - | - | - | - | - | - | - |
| CO5 | - | 2 | 1 | - | - | - | - | - | - | - | - | - |
| CO6 | - | 1 | 2 | - | - | - | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Engineering Applications of Digital Computers: ESP4154**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 2 | 1 | 2 | - |
| CO2 | 3 | 2 | 2 | 1 | 1 |
| CO3 | 2 | 2 | 1 | 1 | 1 |
| CO4 | 2 | 1 | 2 | - | - |
| CO5 | 2 | 1 | 1 | - | - |
| CO6 | 1 | 1 | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **IKS** | **Course Code: HUT4153** | **Course Title: MOOC- Indian Knowledge System- Chemical Technology** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 30** | **1** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

Cultivation of arts is an integral part of the development of human beings since the arts are what make us most human, most complete as people. They offer us the experience of wholeness because they touch us at the deepest levels of mind and personality. They come into being not when we move beyond necessity but when we move to a deeper necessity, to the deeper human need to create order, beauty and meaning out of chaos. They are the expressions of deepest human urges, imperatives and aspirations

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | **Introduction to Indian Knowledge System (IKS):**<br>- Introduction, Definition and History<br>- Need to study it in current times<br>Chemists and texts of the ancient era | 2 |
| 2 | **Traditional Indian Pharmaceutical Sciences and Technology:**<br>- Alternative systems of Medicine/ Welfare of the society: Principles of Ayurveda<br>– Medicinal plants and crude drugs<br>– Reappraisal of Ayurvedic Phytochemistry<br>– Ayurvedic Dosage forms and similarity to that of modern dosage forms<br>– Extraction of herbs in Ayurvedic System and comparison to that of modern extraction process<br>– Detoxification of poisonous plants (*Shodhan Prakriya*)<br>Ancient perspective of Adulterants and Substitutes | 6 |
| 3 | **Traditional Indian Knowledge on Oils, Perfumery and Flavoring agents**<br>Essential oils and fixed oils<br>Applications in perfumery and flavoring-fragrance industry | 3 |
| 4 | **Traditional Indian Knowledge on Textile and Fibers**<br>– Types of fibers<br>– Textile patterns across the country<br>Methods and Techniques | 2 |
| 5 | **Traditional Indian Knowledge on Dyes, Pigments, mordents and specialty chemicals**<br>– Natural dyes and pigments<br>Sources, Methods of dying | 2 |
| 6 | **Traditional Indian Knowledge on Polymers and surface coatings**<br>Waxes, Gums, Carbohydrates | 2 |
| 7 | **Traditional Indian Food Technology** | 2 |
| 8 | Traditional Indian Knowledge about Metallurgy and Materials Science | 3 |
| 9 | **Traditional Indian Preservation Technology**<br>– Methods of preservation: Food, monuments and artifacts<br>Materials used in Preservation | 3 |
| 10 | Science associated with traditional Indian practices during festivals | 2 |
| 11 | Connecting The traditional Indian Knowledge with Modern Science | 3 |
| | **Total** | **30** |

**List of Text Books/ Reference Books**

| | |
|---|---|
| 1 | Acharya Prafulla Chandra Ray, A History of Hindu Chemistry, 1902, republ., Shaibya Prakashan Bibhag, centenary edition, Kolkata, 2002 |

| | | |
|---|---|---|
| 2 | B. Mahadevan and Vinayak Rajat Bhat, Introduction To Indian Knowledge System: Concepts And Applications, PHI Learning publication, 2022 | |
| 3 | The Positive Sciences of the Ancient Hindus; Brijendra Nath Seal; 4th Edition; 2016 | |
| 4 | Fine Arts & Technical Sciences in Ancient India with special reference to Someśvara's Mānasollāsa; Dr. Shiv Shekhar Mishra, Krishnadas Academy, Varanasi 1982 | |
| 5 | A Concise History of Science in India, ed. D M Bose, S N Sen and B V Subbarayappa; INSA; 2009 | |
| 6 | Science and Technology in Medieval India - A Bibliography of Source Materials in Sanskrit, Arabic and Persian by A Rahman, M A Alvi, S A Khan Ghori and K V Samba Murthy; 1982. | |
| 7 | Vaidya Navnitlal B. Pandya, Fundamental principles of ayurveda part – 1. October 1982 Ancient Science of Life. | |
| 8 | Vasant Lad, Textbook of Ayurveda: Fundamental Principle, reprint 2010 | |
| 9 | Lakshmi chandra Mishra (Editor), Scientific Basis for Ayurvedic Therapies, CRC Press LLC 2003 | |
| 10 | H.Panda, Handbook on Speciality Gums, Adhesives , Oils, Rosin & Derivatives, Resins, Oleoresins, Katha, Chemicals with other Natural Products, Asia Pacific Business Press Inc., 2022 | |
| 11 | Achyut Godbole, Anna, Madhushree Publication, 2022, Marathi edition | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | List the key achievements of Ancient India in different areas of Chemical Technology | K3 |
| CO2 | Describe the various features of traditional Indian knowledge in different areas of Chemical Technology | K2 |
| CO3 | Describe Key Principles of Traditional Indian Health Systems | K2 |
| CO4 | Describe the various products and key technology aspects based on traditional Indian Knowledge in context of Modern science | K2 |
| CO5 | Understanding the applications of IKS in current practices. | K3 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**MOOC- Indian Knowledge System- Chemical Technology: HUT4153**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | 1 | 3 | - | 1 | 3 | 3 | 1 | - |
| CO2 | 3 | 2 | 2 | 1 | 1 | 3 | - | 1 | 3 | 3 | 1 | - |
| CO3 | 3 | 2 | 2 | 1 | 1 | 3 | - | 1 | 3 | 3 | 1 | - |
| CO4 | 3 | 2 | 2 | 1 | 1 | 3 | - | 1 | 3 | 3 | 1 | - |
| CO5 | 2 | 1 | 1 | 3 | 1 | 1 | - | 1 | 1 | 3 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**MOOC- Indian Knowledge System- Chemical Technology: HUT4153**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 1 | 1 | 3 | 2 |
| CO2 | 2 | 2 | 1 | 1 | 1 |
| CO3 | 2 | 1 | 1 | 3 | 2 |
| CO4 | 2 | 1 | 1 | 1 | 2 |
| CO5 | 2 | 2 | 1 | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| **IKS** | **Course Code:** **HUT4154** | **Course Title:** **MOOC- Indian Knowledge System- Introduction to Ancient Indian Mathematics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: II** | **Total contact hours: 30** | **1** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

1. Introduce students to major chronological developments in Indian mathematical inventions for science, engineering, and technology.
2. Explore ancient discoveries and research including number systems, Vedic mathematics, measurements, and binary systems.
3. Encourage students to identify and engage with ancient knowledge systems to contribute meaningfully to modern science.
4. Foster respect and pride in Indigenous Knowledge, aiding learners in verifying ancient Indian knowledge on modern scientific and technological grounds.
5. Explain the historicity of the Indian Knowledge System, particularly focusing on Ancient Indian Mathematics.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction to Indian Knowledge System (IKS):<br>• Introduction, Definition and Historical evidences<br>• Need to study it in current times – Legacy and relevance<br>Salient aspects of Indian Mathematics – Indian Mathematicians | 4 |
| 2 | History of Indian Mathematics: Part – I<br>• Brahmhagupta, algebra and zero<br>Bhaskara and development of early calculus | 4 |
| 3 | History of Indian Mathematics: Part – II<br>• Madhava's Infinite Series, Sine series derivation<br>Ramanujan's Discoveries - Making sense of 1+2+3+... = -1/12 | 4 |
| 4 | Mathematicians and their contributions: Part – I<br>Number theory and advanced mathematics – relevance to programming and algorithms | 4 |
| 5 | Mathematicians and their contributions: Part – II<br>• Contributions of Aryabhatta: The mathematical – Astronomical genius of Ancient India<br>Contributions of Bhaskara: The mathematical – Astronomical genius of Ancient India | 4 |
| 5 | Proofs in Indian Mathematics | 5 |
| | **Total** | **30** |

**List of Text Books/ Reference Books**


| | | |
|---|---|---|
| 1 | Mathematics in India – NPTEL course by IIT Bombay, 2023 | |
| 2 | Gérard G. Emch, R. Sridharan, M. D. Srinivas (eds.) Culture and History of Mathematics 3 - Contributions to the History of Indian Mathematics-Hindustan Book Agency (2005) | |
| 3 | C. K. Raju - History of Science, Philosophy and Culture in Indian Civilization X.4 - Cultural Foundations Of Mathematics-Pearson (2007) | |
| 4 | George Gheverghese Joseph - Indian Mathematics – Engaging with the World from Ancient to Modern Times, World Scientific Publishing (UK) (2016) | |
| 5 | B Mahadevan, V R Bhat, and Nagendra Pavana R N; An Introduction to Indian Knowledge Systems: Concepts and Applications, 2022 (Prentice Hall of India). | |
| 6 | Nachum Dershowitz, Edward M. Reingold (auth.), B.S. Yadav, Man Mohan (eds.) - Ancient Indian Leaps into Mathematics-Birkhäuser Basel (2011) | |
| 7 | S. Balachandra Rao, Vedic Mathematics and Science in Vedas,Navakarnataka Publications, Bengaluru, 2019 | |
| 8 | Bibhuti bhushan Datta & Avadhesh Narayan Singh, History of Hindu Mathematics, 1935, repr. Bharatiya Kala Prakashan, Delhi, 2004 | |

| | | |
|---|---|---|
| 9 | Thanu Padmanabhan, (ed.), Astronomy in India: A Historical Perspective, Indian National Science Academy, New Delhi & Springer (India), 2010 | |
| 10 | P. P. Divakaran, The Mathematics of India Concepts Methods Connections, Hindustan Book Agency 2018. Rep Springer New York 2018. | |
| 11 | S. Balachandra Rao, Indian Mathematics and Astronomy: Some Landmarks, 3rd Ed. Bhavan's Gandhi Centre, Bangalore 2004. | |
| 12 | SWAYAM – MOOC courses and YouTube videos | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | List the key achievements of Ancient India in different areas of Mathematical Sciences | K3 |
| CO2 | Describe the various features of traditional Indian knowledge in different areas of Mathematics | K2 |
| CO3 | Describe Key Principles of Traditional Indian Mathematics | K2 |
| CO4 | Describe the various applications and key aspects based on traditional Indian Knowledge in context of Modern science | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**MOOC- Indian Knowledge System- Introduction to Ancient Indian Mathematics: HUT4154**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | 1 | 3 | 0 | 1 | 3 | 3 | 1 | 0 |
| CO2 | 3 | 2 | 2 | 1 | 1 | 3 | 0 | 1 | 3 | 3 | 1 | 0 |
| CO3 | 3 | 2 | 2 | 1 | 1 | 3 | 0 | 1 | 3 | 3 | 1 | 0 |
| CO4 | 3 | 2 | 2 | 1 | 1 | 3 | 0 | 1 | 3 | 3 | 1 | 0 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**MOOC- Indian Knowledge System- Introduction to Ancient Indian Mathematics: HUT4154**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 1 | 1 | 3 | 2 |
| CO2 | 2 | 2 | 1 | 1 | 1 |
| CO3 | 2 | 1 | 1 | 3 | 2 |
| CO4 | 2 | 1 | 1 | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| CCA | Course Code: HUP4154 | Course Title: OPEN Activity - Sports - II | Credits = 2 | | |
| | | | L | T | P |
| | Semester: II | Total contact hours: 60 | 1 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | None | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Not Applicable | |

**Description of relevance of this course in the Int. M. Tech. Program**

Games and sports are necessary and useful for all. Games play an important part in life. Education is incomplete without games. Games are necessary to keep the body fit and trim. Moreover, they provide recreation. As a result, one feels smart and cheerful throughout the day. If one is cheerful and healthy, he or she is able to get the best out of life. A player really enjoys life. For him, life is a song and a beauty. Games teach us the lesson of discipline, teamwork, patience and punctuality. In the playground, the players obey the captain and abide by the rules of the games. Games also teach us that we should play a game for game's sake, not for victory or defeat. A healthy man is always hopeful and cheerful.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | The students shall select participating a specific sports/game/physical activity of their choice in morning/evening or at other suitable times according to the local climate. This would involve a routine of physical activity with games and sports.<br>Physical activity means any bodily movement produced by skeletal muscles requiring energy expenditure, for example, Walking, gardening, climbing the stairs, playing soccer.<br>Activities can be considered vigorous, moderate, or light in intensity. Activity makes one breathe harder and one's heartbeat faster.<br>**Moderate physical activities** include:<br>□ Walking briskly (about 3½ miles per hour)<br>□ Bicycling (less than 10 miles per hour)<br>□ General gardening (raking, trimming shrubs)<br>□ Dancing □ Golf (walking and carrying clubs)<br>□ Water aerobics<br>□ Canoeing<br>□ Tennis (doubles)<br>**Vigorous physical activities** include:<br>□ Running/jogging (5 miles per hour)<br>□ Walking very fast (4½ miles per hour)<br>□ Bicycling (more than 10 miles per hour)<br>□ Heavy yard work, such as chopping wood<br>□ Swimming (freestyle laps)<br>□ Aerobics<br>□ Basketball (competitive)<br>□ Tennis (singles) | 60 |
| | **Total** | **60** |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Keep physically fit and mentally agile | K2 |
| CO2 | Manage stress in studies and later in life | K2 |
| CO3 | Coordinate body and mind together | K2 |
| CO4 | Understand own emotions and maintain healthy daily routine | K2 |
| CO5 | Develop teamwork and an ability to work with others for a common goal | K3 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| OPEN Activity - Sports - II: HUP4154<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 1 | - | - | - | 1 | 1 | 1 | 1 | 1 | - | 1 |
| CO2 | - | 1 | - | - | - | 1 | 1 | 1 | 1 | 1 | - | 1 |
| CO3 | - | 1 | - | - | - | 1 | 1 | 1 | 1 | 1 | - | 1 |
| CO4 | - | 1 | - | - | - | 1 | 1 | 1 | 1 | 1 | - | 1 |
| CO5 | - | 1 | - | - | - | 1 | 1 | 1 | 1 | 1 | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**OPEN Activity - Sports - II: HUP4154**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| CO5 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester II | | | | | |
|---|---|---|---|---|---|
| CCA | Course Code: HUT4156 | Course Title: OPEN Activity - Fine arts - II | Credits = 2 | | |
| | | | L | T | P |
| | Semester: II | Total contact hours: 60 | 1 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | None | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Not Applicable | |

**Description of relevance of this course in the Int. M. Tech. Program**

The focus of the course is to encourage creative expression through lines and colors. The course would inculcate appreciation of the local and global art and artists will broaden the perspective and social interactions.
The students will learn the basics of sketching, painting, photography and related art forms. Discussion of artists and art forms will be conducted to encourage appreciation.

**Selection Criteria**
Keen interest in fine arts as demonstrated by previous performance / participation in events, clubs, etc.
Selection on the basis of interview
Maximum limit for enrollment – 30 students
**Evaluation** – based on Student Attendance, Continuous assessment and Project.
The students will be expected to submit a fine arts project which will be part of the evaluation. Additional consideration will be given to participation in Institute-level and inter-collegiate fine arts events.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Concept: Basics of line, form, color and composition | 6 |
| 2 | Sketching of objects, faces, Nature, abstract forms – emphasis on composition, light / shadow, texture, depth | 6 |
| 3 | Types of sketches: Doodle, caricature, cartoons, anime, hyper-realistic, etc (Students can explore anyone) | 12 |
| 4 | Painting: Types of media (watercolor / oil / acrylics), types of base (paper / fabric / wood), emphasis on techniques, layering, color composition<br>Painting styles: realistic, portraits, boho, impressionist | 12 |
| 5 | Indian art form: Students can explore any two from Mandala / Madhubani / Pichwai / Warli / Kalamkari / Gond / Patachitra etc.<br>Discussion, appreciation and hands-on sessions | 12 |
| 6 | Artists and art: discussion of international and national artist, art appreciation | 6 |
| 7 | Project work | 6 |
| | **Total** | **60** |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understanding of conceptual skills by assimilating the elements and principles of Art and applying creative, critical, and philosophical thinking of the work. | K2 |
| CO2 | Understand the contextual basis for the art through a study of the art history of diverse cultures, modern and contemporary art, and through the integration of this study in the hands-on process of art making. | K3 |
| CO3 | Specialization Course in Applied have great potential in providing creative solutions to communication of complex phenomena of print media such as books, magazines and newspaper, known as pictographic depictions or concept visualization. | K4 |
| CO4 | Demonstrate foundation skills in the use of art process and media that enable clear, creative visual communication. Identify and explain the various mediums and methods/processes used in the creation of two-dimensional and three-dimensional artworks. | K5 |
| CO5 | Develops the drawing ability and improve the observational skill and rendering of shape, tone, color, pattern, and texture. | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| OPEN Activity - Fine arts - II: HUP4156<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | - | 2 | - | - | - | - | - | 1 | 2 | - | - | - |
| CO2 | - | 3 | - | - | - | - | - | 1 | 3 | - | - | - |
| CO3 | - | 2 | - | - | - | - | - | 1 | 2 | - | - | - |
| CO4 | - | 2 | - | - | - | - | - | 1 | 3 | - | - | - |
| CO5 | - | 3 | - | - | - | - | - | 1 | 2 | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| OPEN Activity - Fine arts - II: HUP4156<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| CO5 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

<table>
<tr><th colspan="6">Semester II</th></tr>
<tr><td rowspan="2">CCA</td><td>Course Code:<br>HUP4160</td><td>Course Title:<br>OPEN Activity - Yoga - II</td><td colspan="3">Credits = 2</td></tr>
<tr><td>Semester: II</td><td>Total contact hours: 60</td><td>L<br>1</td><td>T<br>1</td><td>P<br>0</td></tr>
<tr><th colspan="6">List of Prerequisite Courses</th></tr>
<tr><td></td><td colspan="4">Yoga and Self Development (HUP4156)</td><td></td></tr>
<tr><th colspan="6">List of Courses where this course will be prerequisite</th></tr>
<tr><td></td><td colspan="4">Not Applicable</td><td></td></tr>
<tr><th colspan="6">Description of relevance of this course in the Int. M. Tech. Program</th></tr>
<tr><td colspan="6">The course aims to improve knowledge, skills, and different health practices related to selected sports disciplines and promote Health and wellness through Healthy Lifestyle.</td></tr>
<tr><td></td><td colspan="4">Course Contents (Topics and subtopics)</td><td>Reqd. hours</td></tr>
<tr><td>1.</td><td colspan="4">
1. Suksham Vyayam<br>
• Beneficial for whole Body<br>
2. Yogic Jogging<br>
• Hastpadsanchalan<br>
• Purn Hastpadsanchalan<br>
• Janu Sanchal<br>
• Aardha Baithak<br>
• Janu Vikasak<br>
• Januvaksha Vikasak<br>
• Vaksha Vikasak<br>
• Trikonasan<br>
• Konasan<br>
• Paad Hastasan<br>
• Chalit Paad Hastasan<br>
• Yog Nrutyasan<br>
3. Surya Namaskar<br>
• Aasana<br>
• Condition<br>
• Common Rule<br>
• Benefits<br>
4. Pranayam and Its Benefits<br>
• Bhastrika Pranayam<br>
• Kapalbhati Pranayam<br>
• Tribandh Pranayam<br>
• Ujjayai Pranayam<br>
• Anulom-Vilom Pranayam<br>
• Bhramri Pranayam<br>
• Udgith Pranayam<br>
• Pranav Pranayam/Onkar Meditation<br>
5. Aasana<br>
▪ <u>Standing Position</u><br>
▪ Kaatichakrasan-1<br>
▪ Kaatichakrasan-2<br>
▪ Taadasan<br>
▪ Tirak Taadasan<br>
▪ Vrukshasan<br>
▪ Dhruvasan<br>
▪ <u>Back touching the Earth</u><br>
▪ Markatasana-1<br>
▪ Markatasana-2<br>
▪ Markatasana-3<br>
▪ Pavanamuktasana-1
</td><td>60</td></tr>
</table>

| | | |
|---|---|---|
| | ▪ Pavanamuktasana-2<br>▪ Ardhahalasana<br>▪ Padavrittasana-1<br>▪ Padavrittasana-2<br>▪ Dwi-Chakrikasana-1<br>▪ Dwi-Chakrikasana-2<br>▪ Belly touching the Earth<br>▪ Makarasana<br>▪ Bhujangasana-1<br>▪ Bhujangasana-2<br>▪ Bhujangasana-3<br>▪ Shalabhasana-1<br>▪ Shalabhasana-2<br>▪ Shalabhasana-3<br>▪ Dhanurasan<br>▪ Sitting Position<br>▪ Mandukasana-1<br>▪ Mandukasana-2<br>▪ Shashankasan<br>▪ Vakrasan<br>▪ Wajrasan<br>Kandharasan | |
| | **Total** | **60** |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | To understand the basic training and practices required in the selected asana's. | K2 |
| CO2 | To understand the importance of yoga practice and demonstrate the basic skills in the selected vyayam. | K3 |
| CO3 | To develop a set of core skills in the selected Yog-asana's for overall growth and development | K5 |
| CO4 | To create a foundation for professionals in the selected yoga. | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**OPEN Activity - Yoga - II: HUP4160**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | - | - | - | - | - | 1 | 2 | - | - | - |
| CO2 | - | - | - | - | - | - | - | 1 | 3 | - | - | - |
| CO3 | - | - | - | - | - | - | - | 1 | 2 | - | - | - |
| CO4 | - | - | - | - | - | - | - | 1 | 3 | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**OPEN Activity - Yoga - II: HUP4160**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | - | - | - | - | 1 |
| CO2 | - | - | - | - | 1 |
| CO3 | - | - | - | - | 1 |
| CO4 | - | - | - | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Second Year

# Semester-III

| Semester III | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4251 | Course Title: Fluid Flow | Credits = 2 | | |
| | | | L | T | P |
| | Semester: III | Total contact hours: 30 | 1 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | XIIth Standard Physics and Mathematics, Applied Physics (PHT4151), Applied Mathematics: I and II (MAT4151 and MAT4152); Introduction to Chemical Engineering (EST4154) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Momentum Transfer (CET4352), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This basic course introduces concepts of fluid transfer to students. Various concepts such as pressure, momentum, energy are introduced.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Fluid Statics and applications to engineering importance. | 4 |
| 2 | Bernoulli's Equation and engineering applications, Pressure drop in pipes and Fittings, Piping systems | 6 |
| 3 | Utility network in chemical process industries: Cooling water, Steam, Chilled water, Thermic fluid system | 8 |
| 4 | Types and design of Fluid moving machinery such as pumps, blowers, compressors, vacuum systems, etc. | 6 |
| 5 | Particle Dynamics, Boundary layer separation: skin and form drag, Flow through Fixed and Fluidized Beds, Flow through porous media | 6 |
| | **Total** | **30** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N. | |
| 2 | Fluid Mechanics, Kundu Pijush K. | |
| 3 | Fluid Mechanics, F. W. White | |
| 4 | Unit Operations of Chemical Engineering, McCabe, Smith and Harriott | |

| Course Outcomes (students will be able to….) | | |
|---|---|---|
| CO1 | Calculate pressure drop in pipelines and equipment for different situations such as single- and two-phase flow, fixed and fluidized beds | K3 |
| CO2 | Calculate forces on particles and terminal velocities of particles | K3 |
| CO3 | Design pumps and piping systems for simple situations | K6 |
| CO4 | Estimate and analyze the fluid mechanics problem in chemical industry | K4 |
| CO5 | Evaluate the fluid flow calculation in design the pumps and piping systems | K5 |
| CO6 | Design and create the fluid piping systems in chemical industry | |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Fluid Flow: CET4251**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 3 | - | 2 | 1 | - | 1 | - | - | 1 | 2 | 1 |
| CO2 | 3 | 3 | - | 1 | - | - | - | - | - | - | 2 | 1 |
| CO3 | - | - | 1 | 1 | - | 1 | 1 | 1 | - | - | 1 | 1 |
| CO4 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | - | 1 | 2 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | 3 | 2 | 1 | 1 | - | - | - | - | - | - | - | 1 |
| CO6 | 2 | 3 | 2 | 1 | 1 | - | - | - | - | - | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Fluid Flow: CET4251**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | - | - |
| CO2 | 1 | 2 | 2 | 2 | - |
| CO3 | 2 | 2 | 2 | 3 | 1 |
| CO4 | 2 | 2 | 2 | 2 | 1 |
| CO5 | 3 | 2 | 1 | - | - |
| CO6 | 1 | 2 | 3 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4252 | Course Title: Heat Transfer | Credits = 2 | | |
| | | | L | T | P |
| | Semester: III | Total contact hours: 30 | 1 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Momentum transfer (CET4352), Chemical Engineering Operation (CET4254), Applied Mathematics I and II (MAT4151 and MAT4152), Material and Energy Balance Calculations (CEP4151); Introduction to Chemical Engineering (EST4154) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Chemical Reaction engineering (CET4351), Multiphase Reactor Engineering (HONOURS Syllabus), Process Development and Engineering (CEP4451), Process Safety (CET4255), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Instrumentation and Process Dynamics (CET4256), Chemical Process Development and Engineering (CET4451), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Refinery Science and Engineering (Hon.) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This is a basic course that deals with heat transfer, overview of heat exchangers Heat transfer forms one of the basic pillars of Chemical Engineering Education and is required in all future activities. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Revision of Basics of Heat transfer: Steady state and unsteady state conduction, Fourier's law, Concepts of resistance to heat transfer and the heat transfer coefficient. Heat transfer in Cartesian, cylindrical and spherical coordinate systems, Insulation, critical radius. | | 6 | | |
| 2 | Convective heat transfer in laminar and turbulent boundary layers. Theories of heat transfer and analogy between momentum and heat transfer. | | 4 | | |
| 3 | Heat transfer by natural convection. | | 4 | | |
| 4 | Heat transfer in laminar and turbulent flow in circular pipes: Double pipe heat exchangers: Concurrent, counter-current and cross flows, mean temperature difference, NTU: epsilon method for exchanger evaluation. Heat transfer outside various geometries in forced convection, such as, single spheres, banks of tubes or cylinders, packed beds and fluidized beds | | 8 | | |
| 5 | Heat transfer in agitated vessels: coils, jackets, limpet coils, calculation of heat transfer coefficients, heating and cooling times, applications to batch reactors and batch processes | | 4 | | |
| 6 | Basics of Radiative heat transfer and application to Furnace Design | | 4 | | |
| | Total | | 30 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Heat Transfer, Kern D.Q. | | | | |
| 2 | Heat Exchangers, Kakac S., Bergles A.E., Mayinger F | | | | |
| 3 | Process Heat Transfer, G. Hewitt | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | Calculate temperature profiles in a slab at steady state | | K3 | | |
| CO2 | Calculate heat transfer coefficients for free and forced convection in different heat transfer equipment | | K3 | | |
| CO3 | Rate performance of heat exchanger using NTU-epsilon method | | K5 | | |
| CO4 | Design agitated vessel for heat transfer controlled process | | K6 | | |
| CO5 | Design heat transfer equipment and their design calculation | | K6 | | |
| CO6 | Design the furnace and its design calculation | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Heat Transfer: CET4252<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 3 | - | 2 | 1 | - | 1 | - | - | 1 | 1 | 1 |
| CO2 | - | 3 | - | 2 | 1 | - | 1 | - | - | 1 | - | 1 |
| CO3 | - | - | - | 3 | 2 | 1 | 1 | - | - | - | - | 1 |
| CO4 | - | - | 1 | 2 | 2 | 3 | 2 | 1 | - | - | 2 | 2 |
| CO5 | - | 3 | 1 | 2 | 2 | 1 | 2 | 1 | - | 1 | 1 | 1 |
| CO6 | - | 2 | 2 | 1 | - | - | - | - | - | 1 | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Heat Transfer: CET4252**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 3 | 2 | 1 | - |
| CO2 | 2 | 3 | 2 | 1 | - |
| CO3 | 1 | 2 | 3 | 3 | 1 |
| CO4 | 2 | 1 | 3 | 3 | 2 |
| CO5 | 3 | 2 | 3 | 3 | 1 |
| CO6 | 1 | 2 | 1 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: EST4155** | **Course Title: Engineering Thermodynamics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: III** | **Total contact hours: 30** | **1** | **1** | **0** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | Mechanical Engineering (EST4152); Material and Energy Balance Calculations (CEP4151); Introduction to Chemical Engineering (EST4154) | |
| **List of Courses where this course will be prerequisite** | | |
| | Chemical Engineering Lab I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4253), Chemical Engineering Thermodynamics (CEP4353), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Engineering Operation (CET4254), Chemical Reaction Engineering (CET4351), Separation Processes (CET4356), Chemical Process Development and Engineering (CET4451) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Thermodynamics sets hard limits on performance of processes and equipment. This course gives students the formalism and insights necessary to do a preliminary thermodynamic analysis of a process for the purpose of establishing feasibility assuming ideal mixing.

| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
|---|---|---|
| 1 | Revision of basic Concepts of thermodynamics. State functions; Equilibrium; Phase Rule; Reversible process; Constant P, V, T processes; Energy conservation & first law of thermodynamics; Mass and energy balances for open systems, nozzles, diffuser, turbines, and pump | 6 |
| 2 | Statements of the second law; Heat engines, Carnot's theorem, Thermodynamic Temperature Scales; Entropy; Entropy changes of an ideal gas; Mathematical statement of the second law; Entropy balance for open systems<br>Industrial Applications of Second Law of Thermodynamics using Ideal Gas Law and Thermodynamic Property Charts and Tables | 6 |
| 3. | Thermodynamic analysis of flow process, steam power plants; Rankine cycle; Internal combustion engine, Otto engine, diesel engine; Jet engine. | 6 |
| 4. | Carnot refrigerator; Vapor-compression cycle; Absorption refrigeration; Heat pump, Liquefaction processes. | 6 |
| 5 | Phases, phase transitions, PVT behavior; description of materials: Ideal gas law, van der Waals, virial and cubic equations of state; Reduced conditions & corresponding states theories; correlations in description of material properties and behavior | 6 |
| | **Total** | **30** |

| **List of Text Books/ Reference Books** | |
|---|---|
| 1 | Introduction to Chemical Engineering Thermodynamics: Smith, van Ness, Abbott |
| 2 | Chemical, Biochemical and Engineering Thermodynamics: S. I. Sandler |
| 3 | Properties of Gases and Liquids: Reid, Prausnitz, Pauling |

| **Course Outcomes (students will be able to…..)** | | |
|---|---|---|
| CO1 | Calculate Enthalpy, Entropy and Gibbs energy changes in fluids with changes in temperature and pressure | K3 |
| CO2 | Analyze process efficiencies using first law and second law of thermodynamics concepts | K4 |
| CO3 | Calculate saturation temperature and pressure relationship for pure fluids from equations of state | K3 |
| CO4 | Analyze process efficiencies of various engines and refrigeration units | K4 |
| CO5 | Estimate and evaluate the thermodynamics calculation | K5 |
| CO6 | Develop and create the thermodynamic model equation | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Engineering Thermodynamics: EST4155<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 3 | - | 1 | - | - | 1 | - | - | 1 | 1 | - |
| CO2 | - | - | - | 2 | 1 | 1 | - | - | - | 1 | - | - |
| CO3 | 3 | 3 | - | 1 | - | - | 1 | - | - | - | 1 | - |
| CO4 | 3 | 3 | - | 2 | - | 1 | 1 | 1 | - | 1 | 1 | - |
| CO5 | 3 | 3 | - | 2 | 1 | 1 | 1 | 1 | - | 1 | 1 | - |
| CO6 | 3 | 2 | 1 | 2 | - | - | - | 1 | 2 | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Engineering Thermodynamics: EST4155<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 1 | 2 | 2 | 3 | 1 |
| CO3 | 2 | 3 | 1 | 2 | - |
| CO4 | 2 | 3 | 3 | 2 | - |
| CO5 | 2 | 3 | 2 | 2 | 1 |
| CO6 | 2 | 1 | 2 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4253 | Course Title: Industrial Chemistry and Reaction Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: III | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemistry (CHT4151 and CHT4152), Material & Energy Balance Calculations (CEP4151), Applied Mathematics I and II (MAT4151 and MAT4152), Momentum Transfer (CET4352) | |
| **List of Courses where this course will be prerequisite** | | |
| | Separation process and Membrane (CET4356), Chemical Engineering Thermodynamics (CET4353), Process Safety (CET4255), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Process Development and Engineering (CET4451) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course gives information about the chemical industry information and different types of production of fuels and inorganic products. This course also provides the information about the batch and semi batch reactors, other types of reactors, types of single phase and multiphase reactors.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Raw material and energy sources, Organic and inorganic intermediates and final products, Bulk and specialty chemicals | 10 |
| 2 | Production costs of fuels and chemicals | 2 |
| 3 | Industrial gases and inorganic products | 4 |
| 4 | Examples of major industrial processes | 6 |
| 5 | Types of chemical reactions: elementary/non-elementary, single/multiple, irreversible/reversible | 8 |
| 6 | Types of chemical reactors: batch and semi-batch reactors, continuous reactors (CSTR and PFR) | 8 |
| 7 | Reaction kinetics (homogeneous reactions) | 8 |
| 8 | Isothermal, adiabatic and non-isothermal operation modes | 8 |
| 9 | Different types of single phase and multiphase reactors | 6 |
| | **Total** | **60** |

| List of Text Books | | |
|---|---|---|
| 1 | Elements of Chemical Reaction Engineering: H. Scott FOGLER | |
| 2 | Chemical Reaction Engineering: Octave LEVENSPIEL | |
| 3 | The Engineering of Chemical Reactions: Lanny D. SCHMIDT | |
| 4 | An introduction to Chemical Engineering Kinetics and Reactor Design: Charles HILL | |
| **List of Additional Reading Material / Reference Books** | | |
| 1 | Encyclopedia of Chemical Technology, Kirk-Othmer | |
| 2 | Ulmann's Encyclopedia of Industrial Chemistry | |
| 3 | Industrial Organic Chemistry, Weissermel & Arpe | |
| 4 | Chemical Process Industries, Shreve B. Austin | |
| 5 | Chemical Process Technology, Moulijn, M. and van Dippen | |
| 6 | Dryden's Outlines of Chemical Technology | |
| 7 | Elements of Fuels, Furnaces and Refractories, O.P. Gupta | |
| 8 | Fuels handbook, Johnson | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Draw process flow diagrams/process block diagrams for the manufacture of various chemicals from process description | K2 |
| CO2 | List out various alternatives for carrying out a particular process and provide recommendations for the best choice | K3 |

| | | |
|---|---|---|
| CO3 | List Principles of combustion systems for solid, liquid and gaseous fuel | K2 |
| CO4 | Design chemical reactors optimally, using minimum amount of data | K3 |
| CO5 | Design experiments in a judicious way to get the required data, if not available | K6 |
| CO6 | Increase capacity and/or selectivity and/or safety by improving/changing the reactor type/sequence and/or operating conditions | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Industrial Chemistry and Reaction Engineering: CET4253**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | - | 1 | 2 | 1 | - | - | 1 | 1 | 2 |
| CO2 | - | 2 | 1 | 1 | - | - | - | - | - | 1 | 1 | 1 |
| CO3 | 2 | 1 | 1 | 2 | - | 1 | - | - | - | 1 | - | 2 |
| CO4 | 2 | 1 | 1 | 2 | 1 | - | - | - | - | - | 1 | 1 |
| CO5 | 2 | 1 | - | 1 | 1 | - | 1 | - | - | - | 2 | - |
| CO6 | 3 | 2 | 2 | 1 | 2 | 1 | - | - | - | 1 | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Industrial Chemistry and Reaction Engineering: CET4253**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 3 | 2 | 1 | - |
| CO2 | 2 | 2 | 1 | 1 | - |
| CO3 | 1 | 1 | 2 | - | - |
| CO4 | 2 | 2 | 1 | - | - |
| CO5 | 1 | 2 | 3 | 3 | 1 |
| CO6 | 1 | 1 | 2 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CEP4251 | Course Title: Chemical Engineering Laboratory - I | Credits = 2 | | |
| | | | L | T | P |
| | Semester: III | Total contact hours: 60 | 0 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Introduction to Chemical Engineering (EST4154), Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT5141 and MAT5142), Applied Physics (PHT4151), Applied Chemistry (CHT4151) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Engineering Lab - II (CEP4252) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | 6-8 Experiments on Fluid Flow | 40 |
| 2 | 2-3 Experiments on Heat Transfer | 10 |
| 3 | 2-3 Experiments on Kinetics | 10 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014 | |
| 2 | Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007 | |
| 3 | Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996. | |
| 4 | Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Student would be able to Learn to experimentally verify various theoretical principles | K3 |
| CO2 | Student would be able to Visualize practical implementation of basic chemical engineering principles | K2 |
| CO3 | Student would be able to Develop experimental skills | K4 |
| CO4 | Student would be able to Connect classroom teaching with the laboratory practical | K3 |
| CO5 | Student would be able to Improve understanding about safety in the laboratory | K4 |
| CO6 | Student would be able to evaluate and write the report based on results | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Laboratory - I: CEP4251**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - | 2 | - | - | - | 2 | 1 | 1 |
| CO2 | 3 | 2 | 2 | - | - | - | - | - | - | 1 | 1 | 2 |
| CO3 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | 1 | 2 | |
| CO4 | 3 | 1 | 1 | 2 | - | - | - | - | - | 2 | 1 | - |
| CO5 | 3 | 2 | - | - | - | - | 1 | - | - | 2 | 1 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| Chemical Engineering Laboratory - I: CEP4251<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 3 | 2 | 3 | 1 |
| CO2 | 3 | 1 | 1 | 3 | - |
| CO3 | 1 | 2 | 3 | 1 | 2 |
| CO4 | 2 | 1 | 2 | 2 | 2 |
| CO5 | 2 | 1 | 2 | 2 | 2 |
| CO6 | 1 | 2 | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| **AEC** | **Course Code: HUP4153** | **Course Title: Modern Indian Language – मराठी भाषा: कौशल्य विकास** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: III** | **Total contact hours: 60** | 0 | 0 | 4 |
| **List of prerequisite courses** | | | | | |
| | मराठी – (X + XII) | | | | |
| **List of courses where this course will be prerequisite** | | | | | |
| | Nil | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| १ संज्ञापनातील भाषेची भूमिका, विविध भाषिक आविष्कार समजावून देणे.<br>२ भाषिक कौशल्यांचा परिचय करून देऊन विद्यार्थ्यांमधील क्षमता विकसित करणे.<br>३ भाषिक कौशलयांचा प्रत्यक्ष सराव करून घेणे. | | | | | |
| | **Course contents (topics and subtopics)** | | **Reqd. hours** | | |
| 1 | १. भाषिक कौशल्ये प्राथमिक आणि प्रगत यांचा परिचय<br>२. लेखन कौशल्य: अर्ज लेखन, एमेल लेखन, निबंध लेखन, कल्पना विस्तार, अनौपचारिक पत्र लेखन | | 20 | | |
| 2 | १. संवाद कौशल्ये: निवेदन, मुलाखत, भाषण, सूत्रसंचालन अभिवाचन (गद्य आणि पदय) इ. मधील उपयोग<br>२. देहबोली, उच्चारण आणि शब्दसंहिता यांचे महत्व | | 20 | | |
| 3 | १. भाषा, जीवन यवहार आिण नवमा यमे, समाजमायमे<br>२. नवमा यमे आिण समाजमा यमाचे कार: लॉग, फेसबक, टिवटर.<br>३. नवमा यमे आिण समाजमा यमाि◌वषयक सा रता, द ता, वापर आिण परणाम | | 20 | | |
| | **Total** | | **60** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | भाषातर मीमासा, सपा. डॉ. कयाण काळे, डॉ. अजली सोमण | | | | |
| 2 | उपयोि◌जत मराठी, सपादक डॉ. केतक मोडक, सतोष शेणई, सजाता शेणई | | | | |
| 3 | भाषातरमीमासा, कयाण काळे, अजली सोमण. | | | | |
| 4 | यावहारक आिण उपयोि◌जत मराठी, डॉ. मनोहर रोकडे | | | | |
| **Course Outcomes (students will be able to….)** | | | | | |
| CO1 | विद्यार्थ्यांमध्ये विविध भाषिक कौशल्ये विकसित होतील | | K3 | | |
| CO2 | विविध समाजमध्यमांमध्ये प्रभावी संवाद साधण्याची कला विकसित होईल. | | K3 | | |
| CO3 | विद्यार्थ्यांचा व्यक्तिमत्व विकास साध्य होण्यास मदत होईल. | | K3 | | |
| CO4 | विद्यार्थ्यांमध्ये नवमाध्येमे आणि समाज माध्यमाविषयी साक्षरता निर्माण होतील. | | K3 | | |
| CO5 | विद्यार्थ्यांमध्ये नवमाध्येमे आणि समाज माध्यमाचा परिणाम त्याबद्धल चर्चा होतील. | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Modern Indian Language – मराठी भाषा: कौशल्य विकास: HUP4153**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | - | - | - | - | - | - | - | 3 | - | - |
| CO2 | - | - | - | - | - | - | - | - | - | 3 | - | - |
| CO3 | - | - | - | - | - | - | - | - | - | 3 | - | - |
| CO4 | - | - | - | - | - | - | - | - | - | 3 | - | - |
| CO5 | - | - | - | - | - | - | - | - | - | 3 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Modern Indian Language – मराठी भाषा: कौशल्य विकास: HUP4153<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | - | - | - | 3 | - |
| CO2 | - | - | - | 3 | - |
| CO3 | - | - | - | 3 | - |
| CO4 | - | - | - | 3 | - |
| CO5 | - | - | - | 3 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| MGT | Course Code: HUT4156 | Course Title: Basic Principles of Finance and Economics | Credits = 2 | | |
| | | | L | T | P |
| | Semester: III | Total contact hours: 30 | 2 | 0 | 0 |
| List of Prerequisite Courses | | | | | |
| | Applied Mathematics: I and II (MAT4151 and MAT4152) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Project economics (CET4358); Fundamentals of marketing management and market research | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This course gives the information about Basic Principles of Finance and Economics. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | INTRODUCTION<br>Explaining the Economy<br>The Supply and Demand Model<br>Using the Supply and Demand Model | | 3 | | |
| 2 | THE COMPETITIVE EQUILIBRIUM MODEL<br>Deriving Demand<br>Deriving Supply<br>Market Equilibrium and Efficiency | | 5 | | |
| 3 | DEVIATIONS FROM COMPETITION<br>Monopoly and Market Power<br>Between Monopoly and Competition<br>Antitrust Policy and Regulation | | 5 | | |
| 4 | MACRO FACTS AND MEASURES<br>Getting Started with Macroeconomic Ideas<br>Measuring Production, Income and Spending of Nations | | 5 | | |
| 5 | ACCOUNTING TRANSACTIONS<br>Journal entries.<br>Debit credit rules.<br>Compound journal entry.<br>Journal and ledger.<br>Rules of posting entries<br>Trial balance | | 5 | | |
| 6 | CAPITAL AND REVENUE<br>Income and expenditure<br>Expired costs and income<br>Final accounts<br>Manufacturing accounts<br>Trading accounts<br>Profit and Loss account.<br>Suspense account<br>Balance sheet | | 5 | | |
| 7 | CONCEPT OF DEPRECIATION | | 2 | | |
| | Total | | 30 | | |
| List of Textbooks | | | | | |
| 1 | Finance and Accounting for Nonfinancial Managers: All the Basics You Need to Know - William G. Droms and Jay O. Wright Microeconomics: Basic Principles and Applications- A A Temu, D W Ndyetabula, et al PRINCIPLES OF ECONOMICS(12e)- E. Case Karl, C. Fair Ray, et al | | | | |
| List of Additional Reading Material / Reference Books | | | | | |

| | | |
|---|---|---|
| 1 | Basic Finance for Nonfinancial Managers: A Guide to Finance and Accounting Principles for Nonfinancial Managers- Kendrick Fernandez | |
| 2 | Microeconomic Theory: Basic Principles and Extensions- Walter Nicholson and Christopher Snyder | |
| 3 | Macroeconomics(10e) Part of: Pearson Series in Economics (23 books) - by Froyen | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Students will be able to know and apply accounting and finance theory. | K2 |
| CO2 | Students will be able to understand the mechanics of preparation of financial statements, their analysis and interpretation | K2 |
| CO3 | Students will be able to explain basic economic terms, concepts, and theories | K3 |
| CO4 | Students will be able to identify key macroeconomic indicators | K4 |
| CO5 | Student will be able to evaluate the accounting statements | K5 |
| CO6 | Student will be able to create the statemen and capital statement. | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Basic Principles of Finance and Economics: HUT4156**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 1 | 1 | 1 | - | 1 | - | - | - | 1 | 2 | 1 |
| CO2 | - | 1 | 3 | - | - | - | - | - | - | 1 | 1 | 1 |
| CO3 | - | - | - | 1 | - | 1 | - | - | - | - | 1 | 1 |
| CO4 | - | - | 3 | 2 | - | - | - | - | - | 1 | 1 | - |
| CO5 | - | 1 | 3 | 2 | - | 1 | 1 | - | - | 1 | 1 | 1 |
| CO6 | - | - | 2 | 2 | - | 1 | - | - | - | - | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Basic Principles of Finance and Economics: HUT4156**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 2 | 3 | 1 | 1 | - |
| CO3 | 1 | 2 | 3 | - | - |
| CO4 | 2 | 1 | 2 | - | - |
| CO5 | 1 | 3 | 2 | 1 | 1 |
| CO6 | 3 | 3 | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester III | | | | | |
|---|---|---|---|---|---|
| **VEC** | **Course Code: CET4257** | **Course Title: Environmental Sciences** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: III** | **Total contact hours: 30** | **2** | **0** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Environmental Studies of Standard XII | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Project Economics (CET4358) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course gives the information about Basic Principles of Environmental Sciences.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | (a) Concept of circular economy, EHS management (b) Environment management systems in the chemical industry (c) Legal provisions for environmental management: EP Act 1986; Air Act, 1981; Water Act, 1974; Hazardous waste management Rules, 2019 | 6 |
| 2 | Importance of ecology, effluent treatment and discharging norms for treated water | 6 |
| 3 | SPCB consent parameters, monitoring, and analysis | 4 |
| 4 | External monitoring of ambient air, noise, stacks, etc | 4 |
| 5 | Air pollutants, sources and effects on human health and environment, monitoring, and analysis | 6 |
| 6 | Life cycle analysis, environmental impact assessment | 4 |
| | **Total** | **30** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Introduction to Environmental Engineering and Science by Gilbert M Masters and Wendell P Ela | |
| 2 | Environmental Pollution Control Engineering, C. S. Rao | |
| 3 | Principles of Instrumental Analysis by D. A. Skoog, F. James Holler and S. R. Crouch, Cengage Learning, 2007 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Describe the methods of industrial effluent treatment | K2 |
| CO2 | apply the learning for selection and implementation of appropriate waste management technique for sustainable development | K2 |
| CO3 | Basic understanding and awareness about the components of environment | K2 |
| CO4 | Gaining knowledge about Climate patterns of India | K3 |
| CO5 | Awareness about diseases caused due to polluted environment | K3 |
| CO6 | Understanding the different strategies used to control pollution. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Environmental Sciences: CET4257**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 1 | 1 | 2 | 1 | - | - | - | 2 | 1 | 1 | 2 |
| CO2 | 1 | 2 | - | 2 | - | - | 1 | - | 2 | 1 | 1 | 1 |
| CO3 | 1 | 1 | 1 | 2 | 1 | - | 1 | - | 2 | 1 | 1 | 1 |
| CO4 | 1 | 2 | 1 | 1 | - | - | 3 | 1 | 2 | - | 2 | 3 |
| CO5 | 1 | 2 | 1 | 1 | - | - | 3 | 1 | 2 | - | 2 | 1 |
| CO6 | - | 1 | 1 | - | - | - | 3 | 1 | - | - | 1 | 2 |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| **Environmental Sciences: CET4257**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 3 | 2 | 1 | - |
| CO2 | 2 | 2 | 3 | 1 | - |
| CO3 | 2 | 3 | 3 | 1 | - |
| CO4 | 1 | 2 | 2 | 1 | - |
| CO5 | 1 | 2 | 3 | 1 | - |
| CO6 | 1 | 2 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Second Year

# Semester-IV

| Semester IV | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4254** | **Course Title: Chemical Engineering Operations** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: IV** | **Total contact hours: 60** | **2** | **2** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Material and Energy Balance Calculations (CEP4151), Chemistry (CHT4151 and CHT4152), Engineering Thermodynamics (EST4155) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Momentum transfer (CET4352), Separation Processes (CET4356), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Process Simulation Lab: I and II (CEP4255 and CEP4256), Heat Transfer Equipment design (CET4357), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety, Biochemical Engineering (Hon.), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Refinery Science and Engineering (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| | This is a basic Chem Eng. course. The principles learnt in this course are required in almost all the courses and throughout the professional career of Chemical Engineer | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Introduction to Unit Operations and Chemical Engineering Processes, Introduction to mass transfer: Concepts of Convective and diffusive transport | | 4 | | |
| 2 | Distillation of binary mixtures: Differential distillation, Flash or equilibrium distillation, Fractionating column and multistage column, reflux, reflux ratio, need for reflux, McCabe-Thiele, Lewis-Sorel methods of estimation of number of equilibrium stages, Operating and feed lines, minimum and optimum reflux ratio, Tray and column efficiency, Packed column distillation: rate-based methods: HETP, HTU, Ponchon Savarit method, Introduction to batch distillation and steam distillation. Methods for multicomponent separations: Fenske-Underwood-Gilliland Method | | 12 | | |
| 3 | Absorption and Stripping of dilute mixtures: Fundamentals of absorption, equilibrium curves, Operating lines from material balances, Number of equilibrium stages, Kremser Equation, Stage efficiency and column performance, Absorption columns, Rate based methods for packed columns (HTU, NTU), Design considerations: loading and flooding zones, pressure drop and column diameter | | 12 | | |
| 4 | Liquid Filtration: Filtration theory: constant pressure, constant rate, and variable pressure-variable rate filtration, Incompressible and compressible cake filtration, Continuous filtration, filter aids, Filtration equipment, Selection, Sizing and Scale-up | | 10 | | |
| 5 | Sedimentation, Classification and Centrifugal Separations: Design and scale up equations, Performance evaluation, Sedimentation equipment, classifiers, centrifugal equipment, Sieving operations, types of sieving (dry, wet, vibro), magnetic separators, and froth flotation, Selection, sizing and scale-up | | 8 | | |
| 6 | Drying of solids: Mechanism of drying, drying rate curves, Estimation of drying time, Drying Equipment, operation, Process design of dryers, material, and energy balances in direct dryers, Drying of bioproducts | | 10 | | |
| 7 | Particle Size Reduction: Energy requirements for size reduction and scale-up considerations, Operational considerations, Crushing and grinding equipment: impact and roller mills, fluid energy mills, wet/dry media mills, Selection of equipment | | 4 | | |
| | **Total** | | **60** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Richardson, J.F., Coulson, J.M., Harker, J.H., Backhurst, J.R., 2002. Chemical engineering: Particle technology and separation processes. Butterworth-Heinemann, Woburn, MA. | | | | |
| 2 | Seader, J.D., Henley, E.J., 2005. Separation Process Principles, 2 ed. Wiley, Hoboken, N.J. | | | | |
| 3 | Svarovsky, L., 2000. Solid-Liquid Separation. Butterworth-Heinemann, Woburn, MA. | | | | |
| 4 | McCabe, W., Smith, J., Harriott, P., 2004. Unit Operations of Chemical Engineering, 7 ed. McGraw-Hill Science/Engineering/Math, Boston. | | | | |

| | | |
|---|---|---|
| 5 | Green, D., Perry, R., 2007. Perry's Chemical Engineers' Handbook, Eighth Edition, 8 ed. McGraw-Hill Professional, Edinburgh. | |
| 6 | Dutta, B.K., 2007. Principles of Mass Transfer and Separation Process. Prentice-Hall of India Pvt. Ltd, New Delhi. | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Know the significance and usage of different particulate characterization parameters, and equipment to estimate them | K2 |
| CO2 | Describe Size reduction energy requirements, estimate performance of equipment, selection and sizing of equipment | K3 |
| CO3 | Analyze filtration data and select systems based on requirements, estimate filtration area for given requirements, understand filter aids and their usage | K4 |
| CO4 | Draw T-y-x diagrams, and y-x diagrams, operating lines, feed line, bubble point, dew point calculations, ternary phase diagrams, partition coefficient | K4 |
| CO5 | Describe two common modes of drying, industrial drying equipment | K2 |
| CO6 | Calculate mass transfer coefficient in various equipment, calculate height and diameter required, minimum solvent required in absorption, calculate height and diameter required, minimum reflux required in distillation | K4 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Operations: CET4254**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 2 | 2 | - | 1 | 2 | - | - | 1 | 2 | 1 |
| CO2 | 2 | 2 | 2 | 2 | - | 1 | 2 | - | - | 2 | 1 | 2 |
| CO3 | 3 | 3 | - | - | - | - | 3 | - | - | 1 | 1 | 2 |
| CO4 | 3 | 3 | - | - | - | - | - | - | - | 2 | 2 | 1 |
| CO5 | 2 | 2 | - | - | - | - | - | - | - | 2 | 2 | 1 |
| CO6 | 3 | 3 | - | 3 | - | 3 | 3 | - | - | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Operations: CET4254**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 3 | 3 | 1 | 1 | - |
| CO3 | 2 | 1 | 2 | 3 | 1 |
| CO4 | 1 | 2 | 1 | 2 | - |
| CO5 | 2 | 2 | 1 | 1 | - |
| CO6 | 1 | 3 | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IV | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4255 | Course Title: Process Safety | Credits = 2 | | |
| | | | L | T | P |
| | Semester: IV | Total contact hours: 30 | 1 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Industrial Engineering Chemistry and Engineering (CET4253) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety (CETxxx), Chemical Process Control (CET4354), Chemical Process Development and Engineering (CET4451) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| The principles learnt in this course are learnt the process safety inters of handing and performing the experiment in laboratory, as well as handing, storage, and transportation of hazardous chemicals. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Safety management in chemical industry<br>(a) o Regulations in chemicals manufacturing units (b) Overview of hazards, contributors to chemical process accidents, importance of safety culture (c) Causes of fires and explosion, , accident prevention, work permits | | 10 | | |
| 2 | Transport, storage and safe handling of hazardous chemicals.<br>(a) Flammable and combustible liquids<br>(b) Storage and handling of hazardous chemicals<br>(c) Norms for safe handling of chemicals at workplace<br>(d) Safety during transportation of hazardous substances | | 10 | | |
| 3 | Basics of laboratory safety<br>(a) MSDS and personal protective equipment (b) Electrical safety (c) Fire safety (d) Machine safety (e) Cylinder safety (f) Bio safety | | 10 | | |
| | Total | | 30 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Chemical Process Safety: Fundamentals with Applications: Daniel A. CROWL and Joseph F. LOUVAR | | | | |
| 2 | Guidelines for Process Safety Management, Environment, Safety, Health, and Quality: Centre for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | | | | |
| 3 | Chemical Process Safety Learning from Case Histories: Roy E. SANDERS | | | | |
| 4 | Guidelines for Process Safety Documentation: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | Identify hazards in a given process and assess the same and provide solutions for operating safely. | | K2 | | |
| CO2 | Specify safety requirements for storage and handling of a given chemical. | | K2 | | |
| CO3 | Students learn what process safety is, the consequences of poor process safety, and the factors that influence it. | | K3 | | |
| CO4 | Students learn how to manage risk and define critical controls, or barriers, to prevent unintentional releases of dangerous materials. | | K5 | | |
| CO5 | Students learn how to implement sustainable improvements in PSM. | | K5 | | |
| CO6 | Students may gain hands-on experience with bowtie diagrams and other tools and learn to apply critical thinking skills to analyze scenarios. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Process Safety: CET4255<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 2 | 2 | - | 1 | 2 | - | - | 1 | 1 | - |
| CO2 | 2 | 2 | 2 | 2 | - | 1 | 2 | - | - | 2 | 1 | - |
| CO3 | 3 | 3 | 3 | 3 | - | 1 | 3 | - | - | 1 | 1 | - |
| CO4 | - | 2 | 1 | 2 | - | - | - | - | 1 | 1 | 2 | 2 |
| CO5 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | - | - | 3 | 1 |
| CO6 | 1 | 1 | 2 | 2 | 1 | - | - | - | - | - | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Process Safety: CET4255**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 2 | 3 | 1 | - |
| CO2 | 3 | 2 | 2 | - | 1 |
| CO3 | 2 | 2 | 2 | 1 | 1 |
| CO4 | 1 | 2 | 1 | 1 | - |
| CO5 | 2 | 1 | 3 | 1 | - |
| CO6 | 1 | 2 | 2 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IV | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4256** | **Course Title: Instrumentation and Process Dynamics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: IV** | **Total contact hours: 30** | **1** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Mathematics I (MAT4151), Physics (PHT4151), Fluid Flow (CET4251), Heat Transfer (CET4252), Chemistry (CHT4151 and CHT4152) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Process Control (CET4354), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Process Development and Engineering (CET4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The principles learnt in this course are required in almost all the courses and throughout the professional career of Chemical Engineer in terms of instrumentation and process dynamics of process and design. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Revision of basic concepts: Laplace transformation, linearization, step, pulse, ramp, sinusoidal functions | | 4 | | |
| 2. | Unsteady mass and energy balances of system, dynamic equations | | 6 | | |
| 3. | Overview of dynamic model equations of typical chemical engineering operations, such as level in a tank, temperature in a heated tank, reactor, column, heat exchanger | | 6 | | |
| 4. | First and second order systems, Stimulus-Response Techniques, Response of First order systems to step, pulse, sinusoidal stimuli, characteristics of First and second order systems | | 4 | | |
| 5. | Components of control system – precision, sensitivity, accuracy, and error analysis of measurements, Transduces, Transmission of signals | | 2 | | |
| 6 | Combination of systems and their response to input changes, Open Loop response, Instrumentation for measurement of temperature, flow, pressure, level, concentration. Basic underlying principles and physical construction of instruments, | | 2 | | |
| 7 | Feedback control mechanism – To design a simple control system of first order and second order nature, e.g. P, PI and PID | | 6 | | |
| | **Total** | | **30** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Instrumentation, Eckman | | | | |
| 2 | Chemical Process Control- George Stepheanopoulous | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | To identify appropriate instrument for measurement of process variables | | K2 | | |
| CO2 | To estimate time variant nature of process | | K3 | | |
| CO3 | To classify nature of the system as first order, second order, etc, | | K3 | | |
| CO4 | To estimate response of the system when subjected to change | | K3 | | |
| CO5 | To understand behavior of combined systems | | K2 | | |
| CO6 | To evaluate and create the instrumentation and control system of chemical process | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Instrumentation and Process Dynamics: CET4256**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 2 | 2 | 1 | 2 | 2 | - | - | 1 | 1 | - |
| CO2 | 2 | 2 | 1 | 1 | 2 | 1 | - | - | - | 2 | 2 | - |
| CO3 | 3 | - | 2 | 1 | - | 2 | - | - | - | 1 | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO4 | 2 | 1 | 2 | - | 2 | 2 | - | - | - | 1 | 1 | - |
| CO5 | 1 | 2 | 2 | 2 | 1 | - | 1 | - | - | 2 | 1 | - |
| CO6 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | - | - | 2 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Instrumentation and Process Dynamics: CET4256**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 1 | 1 | - | - |
| CO2 | 3 | 1 | 2 | 1 | 1 |
| CO3 | 3 | 2 | 1 | 1 | - |
| CO4 | 3 | 2 | 1 | - | - |
| CO5 | 2 | 1 | 2 | 1 | - |
| CO6 | 3 | 2 | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IV | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CEP4252 | Course Title: Chemical Engineering Laboratory - II | Credits = 2 | | |
| | | | L | T | P |
| | Semester: IV | Total contact hours: 60 | 0 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT4151 and MAT4152), Chemical Engineering Operations (CET4154), Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Engineering Laboratory III and IV (CEP4253 and CEP4254) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 2 | 2-3 Experiments on Heat Transfer | 12 |
| 4 | 6-8 Experiments on Chemical Engineering Operations | 40 |
| 5 | 1-2 Experiments on Instrumentation | 8 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014 | |
| 2 | Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007 | |
| 3 | Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996. | |
| 4 | Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Student would be able to Learn to experimentally implement various theoretical principles | K2 |
| CO2 | Student would be able to Utilize the chemical engineering equipment to generate experimental data | K4 |
| CO3 | Student would be able to Calculate experimental results | K3 |
| CO4 | Student would be able to Improve ability to write laboratory reports | K3 |
| CO5 | Student would be able to Improve ability for oral communication | K3 |
| CO6 | Student would be able to write and conclude the experiment data | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Laboratory - II: CEP4252**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - | 2 | - | - | - | 2 | 1 | 1 |
| CO2 | 3 | 2 | 2 | - | - | - | - | - | - | 1 | 1 | 2 |
| CO3 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | 1 | 2 | |
| CO4 | 3 | 1 | 1 | 2 | - | - | - | - | - | 2 | 1 | - |
| CO5 | 3 | 2 | - | - | - | - | 1 | - | - | 2 | 1 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| **Chemical Engineering Laboratory - II: CEP4252**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 3 | 2 | 3 | 1 |
| CO2 | 3 | 1 | 1 | 3 | - |
| CO3 | 1 | 2 | 3 | 1 | 2 |
| CO4 | 2 | 1 | 2 | 2 | 2 |
| CO5 | 2 | 1 | 2 | 2 | 2 |
| CO6 | 1 | 2 | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IV | | | | | |
|---|---|---|---|---|---|
| **MGT** | **Course Code:** **HUT4157** | **Course Title:** **Industrial Management** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: IV** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256), Process Safety (CET4255) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Process Control (CET4354), Chemical Project Economics (CET4358), Chemical Process Development and Engineering (CET4451), Chemical Industrial Management (CET4452), Chemical Process Equipment Design and drawing (CEP4451), Chemical Process Development and Engineering (CET4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course equips students with human resource management skills to be able to function effectively in their professional career | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | The production functions.<br>Operation concept of production<br>Production as the conversion process<br>Productivity of conversion process<br>Components of production function-Planning, organising, and controlling | | 6 | | |
| 2 | Manufacturing systems<br>Factors influencing choice of manufacturing system.<br>Classification of manufacturing systems<br>Jobbing production<br>Batch production.<br>Mass or flow production | | 8 | | |
| 3 | Facilities location<br>Factors governing plant location.<br>Economic survey of site selection<br>Urban, sub-urban, rural site location | | 6 | | |
| 4 | Productivity techniques<br>Kaizen<br>Kanban<br>JIT<br>5S<br>Poka yoke<br>Six sigma | | 5 | | |
| 5 | Gantt chart for production planning and control | | 5 | | |
| | **Total** | | **30** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Modern Production / Operations Management, (8e)- Buffa and Sarin | | | | |
| 2 | Operations Management,12e-Jay Heizer, Barry Render, et al. | | | | |
| 3 | OPERATIONS MANAGEMENT 13TH EDITION by William J. Stevenson | | | | |
| 4 | Operations and Supply Chain Management (SIE) \| 15th Edition by Richard B. Chase, Ravi Shankar, et al. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Student would be able to explain the concepts of management and explore the management practices in their domain area within society. | | K4 | | |
| CO2 | Student would be able to evaluate different types of organizational structures and design them. | | K6 | | |

| | | |
|---|---|---|
| CO3 | Student would be able to explain about product design process and Design product layout. | K6 |
| CO4 | Student would be able to explain about method study and use various work measurement methods. | K3 |
| CO5 | Student would be able to draw various statistical quality control charts and interpret them. | K3 |
| CO6 | Student would be able to apply the techniques of PERT/CPM in project. | K3 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Industrial Management: HUT4157**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 2 | 2 | - | 3 | 1 | - | - | - | 1 | 3 | 1 |
| CO2 | 2 | 1 | 3 | 1 | 1 | - | - | - | - | 2 | 2 | 2 |
| CO3 | 1 | 3 | 1 | 2 | 2 | - | - | - | 2 | 1 | 1 | 1 |
| CO4 | 2 | 3 | 3 | 2 | 2 | 1 | - | - | 2 | 1 | 3 | 1 |
| CO5 | 2 | 1 | 2 | 1 | 2 | 1 | - | - | 1 | 1 | - | - |
| CO6 | 2 | 3 | 1 | 2 | 1 | - | - | - | 1 | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Industrial Management: HUT4157**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | - |
| CO2 | 2 | 1 | 2 | 3 | 2 |
| CO3 | 1 | 2 | 3 | 1 | 3 |
| CO4 | 2 | 2 | 2 | 1 | 3 |
| CO5 | 2 | 2 | 1 | 2 | 1 |
| CO6 | 2 | 1 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

<table>
<tr><th colspan="6">Semester IV</th></tr>
<tr><td rowspan="2">FP</td><td>Course Code:<br>HUP4158</td><td>Course Title:<br>Community Projects</td><td colspan="3">Credits = 2</td></tr>
<tr><td>Semester: IV</td><td>Total contact hours: 60</td><td>L<br>0</td><td>T<br>0</td><td>P<br>4</td></tr>
<tr><th colspan="6">List of Prerequisite Courses</th></tr>
<tr><td></td><td colspan="4">Nil</td><td></td></tr>
<tr><th colspan="6">List of Courses where this course will be prerequisite</th></tr>
<tr><td></td><td colspan="4">Nil</td><td></td></tr>
<tr><th colspan="6">Description of relevance of this course in the Int. M. Tech. Program</th></tr>
<tr><td colspan="6">Students will explore the various community projects as individual or group related to study of societal technological activities through various organizations.</td></tr>
<tr><td></td><td colspan="4">Course Contents (Topics and subtopics)</td><td>Reqd. hours</td></tr>
<tr><td>1</td><td colspan="4">Engineering sciences have the main objective of making the knowledge useful for the benefit of society.<br>In the first step, students, individually or in a group not more than 5, shall identify the problems faced by the society in their neighborhood or city, or the state. They shall collect necessary data, collate relevant information and identify a problem that can be solved using the knowledge of own field or general sciences and propose an affordable solution.<br>The team shall then execute the project with support from Institute, Local Society groups, NGOs, Industry.<br>Some of the suggested projects are:<br>(i) Identification of water supply Pipeline network, estimation of water requirement, Pressure drop calculations and pumping requirements<br>(ii) Based on census data, identification of food supply, waster generation,<br>(iii) Survey of waste dump areas in local areas, treatment of malodour from dumped materials by biological means<br>(iv) Survey of local hospitals, waste generation, analysis of waste treatment<br>(v) Water and air pollution in the areas, identification and quantitative measurements and effect of the same on local population in the areas.<br>(vi) Identification of waste materials generated by local economic activities, development of recycle of waste, and/or building economic activities<br>(vii) Safety awareness among people in the vicinity of chemical plants, suggesting methods in the event of emergencies<br>(viii) Development of methods to contain fugitive emissions from vehicles, and transport of chemicals<br>(ix) Plastic collection drives and recycle methods<br>(x) Design of rain water harvesting methods in housing societies<br>(xi) Green building concept awareness<br>Any-other project of social relevance with prior approval of the HOD</td><td>60</td></tr>
<tr><td></td><td colspan="4">Total</td><td>60</td></tr>
<tr><th colspan="6">List of Text Books/ Reference Books</th></tr>
<tr><td>1</td><td colspan="4">General Books, Newspaper etc</td><td></td></tr>
<tr><th colspan="6">Course Outcomes (students will be able to…..)</th></tr>
<tr><td>CO1</td><td colspan="4">This course will help students to contribute of social networking as a bridge between the various government schemes and the people of India. The course also outlines the benefits of community engagement through research and innovation.</td><td>K2</td></tr>
<tr><td>CO2</td><td colspan="4">Sensitivity towards the environment and education, safety and energy, enthusiasm towards physical, mental and spiritual health along with simple living and high thinking have been explained for better understanding of the students.</td><td>K2</td></tr>
</table>

| | | |
|---|---|---|
| CO3 | Students will be able to understand the various problems of any community and the possible ways to address them. | K3 |
| CO4 | Student would be able to explain about environmental impact assessment | K3 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Community Projects: HUP4158**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 |
| CO2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 |
| CO3 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 |
| CO4 | 2 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Community Projects: HUP4158**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | - | - | - | 1 | 3 |
| CO2 | - | - | - | 1 | 3 |
| CO3 | - | - | - | 1 | 3 |
| CO4 | - | - | - | 1 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Third Year

# Semester-V

| Semester V | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4351 | Course Title: Chemical Reaction Engineering | Credits = 2 | | |
| | | | L | T | P |
| | Semester: V | Total contact hours: 30 | 1 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemistry (CHT4151 and CHT4152), Material & Energy Balance Calculations (CEP4151), Applied Mathematics I and II (MAT4151 and MAT4152), Fluid Flow (CET4251), Engineering Thermodynamics (EST4155) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Process Control (CET4354), Chemical Process Development and Engineering (CET4451), Chemical Engineering Lab - III and IV (CEP4253 and CEP4254), Process Simulation Lab - I and II (CEP4255 and CEP4256), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety, Biochemical Engineering (Hon.), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Refinery Science and Engineering (Hon.), Catalytic Science and Engineering (Hon.) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course is very relevant but not limited to the following industries: Inorganic chemicals, organic chemicals, petroleum & petrochemicals, Pulp & paper, Pigments & paints, rubber, plastics, synthetic fibers, Foods, Dyes and intermediates, Oils, oleochemicals, and surfactants, Minerals, cleansing agents, Polymers and textiles, Biochemicals and biotechnology, pharmaceuticals and drugs, Microelectronics, energy from conventional and non-conventional resources, Metals

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Sizing and analysis of chemical Reactors (single and multiple reactions (series/parallel)) | 6 |
| 2 | Series of reactors, Recycle reactors, Use of energy balance in reactor sizing and analysis, non-isothermal reactor design | 6 |
| 3 | Non-idealities in chemical reactors: RTD, Axial dispersion models | 6 |
| 4 | Gas-Solid reactions: Catalytic and Non-catalytic | 4 |
| 5 | Heterogeneous catalysis: internal and external transport, kinetics, and mechanisms | 4 |
| 6 | Gas-solid reactions (non-catalytic), Kinetics of fluid-fluid reactions | 4 |
| | **Total** | **30** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Elements of Chemical Reaction Engineering: H. Scott FOGLER | |
| 2 | Chemical Reaction Engineering: Octave LEVENSPIEL | |
| 3 | The Engineering of Chemical Reactions: Lanny D. SCHMIDT | |
| 4 | An introduction to Chemical Engineering Kinetics and Reactor Design: Charles HILL | |
| 5 | Heterogeneous Reactions, Vol. I and II: L. K. Doraiswamy, M. M. Sharma | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Design chemical reactors optimally, using minimum amount of data | K4 |
| CO2 | Design experiments in a judicious way to get the required data, if not available | K4 |
| CO3 | Fix some problems related to operability and productivity | K4 |
| CO4 | Select appropriate single and multiphase reactor configuration for given application | K3 |
| CO5 | Students may learn to develop skills to choose the right reactor for isothermal, non-isothermal, or adiabatic reactions. | K6 |
| CO6 | Students may learn to calculate conversion and extent values for different systems, including constant volume systems. | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Reaction Engineering: CET4351<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 2 | 1 | 2 | 1 | - | - | - | 1 | 1 | - |
| CO2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | - | 1 | 2 | 2 | - |
| CO3 | 1 | 2 | 1 | 1 | - | 1 | - | - | - | 1 | 1 | - |
| CO4 | 2 | 1 | 2 | 1 | 1 | 2 | - | - | - | - | 1 | - |
| CO5 | 3 | 2 | 2 | 1 | 2 | 2 | 3 | - | - | 1 | 1 | - |
| CO6 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | - | - | - | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Reaction Engineering: CET4351<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 1 | 2 | 3 | 3 | - |
| CO2 | 2 | 3 | 3 | 3 | 1 |
| CO3 | 1 | 2 | 2 | 3 | - |
| CO4 | 2 | 2 | 3 | 2 | 1 |
| CO5 | 2 | 2 | 3 | 3 | 1 |
| CO6 | 2 | 3 | 2 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester V | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4352 | Course Title: Momentum Transfer | Credits = 2 | | |
| | | | L | T | P |
| | Semester: V | Total contact hours: 30 | 1 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | XIIth Standard Physics and Mathematics, Applied Physics: I and II (PHT4151), Fluid Flow (CET4255), Applied Mathematics: I and II (MAT4151 and MAT4152), Chemical Engineering Operations (CET4254) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Engineering Lab - III and IV (CEP4253 and CEP4254), Separation Processes + Membrane (CET4356), Heat Transfer Equipment design (CET4357), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety (CETxxx), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This basic course introduces concepts of momentum transfer to students. Various concepts such as pressure, momentum, energy are introduced. Laws related to conservation of momentum; energy are taught. Applications of these laws to various engineering situations and process equipment is explained with the help of several problems

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Equations of Continuity and Motion (Cartesian, cylindrical, and spherical coordinates) in laminar flows and its applications for the calculation of velocity profiles, shear stresses, power, etc. in various engineering applications. | 8 |
| 2 | Boundary Layer Flows: Blasius equations and solution, Von-Karman integral equations and solutions, | 6 |
| 3 | Introduction to turbulence: turbulent pipe flow, basis of Universal velocity profile and its use | 6 |
| 4 | Similarities in Momentum, Heat and Mass Transfer | 6 |
| 5 | Introduction to experimental and computational fluid dynamics: HFA, LDA, PIV, UVP, tomography etc., Turbulence modelling, multiphase system modelling etc. | 4 |
| | **Total** | **30** |

| List of Textbooks/ Reference Books | | |
|---|---|---|
| 1 | Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N. | |
| 2 | Fluid Mechanics, Kundu Pijush K. | |
| 3 | Fluid Mechanics, F. W. White | |
| 4 | Unit Operations of Chemical Engineering, McCabe, Smith | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Calculate velocity profiles, forces, pressure drops for simple 1 –D laminar flow situations | K2 |
| CO2 | Calculate forces on particles and terminal velocities of particles | K2 |
| CO3 | Apply Momentum, Heat and mass transfer concepts to simple situations | K3 |
| CO4 | Select appropriate measurement technique for detailed characterization in chemical process equipment | K3 |
| CO5 | Analyze compressible fluids. | K4 |
| CO6 | Select different equipment for transportation and metering of fluids. | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Momentum Transfer: CET4352**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | - | - | - | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | - | - | - | 1 | - |
| CO3 | 3 | 2 | 1 | 2 | 2 | 1 | 2 | - | - | 1 | - | - |
| CO4 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | - | - | - | 1 | - |
| CO5 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | - | - | 1 | 1 | - |
| CO6 | 2 | 2 | 1 | 1 | 2 | 1 | - | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Momentum Transfer: CET4352**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 3 | 2 | 1 | - |
| CO2 | 3 | 2 | 3 | 1 | - |
| CO3 | 2 | 2 | 2 | 1 | 1 |
| CO4 | 2 | 1 | 2 | 2 | 1 |
| CO5 | 3 | 2 | 2 | 1 | 1 |
| CO6 | 2 | 1 | 2 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester V | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CEP4353** | **Course Title: Chemical Engineering Thermodynamics** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: V** | **Total contact hours: 60** | 3 | 1 | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Engineering Thermodynamics (CET4155) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Engineering Lab - III and IV (CEP4253 and CEP4254), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety (CETxxx), Biochemical Engineering (Hon.), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Statistical Thermodynamics (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course builds on the preceding course by developing the concept of non-ideal mixing and provides students with the formalism and insights necessary to tackle real industrial problems like liquid-liquid phase splitting, azeotropic, non-zero heats of mixing, sparingly soluble gases and solids, electrolytes etc. Student who has taken this course may be expected to intelligently analyze the full spectrum of industrial chemical processes. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1. | Revision of Concepts of Ideal and non-ideal mixtures. Equations for Property Changes, Maxwell Relations, and the need for Equations of State. Residual Properties | | 6 | | |
| 2. | Phase Equilibria for Pure Fluids, Fugacity and Fugacity Coefficient, Clausius-Clapeyron equation, Gibbs energy | | 6 | | |
| 3. | Thermodynamic Properties of Mixtures, Gibbs Duhem Equation, Phase Equilibrium in Mixtures, Fugacity and Fugacity Coefficient in Mixtures | | 6 | | |
| 4. | Non-Ideal Mixtures, Excess Properties, and activity coefficients | | 6 | | |
| 5. | Models of the Liquid Phase: Activity Coefficient Models (Margules, Van Laar, Wilson et al, UNIQUAC and NRTL) | | 4 | | |
| 6. | Vapor: Liquid Equilibria in Ideal Mixtures, T-x-y and P-x-y diagrams, Bubble point and Dew point calculations for Ideal mixtures | | 6 | | |
| 7 | Vapor: liquid equilibria in non-ideal mixtures including azeotropes and high-pressure vapor: liquid equilibria using gamma-phi and phi-phi approaches | | 6 | | |
| 8 | Solubility of Gases in Liquids, concept of infinite dilution activity coefficient, Henry's law | | 4 | | |
| 9 | Liquid: Liquid Equilibria and Phase splitting, applications to extraction | | 4 | | |
| 10 | Solubility of Solids in Liquids | | 2 | | |
| 11 | Debye Huckel Theory, activity coefficients of electrolytes | | 4 | | |
| 12 | Chemical Equilibrium in Ideal and non-ideal Mixtures in single phase reacting mixtures and in Heterogenous reacting mixtures | | 6 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Chemical, Biochemical and Engineering Thermodynamics: S. I. Sandler | | | | |
| 2 | Introduction to Chemical Engineering Thermodynamics: Smith, van Ness, Abbott | | | | |
| 3 | Properties of Gases and Liquids: Reid, Prausnitz, Pauling | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Calculate Vapor: liquid equilibria in binary non-ideal mixtures using activity coefficient models | | K3 | | |
| CO2 | Calculate solubility of solutes (gases and solids) in liquids | | K3 | | |
| CO3 | Calculate liquid: liquid equilibria using activity coefficient models | | K3 | | |
| CO4 | Analyze equilibria in reacting mixtures | | K4 | | |
| CO5 | Students should be able to solve problems involving multi-phase chemical systems and reactive systems, some of which may be related to safety. | | K5 | | |
| CO6 | Students should be able to interpret thermodynamic data for applications in chemical engineering processes, process safety, biological sciences, energy, and environmental sciences. | | K6 | | |

| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating |
|---|

| **Chemical Engineering Thermodynamics: CEP4353<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 2 | 1 | 2 | 1 | - | - | - | 1 | 1 | - |
| CO2 | 2 | 2 | 1 | 2 | 1 | 2 | - | - | - | - | 1 | - |
| CO3 | 2 | 2 | 1 | 2 | 1 | 1 | - | - | - | - | 2 | - |
| CO4 | 3 | 2 | - | 2 | - | 2 | 1 | - | - | - | 1 | - |
| CO5 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | - | - | - | 2 | - |
| CO6 | 3 | 2 | 1 | 1 | 1 | - | - | - | - | - | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Thermodynamics: CEP4353<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 2 | 3 | 2 | 2 | - |
| CO3 | 2 | 2 | 1 | 2 | 1 |
| CO4 | 1 | 2 | 3 | 2 | 1 |
| CO5 | 2 | 3 | 2 | 2 | 1 |
| CO6 | 2 | 3 | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester V | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CEP4253 | Course Title: Chemical Engineering Laboratory - III | Credits = 2 | | |
| | | | L | T | P |
| | Semester: V | Total contact hours: 60 | 0 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemical Engineering Laboratory I and II (CEP4251 and CEP4252), Momentum Transfer (CET4352), Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT4151 and MAT4152), Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Chemical Engineering Thermodynamics (CET4253), Chemical Engineering Operations (CET4254) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Engineering Lab - IV (CEP4254) | |

**Description of relevance of this course in the Int. M. Tech. Program**

Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | 2-3 Experiments on Momentum Transfer | 10 |
| 2 | 3-4 Experiments on Chemical Engineering Thermodynamics | 20 |
| 3 | 4-6 Experiments on Reaction Engineering | 30 |
| | **Total** | **60** |

| List of Textbooks/ Reference Books | |
|---|---|
| 1 | McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014 |
| 2 | Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007 |
| 3 | Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996. |
| 4 | Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007. |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Student would be able to implement the experimental procedure with minimal assistance | K3 |
| CO2 | Student would be able to Connect various chemical engineering subjects for common output | K2 |
| CO3 | Student would be able to Analyze large experimental data and results | K4 |
| CO4 | Student would be able to Improve ability to write scientific reports | K3 |
| CO5 | Student would be able to Improve ability draw conclusions | K3 |
| CO6 | Student would be able to write and present technical reports and documents, and communicating experimental findings orally to colleagues | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Laboratory - III: CEP4253**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - | 2 | - | - | - | 2 | 1 | 1 |
| CO2 | 3 | 2 | 2 | - | - | - | - | - | - | 1 | 1 | 2 |
| CO3 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | 1 | 2 | |
| CO4 | 3 | 1 | 1 | 2 | - | - | - | - | - | 2 | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | 3 | 2 | - | - | - | - | 1 | - | - | 2 | 1 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Laboratory - III: CEP4253**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 3 | 2 | 3 | 1 |
| CO2 | 3 | 1 | 1 | 3 | - |
| CO3 | 1 | 2 | 3 | 1 | 2 |
| CO4 | 2 | 1 | 2 | 2 | 2 |
| CO5 | 2 | 1 | 2 | 2 | 2 |
| CO6 | 1 | 2 | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester V | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CEP4255** | **Course Title: Process Simulation Laboratory - I** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: V** | **Total contact hours: 60** | **0** | **0** | **4** |

| List of Prerequisite Courses | | |
|---|---|---|
| | XIIth Standard Physics and Mathematics, Applied Physics: I and II (PHT4151), Applied Mathematics: I and II (MAT4151 and MAT4152) | |
| **List of Courses where this course will be prerequisite** | | |
| | Process Simulation Lab-II (CEP4256), Advanced Reaction Engineering (CET4553), Advanced Transport Phenomena (CET4551) | |

**Description of relevance of this course in the Int. M. Tech. Program**

To learn to write programs on Chemical Engineering processes and equipment.
To learn the design aspects equipment through programming
To Learn the solving process of Chemical Engineering problems through computational techniques

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1. | 3-4 experiments on calculation of chemical properties by equation of state, fugacity and Gibbs' energy models | 12 |
| 2. | 2-3 experiments on computation of vapor-liquid equilibria and liquid-liquid equilibria | 8 |
| 4 | 2-3 experiments on flash vessel calculations, estimation of bubble point and dew point conditions | 12 |
| 6 | 5-6 Design of chemical engineering equipment such as absorber, stripping unit, distillation unit, liquid-liquid extractor, cooling tower | 28 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Coker, Ludwig's Applied Process Design for Chemical and Petrochemical Plants | |
| 2 | Perry's Chemical Engineering Handbook | |
| 3 | Albright's Chemical Engineering Handbook | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Use advanced programming software with built in functions | K3 |
| CO2 | Write own functions | K4 |
| CO3 | Solve chemical engineering problems using computers | K4 |
| CO4 | Design a chemical engineering equipment for separation process | K4 |
| CO5 | Students will acquire skills in building and running a process simulation model to predict the behavior of a process and to conduct technical-economic optimization. | K4 |
| CO6 | Pursue by using a commercial simulation software. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Process Simulation Laboratory - I: CEP4255**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | 3 | 1 | 1 | 1 | - | - | - | - | 2 | - |
| CO2 | 1 | 2 | 3 | 1 | 2 | 1 | - | - | - | - | 2 | - |
| CO3 | 1 | 2 | 1 | 2 | 1 | 1 | - | - | - | - | 3 | - |
| CO4 | 3 | 1 | 1 | 1 | - | 1 | - | 2 | - | - | 1 | - |
| CO5 | 2 | 2 | 2 | 1 | 1 | 1 | - | 2 | - | - | 2 | - |
| CO6 | 3 | 2 | 1 | - | - | - | - | 1 | - | - | 1 | 2 |

| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; |
|---|

| **Process Simulation Laboratory - I: CEP4255**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 1 | 2 | - |
| CO2 | 2 | 3 | 2 | 1 | - |
| CO3 | 2 | 1 | 3 | 3 | 1 |
| CO4 | 1 | 2 | 3 | 3 | 1 |
| CO5 | 2 | 2 | 3 | 3 | 1 |
| CO6 | 2 | 3 | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Third Year

# Semester-VI

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4354** | **Course Title: Chemical Process Control** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 30** | **1** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Mathematics I and II (MAT4151 and MAT4152), Instrumentation and Process dynamics (CET4256), Chemical Reaction Engineering (CET4351), Process safety (CET4255), Mathematical Methods & Optimization in Chemical Engineering (Hon.) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Industrial Management (HUT4157), Chemical Engineering Lab-IV (CEP4354), Chemical Process Development and Engineering (CET4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Process control plays an overly critical role in the context of actual operation of a chemical plant. Most of the core chemical engineering courses focus on the steady state operation. In the real-life environment, process is continuously subjected to various disturbances which deviate the operation from the designed steady state. This course specifically prepares students to assess the impact of such disturbances and equip them with the tools available with the chemical engineer to tackle these situations. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Controller tuning: Open loop tuning, closed loop tuning, characteristic equation, Routh-Hurwitz criterion | | 6 | | |
| 2 | Design of controllers using simple performance criteria, time-integral performance criteria. Design of controllers using frequency response technique, Nyquist, and Bode Stability criteria, | | 8 | | |
| 3 | Control Strategies- Cascade control, Ratio Control, Feedforward control, Dead time compensation | | 6 | | |
| 4 | Modern control strategies, Internal model control, Dynamic Matrix control | | 4 | | |
| 6 | Control of batch processes, programmable logical controllers, Distributed control systems, supervisory Control systems | | 2 | | |
| 7 | Digital control systems, Introduction to z-transforms | | 4 | | |
| | **Total** | | **30** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Chemical Process Control- George Stephenopoulus | | | | |
| 2 | Process control- Shinskey | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | To design a controller and understand behavior of a close loop-controlled system | | K4 | | |
| CO2 | To evaluate performance of a close loop control system, stability and controllability, Robustness | | K4 | | |
| CO3 | To select and Design control strategy | | K3 | | |
| CO4 | To evaluate a advanced control system, design feedforward controllers | | K4 | | |
| CO5 | To evaluate digital control systems | | K4 | | |
| CO6 | Develop the transfer function for a given system to generate response for a given forcing function. and develop block diagram for a given process | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Chemical Process Control: CET4354**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 1 | 3 | 2 | 1 | - | - | 1 | 1 | - |
| CO2 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 3 | - |
| CO3 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | - | - | 3 | 2 | - |
| CO4 | 1 | 1 | 2 | 1 | 1 | 1 | - | - | - | 1 | 2 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | 2 | 3 | 1 | 1 | 3 | 1 | - | - | 1 | 2 | 1 | - |
| CO6 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | - | 1 | - | 3 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Process Control: CET4354**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 2 | 3 | 3 | 1 |
| CO2 | 1 | 2 | 3 | 2 | - |
| CO3 | 1 | 3 | 2 | 3 | 2 |
| CO4 | 2 | 2 | 3 | 2 | 1 |
| CO5 | 1 | 2 | 2 | 3 | 1 |
| CO6 | 2 | 2 | 3 | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4356** | **Course Title: Separation Processes** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 30** | **1** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Material & Energy Balance Calculations (CEP4151), Chemical Engineering Operations (CET4254), Engineering Thermodynamics (EST4155), Momentum Transfer (CET4352), Applied Mathematics I and II (MAT4151 and MAT4152), Chemical Engineering Laboratory I, II and III (CEP4251, CEP4252 and CEP4253), Process Simulation Lab: I (CEP4255) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Chemical Engineering Laboratory IV (CEP4254), Process Simulation Lab - II (CEP4256), Chemical Process Development and Engineering (CET4451), Chemical Process Development and Engineering (CET4451), Multiphase Reaction Engineering (Non.) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This is a course further built up on and in continuation with Chem. Eng. operations. It forms the basis of Chemical Engineering Principles and hence it is required in almost all the courses and throughout the professional career of a Chemical Engineer.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Extraction and Leaching of ternary systems: Ternary diagrams, Hunter-Nash graphical method and Maloney–Schubert graphical equilibrium-stage method, Solvent Selection, Operating point, number of stages, maximum solvent to feed ratios, minimum reflux, minimum number of stages, Introduction to reactive extraction, aqueous two phase extraction, extraction of biomolecules, supercritical fluid extraction, Solid-liquid extraction: Solid - liquid equilibria, efficiency, performance evaluation, Equipment for extraction, leaching and their sizing, Design considerations | 10 |
| 2 | Adsorption and Ion exchange: Liquid Adsorption, Ion-Exchange Equilibria, Equilibria in Chromatography, Breakthrough Curves, Kinetic and transport considerations, Convection-Dispersion Model, Separation Efficiency (Plate Height or Bandwidth), Correlations for Transport-Rate Coefficients, Equipment for sorption operations, Scale-Up and Process Alternatives, Adsorptive Membranes, simulated-moving-bed operation, modes of operation | 5 |
| 3 | Crystallization: Theory of solubility and crystallization, phase diagram (temp/solubility relationship), Supersaturation, Nucleation, Crystal Growth, Population balance analysis, method of moments for rate expressions for, volume, area and length growth, CSD distribution, MSMPR operation, evaporative and cooling (rate expressions), most dominant size, ideal classified bed, Precipitation, Melt crystallization, Process design of crystallizers and their operation | 5 |
| 4 | Humidification and Cooling Towers: Method of changing humidity and equipment, Cooling tower process design, counter-current, concurrent, and cross current, mass and heat balances in bulk and interfaces, Estimation of air quality, performance evaluation of cooling towers. | 5 |
| 5 | Membrane Separations: Types of separations, reverse osmosis, ultrafiltration, gas separation, vapour permeation and pervaporation, dialysis, electrodialysis, nanofiltration, Transport Through Porous Membranes, Resistance Models, Liquid Diffusion Through Pores, Gas Diffusion Through Porous Membranes, Transport Through Nonporous Membranes, Solution-Diffusion for Liquid Mixtures, Gas Mixtures, Concentration Polarization and Fouling, Membrane modules, arrangement of modules in cascades, performance criteria and design considerations | 5 |
| | **Total** | **30** |

**List of Textbooks/ Reference Books**


| | |
|---|---|
| 1 | Richardson, J.F., Coulson, J.M., Harker, J.H., Backhurst, J.R., 2002. Chemical engineering: Particle technology and separation processes. Butterworth-Heinemann, Woburn, MA. |
| 2 | Seader, J.D., Henley, E.J., 2005. Separation Process Principles, 2 ed. Wiley, Hoboken, N.J. |
| 3 | McCabe, W., Smith, J., Harriott, P., 2004. Unit Operations of Chemical Engineering, 7 ed. McGraw-Hill Science/Engineering/Math, Boston. |
| 4 | Green, D., Perry, R., 2007. Perry's Chemical Engineers' Handbook, Eighth Edition, 8 ed. McGraw-Hill Professional, Edinburgh. |

| | | |
|---|---|---|
| 5 | Dutta, B.K., 2007. Principles of Mass Transfer and Separation Process. Prentice-Hall of India Pvt. Ltd, New Delhi. | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | List situations where liquid–liquid extraction might be preferred to distillation, Make a preliminary selection of a solvent using group-interaction rules, Size simple extraction equipment | K2 |
| CO2 | Differentiate between chemisorption and physical adsorption, List steps involved in adsorption of a solute, and which steps may control the rate of adsorption, Explain the concept of breakthrough in fixed-bed adsorption | K2 |
| CO3 | Explain how crystals grow, Explain the importance of supersaturation in crystallization. | K2 |
| CO4 | Explain membrane processes in terms of the membrane, feed, sweep, retentate, permeate, and solute-membrane interactions. | K2 |
| CO5 | Distinguish among microfiltration, ultrafiltration, nanofiltration, virus filtration, sterile filtration, filter-aid filtration, and reverse osmosis in terms of average pore size. Explain common idealized flow patterns in membrane modules. | K5 |
| CO6 | Describe effects of mixing on supersaturation, mass transfer, growth, and scale-up of crystallization | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Separation Processes: CET4356**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | - | - | 1 | 3 | - |
| CO2 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | - | - | 2 | 1 | - |
| CO3 | 3 | 2 | 1 | - | 1 | 1 | 1 | - | - | 1 | 2 | - |
| CO4 | 2 | 1 | 2 | 1 | 1 | 2 | 3 | - | - | 1 | 1 | - |
| CO5 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | - | - | 1 | 2 | - |
| CO6 | 2 | 1 | 2 | 2 | - | - | - | - | - | - | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Separation Processes: CET4356**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | 2 | - |
| CO2 | 3 | 2 | 2 | 1 | 1 |
| CO3 | 1 | 2 | 1 | 2 | 2 |
| CO4 | 1 | 2 | 1 | 1 | 1 |
| CO5 | 2 | 2 | 1 | 2 | 1 |
| CO6 | 1 | 1 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CET4357** | **Course Title:** **Heat Transfer Equipment Design** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 30** | **1** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Momentum transfer (CET4352), Chemical Engineering Operation (CET4254), Applied Mathematics I and II (MAT4151 and MAT4152), Material and Energy Balance Calculations (CEP4151), Chemical Reaction Engineering (CET4351) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Multiphase Reactor Engineering (HONOURS Syllabus), Chemical Process Development and Engineering (CET4451), Environmental Engineering and Process Safety (CETxxx), Chemical Engineering Lab-IV (CEP4354), Chemical Process Development and Engineering (CET4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This is a basic course that deals with heat transfer, heat exchangers and their design. Heat transfer forms one of the basic pillars of Chemical Engineering Education and is required in all future activities. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Shell and tube heat exchangers: Basic construction and features, TEMA exchanger types, their nomenclature, choice of exchanger type, correction to mean temperature difference due to cross flow, multi-pass exchangers. Design methods for shell and tube heat exchangers such as Kern Method, Bell: Delaware method | | 8 | | |
| 2 | Finned tube exchangers, air-cooled cross flow exchangers and their process design aspects | | 3 | | |
| 3 | Compact Exchangers: Plate, Plate fin, Spiral, etc.: Construction, features, advantages, limitations and their process design aspects | | 3 | | |
| 4 | Condensation of vapors: theoretical prediction of heat transfer coefficients, practical aspects, horizontal versus vertical condensation outside tubes, condensation inside tubes, Process Design aspects of total condensers, condensers with de-superheating and subcooling, condensers of multicomponent mixture, condensation of vapors in presence of non-condensable. | | 8 | | |
| 5 | Heat transfer to boiling liquids: Process design aspects of evaporators, natural and forced circulation reboilers | | 8 | | |
| | **Total** | | **30** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Heat Transfer, Kern D.Q. | | | | |
| 2 | Heat Exchangers, Kakac S., Bergles A.E., Mayinger F | | | | |
| 3 | Process Heat Transfer, G. Hewitt | | | | |
| | | | | | |
| | | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Calculate heat duty/outlet temperatures/pressure drops/area required for various equipment like double pipe heat exchangers, shell and tube heat exchangers, plate heat exchangers, condensation, evaporation, agitated tanks. | | K4 | | |
| CO2 | Identify and select type of shell and tube exchanger based on TEMA classification. | | K2 | | |
| CO3 | Design a reboiler system for distillation | | K4 | | |
| CO4 | Analyze the performance of heat transfer equipment, such as parallel and counter flow heat exchangers, and radiation through black and gray bodies. | | K4 | | |
| CO5 | Design heat transfer equipment, such as shell and tube heat exchangers, and plate type heat exchangers. | | K6 | | |
| CO6 | Evaluate the number of stages required for a given mass transfer problem | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Heat Transfer Equipment Design: CET4357<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | - | - | 1 | 2 | - |
| CO2 | 3 | - | - | 1 | 1 | - | - | - | - | 2 | 1 | - |
| CO3 | 3 | 2 | 2 | 1 | 2 | 3 | 3 | - | - | 1 | 2 | - |
| CO4 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | - | - | 1 | 1 | - |
| CO5 | 2 | 3 | 3 | 1 | - | - | - | - | - | 1 | 2 | 2 |
| CO6 | 1 | 2 | 2 | - | - | - | - | - | - | 1 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Heat Transfer Equipment Design: CET4357<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 3 | 3 | 2 | 1 |
| CO2 | 3 | 1 | 2 | 1 | - |
| CO3 | 2 | 1 | 2 | 3 | - |
| CO4 | 2 | 1 | 2 | 2 | 1 |
| CO5 | 2 | 3 | 3 | 1 | - |
| CO6 | 3 | 2 | 1 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CEP4256** | **Course Title: Process Simulation Laboratory - II** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 60** | **0** | **0** | **4** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | XIIth Standard Physics and Mathematics, Applied Physics (PHT4151), Applied Mathematics: I and II (MAT4151-52), Process Simulation Lab-II (CEP4255), Chemical Engineering Operations (CET4254) | |
| **List of Courses where this course will be prerequisite** | | |
| | Advanced Reaction Engineering (CET4553), Advanced Transport Phenomena (CET4551) | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| To learn to write programs on Chemical Engineering processes and equipment.<br>To learn the design aspects equipment through programming<br>To learn the solving process of Chemical Engineering problems through computational techniques | | |
| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
| 1 | Design of multicomponent distillation | 6 |
| 2 | Design of shell and tube heat exchanger | 6 |
| 3. | Design of evaporator | 4 |
| 4. | design of adiabatic drier | 4 |
| 6 | 2-3 experiments on momentum transport | 8 |
| 7. | 1-2 experiment of multicomponent reaction | 4 |
| 8. | Design of reactor | 4 |
| 9 | 2-3 process flow sheet calculation | 20 |
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Coker, Ludwig's Applied Process Design for Chemical and Petrochemical Plants | |
| 2 | Perry's Chemical Engineering Handbook | |
| 3 | Albright's Chemical Engineering Handbook | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Solve chemical engineering design problems involving iterative calculations | K4 |
| CO2 | Solve chemical engineering problems involving non-linear equations coupled with differential equations | K4 |
| CO3 | Solve chemical engineering problems using computers | K4 |
| CO4 | Design a chemical engineering equipment for separation process | K4 |
| CO5 | Students will acquire skills in building and running a process simulation model to predict the behavior of a process and to conduct technical-economic optimization. | K4 |
| CO6 | Pursue by using a commercial simulation software. | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Process Simulation Laboratory - II: CEP4256**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | 3 | 1 | 1 | 1 | - | - | - | - | 2 | - |
| CO2 | 1 | 2 | 3 | 1 | 2 | 1 | - | - | - | - | 2 | - |
| CO3 | 1 | 2 | 1 | 2 | 1 | 1 | - | - | - | - | 3 | - |
| CO5 | 3 | 1 | 1 | 1 | - | 1 | - | 2 | - | - | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO6 | 2 | 2 | 2 | 1 | 1 | 1 | - | 2 | - | - | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Process Simulation Laboratory - II: CEP4256**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 2 | - |
| CO2 | 2 | 3 | 2 | 1 | - |
| CO3 | 2 | 1 | 3 | 3 | 1 |
| CO4 | 1 | 2 | 3 | 3 | 1 |
| CO5 | 2 | 2 | 3 | 3 | 1 |
| CO6 | 2 | 3 | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CEP5254** | **Course Title: Chemical Engineering Laboratory -IV** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 60** | **0** | **0** | **4** |
| **List of Prerequisite Courses** | | | | | |
| | Chemical Engineering Laboratory I, II and III (CEP4251, CEP4252, and CEP4253), Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT4151 and MAT4152), Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Chemical Engineering Thermodynamics (CET4353), Chemical Process Control (CET4354), Separation Processes (CET4356), Heat Transfer Equipment design (CET4357), Chemical Engineering Operations (CET4254) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | 2-3 Experiments on Multiphase Reactors | | 10 | | |
| 3 | 3-5 Experiments on Chemical Process Control and Dynamics | | 20 | | |
| 4 | 6-8 Experiments on Mass Transfer and Separation Processes | | 30 | | |
| | **Total** | | **60** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014 | | | | |
| 2 | Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007 | | | | |
| 3 | Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996. | | | | |
| 4 | Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Student would be able to Completely design and implement the experimental procedure | | K3 | | |
| CO2 | Student would be able to Process complex information to solve chemical engineering problems | | K2 | | |
| CO3 | Student would be able to Connect classroom teaching with the laboratory practical | | K3 | | |
| CO4 | Student would be able to Improve understanding about safety in the laboratory | | K4 | | |
| CO5 | Student would be able to evaluate and write the report based on results | | K6 | | |
| CO6 | Student would be able to Connect classroom teaching with the laboratory practical | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Chemical Engineering Laboratory - IV: CEP4254**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - | 2 | - | - | - | 2 | 1 | 1 |
| CO2 | 3 | 2 | 2 | - | - | - | - | - | - | 1 | 1 | 2 |
| CO3 | 3 | 2 | 1 | 1 | - | 1 | - | - | - | 1 | 2 | |
| CO4 | 3 | 1 | 1 | 2 | - | - | - | - | - | 2 | 1 | - |
| CO5 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO6 | 2 | 3 | 2 | 1 | 1 | 2 | - | - | - | - | 2 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Laboratory - IV: CEP4254**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 2 | 3 | 2 | 3 | 1 |
| CO2 | 3 | 1 | 1 | 3 | - |
| CO3 | 1 | 2 | 3 | 1 | 2 |
| CO4 | 2 | 1 | 2 | 2 | 2 |
| CO5 | 2 | 1 | 2 | 2 | 2 |
| CO6 | 3 | 2 | 1 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4358** | **Course Title: Chemical Project Economics** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Material and Energy Balance Calculations (CEP4151), Industrial Chemistry and reaction Engineering (CET4253) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Industrial Management (HUT4157), Chemical Process Development and Engineering (CET4451) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course is required for the future professional career | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Introduction to greenfield projects and global nature of projects; Impact of currency fluctuations on Project justification and cash flows and Concepts of "Quality by Design" including typical design deliverables and understanding constructability, operability and maintainability during all stages of project execution. Meaning of Project Engineering, various stages of project implementation | | 4 | | |
| 2 | Relationship between price of a product and project cost and cost of production, EVA analysis. Elements of cost of production, monitoring of the same in a plant, Meaning of Administrative expenses, sales expenses etc. Introduction to various components of project cost and their estimation. Introduction to concept of Inflation, location index and their use in estimating plant and machinery cost. Various cost indices, Relationship between cost and capacity. | | 4 | | |
| 4 | Project financing: debt: Equity ratio, Promoters' contribution, Shareholders' contribution, source of finance, time value of money. Concept of interest, time value of money, selection of various alternative equipment or system based on this concept. Indian norms, EMI calculations. Depreciation concept, Indian norms and their utility in estimate of working results of project. Working capital concept and its relevance to project. | | 4 | | |
| 5 | Estimate of working results of proposed project. Capacity utilization, Gross profit, operating profit, profit before tax, corporate tax, dividend, Net cash accruals. Project evaluation: Cumulative cash flow analysis Break-Even analysis, incremental analysis, various ratios analysis, Discounted cash flow analysis | | 4 | | |
| 6 | Process Selection, Site Selection, Feasibility Report | | 4 | | |
| 7 | Project: Conception to Commissioning: milestones, Project execution as conglomeration of technical and non-technical activities, contractual details. Contract: Meaning, contents, Types of contracts. Lump-sum Turnkey (LSTK), Eng, Procurement and Construction (EPC), Eng, Procurement and Construction Management (EPCM). Mergers and Acquisitions | | 4 | | |
| 8 | Reading of Balance Sheets and evaluation of Techno-commercial Project Reports. | | 2 | | |
| 9 | PERT, CPM, bar charts and network diagrams | | 4 | | |
| | **Total** | | **30** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Chemical Project Economics, Mahajani V. V. and Mokashi S M. | | | | |
| 2 | Plant Design and Economics for Chemical Engineers, Peters M. S., Timmerhaus K.D. | | | | |
| 3 | Process Plant and Equipment Cost Estimation, Kharbanda O.P. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Calculate working capital requirement for a given project | | K4 | | |
| CO2 | Calculate cost of equipment used in a plant total project cost | | K4 | | |
| CO3 | Calculate cash flow from a given project | | K4 | | |
| CO4 | Select a site for the project from given alternatives | | K3 | | |
| CO5 | List out various milestones related to project concept to commissioning | | K3 | | |
| CO6 | Evaluate the measurement and treatment of risk in project evaluation and understand how simulation can be applied to risk evaluation. | | K5 | | |

| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating |
|---|

| **Chemical Project Economics: CET4358**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 1 | - | 2 | 3 | 1 | - | - | 1 | 1 | - |
| CO2 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | - | - | 2 | 2 | 2 |
| CO3 | 3 | - | 1 | 1 | 2 | 1 | 1 | - | - | 1 | 1 | - |
| CO4 | 1 | - | 2 | - | 2 | - | 3 | - | - | - | 2 | - |
| CO5 | - | 1 | 2 | 1 | - | - | - | - | - | 1 | 1 | - |
| CO6 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | - | - | 1 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Project Economics: CET4358**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 1 | 2 | 3 | 1 | - |
| CO2 | 2 | 2 | 2 | 2 | 1 |
| CO3 | 2 | 3 | 3 | 1 | - |
| CO4 | 1 | 2 | 2 | 3 | 1 |
| CO5 | - | 2 | 3 | 1 | - |
| CO6 | 2 | 2 | 3 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VI | | | | | |
|---|---|---|---|---|---|
| **IPT** | **Course Code: CEP4373** | **Course Title: IPT** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VI** | **Total contact hours: 40** | **0** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | All | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | All | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course enables students to integrate all the subjects that they have learnt and design plants / Process from Chemical Engineering Principles | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | IPT | | **40** | | |
| | **Total** | | **40** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Identify market requirement related to a particular chemical | | K2 | | |
| CO2 | Draw a process block diagram from a given process description | | K5 | | |
| CO3 | Select a site for the project | | K3 | | |
| CO4 | Develop a PFD based on block diagram | | K5 | | |
| CO5 | Do material and energy for all the equipment in PFD | | K5 | | |
| CO6 | Students will be knowledgeable about the application of IPT theory and practice with a variety of presenting problems and groups. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**IPT: CEP4373**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 3 | 2 | 1 | 1 | 2 | 2 | 1 | - | 1 | 3 | 2 |
| CO2 | 3 | 2 | 1 | 2 | - | 1 | 2 | - | - | 1 | 2 | 1 |
| CO3 | - | 1 | 1 | 2 | 1 | 1 | - | - | 2 | 2 | 1 | 2 |
| CO4 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 2 | 3 |
| CO5 | 2 | 2 | 1 | 2 | 1 | 2 | 3 | - | - | 2 | 3 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**IPT: CEP4373**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 3 | 2 | 1 | 2 | - |
| CO3 | 3 | 3 | 2 | 2 | - |
| CO4 | 2 | 2 | 2 | 1 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| CO5 | 2 | 1 | 2 | 3 | 3 |
| CO6 | 3 | 2 | 2 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Fourth Year

# Semester-VII

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CET4451** | **Course Title:** **Chemical Process Development and Engineering** | **Credits = 3** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 45** | **2** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Chemistry (CHT4151 and CHT4152), Introduction to Chemical Engineering (EST4154), Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4251), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Industrial Chemistry and Reaction Engineering (CET4253),Chemical Engineering Operation (CET4254), Process Safety (CET4255), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Chemical Process Control (CET4354), Separation Process (CET4356), Heat Transfer Equipment Design (CET4357), Chemical Project Economics (CET4358) Material Science and Engineering (CEP4151), Industrial Management (HUT4157), Biochemical Engineering (Hon.) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Chemical Industrial Management (CET4452), Chemical Process Equipment Design and Drawing (CEP4451), Biochemical Engineering (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course integrates all the chemical engineering and allied subjects for appropriate design of process plants, in selection of processes and evaluating alternatives | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Development of a preliminary Process System: Modular approach | | 2 | | |
| 2 | Multiple process synthesis, selection of process, basic economic evaluation | | 2 | | |
| 3 | Sequencing of operations and integration in processes | | 2 | | |
| 4 | Batch vs continuous vs semi-batch processes- Scale up | | 2 | | |
| 5 | Process Engineering aspects of low and medium volume chemicals including process development. | | 4 | | |
| 6 | Concept of dedicated and multiproduct plant facilities, pilot plant, mini plants | | 2 | | |
| 7 | Development and evaluation of alternative flow sheets | | 2 | | |
| 8 | Scale up aspects; identification of controlling steps of process, | | 4 | | |
| 9 | Green Engineering principles | | 3 | | |
| 10 | Utilization of energy; cost of utilities, heat exchange networks | | 4 | | |
| 11 | Process intensification | | 4 | | |
| 12 | Preparation of Conceptual process and instrumentation diagrams. . | | 4 | | |
| 13 | Preparation of process specifications for typical equipment. | | 4 | | |
| 14 | Safety and Risk of chemical processes | | 4 | | |
| 15 | Learn from mistakes | | 2 | | |
| | **Total** | | **45** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Industrial Chemical Process Design, D. L. Erwine | | | | |
| 2 | Laboratory Chemical Process Development, Anderson N. | | | | |
| 3 | Organic Unit Processes, Groggins | | | | |
| 4 | Chemical Process Engineering: Design and Economics, Silla H. | | | | |
| 5 | Handbook of Chemical Process Development, Chandalia S. B. | | | | |
| 6 | Conceptual Chemical Plant Design, Douglas J. M. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | To select a strategy for a process from amongst the alternatives | | K2 | | |

| | | |
|---|---|---|
| CO2 | Determine strategy for carrying out a particular process; Apply knowledge: Use knowledge of mathematics, science, and engineering to design systems, components, or processes that meet needs while considering realistic constraints | K4 |
| CO3 | Prepare specifications for a particular equipment; Conduct experiments: Design and conduct experiments, and analyze and interpret data | K4 |
| CO4 | Calculate utility requirements; Work in teams: Function effectively on multi-disciplinary teams | K6 |
| CO5 | Develop sustainable innovations: Use research skills to develop sustainable innovations in interdisciplinary areas | K6 |
| CO6 | Develop managerial skills: Acquire essential managerial skills and ethical values to become leaders and team players | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Process Development and Engineering: CET4451**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | - | 1 | 1 | 2 | 1 | 2 | - | - | 2 | 2 | 1 |
| CO2 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 3 | 3 | 2 |
| CO3 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | - | - | 1 | 2 | - |
| CO4 | 3 | - | 1 | 1 | 2 | 1 | - | - | - | 2 | 1 | 1 |
| CO5 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | - | - | 3 | 2 | 1 |
| CO6 | 2 | 3 | 2 | 1 | 2 | - | - | - | - | 2 | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Process Development and Engineering: CET4451**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 3 | 2 | 1 | - |
| CO2 | 2 | 2 | 3 | 2 | 1 |
| CO3 | 1 | 2 | 3 | 3 | 2 |
| CO4 | - | 2 | 3 | 3 | 3 |
| CO5 | 2 | 2 | 3 | 3 | 2 |
| CO6 | - | 1 | 2 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code: CET4452** | **Course Title: Chemical Industrial Management** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 30** | **2** | **0** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Chemical Process Development and Engineering (CET 4451), Industrial Management (HUT4157) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course integrates all chemical industrial process and their management. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Basics of management<br>The eras of management<br>Mission and vision of organizations | | 3 | | |
| 2 | Micro organizational behaviour<br>Psychoanalytical framework<br>Common personality traits<br>Hofstede cultural dimensions | | 5 | | |
| 3 | Employee Recruitment and Selection<br>Concept of Role<br>Job description and man specifications<br>Some methods of recruitment<br>Selection methods | | 6 | | |
| 4 | Employee performance<br>MBO<br>Appraisal methods<br>Review meetings | | 5 | | |
| 5 | Employee motivation<br>Employee predisposition to motivation<br>Goal setting<br>Recent motivation theories<br>How to motivate trouble spots | | 5 | | |
| 6 | Group dynamics.<br>Theories of group formation<br>Pitfalls of a group<br>Conflicts | | 6 | | |
| | **Total** | | **30** | | |
| **List of Text Books/ Additional Reading Material / Reference Books** | | | | | |
| 1 | Human Resource Management (15e) - Gary Dessler, Biju Varrkey gement(15e)-Robbins | | | | |
| 2 | Select HBR articles | | | | |
| 3 | Industrial/Organizational Psychology: An Applied Approach- Michael Aamodt | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Student would be able to understand the process of corporate recruitment. | | K2 | | |
| CO2 | Student would be able to use the information while applying for jobs | | K3 | | |
| CO3 | Student would be able to gain knowledge on how to perform well in an interview process. | | K3 | | |
| CO4 | Student would be able to gain knowledge on how goals are set in any organization and performance is measured. | | K3 | | |

| | | |
|---|---|---|
| CO5 | Student would be able to learn basic management concepts and laws, marketing skills, and how to prepare policy documents. They can also learn how to manage human resources in industry, including understanding human psychology, attitudes, morals, and stress limits. | K5 |
| CO6 | Students would be able to learn how to produce industrial acids, bases, gases, cement, glass, soaps, pulp, paper, sugar, industrial alcohol, paint, dyes, and fertilizers. They can also learn about process flow diagrams, process parameters, and how to identify and solve engineering problems during production. | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Industrial Management: CET4452**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | 2 | 1 | - | - | - | 3 | 1 | 2 | 2 | 1 |
| CO2 | - | - | 2 | 2 | - | - | - | 3 | 2 | 1 | 3 | 2 |
| CO3 | - | - | 1 | 1 | - | 1 | - | 2 | 1 | 2 | 1 | 1 |
| CO4 | - | - | 1 | 1 | - | 1 | - | 2 | 1 | 2 | 2 | 2 |
| CO5 | - | - | 2 | 1 | - | 1 | - | 3 | 1 | 2 | 2 | 2 |
| CO6 | - | - | 2 | 3 | - | 3 | 3 | 2 | 3 | 2 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Industrial Management: CET4452**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 2 | 3 | 2 | 2 | 1 |
| CO3 | 2 | 3 | 2 | 1 | - |
| CO4 | 2 | 2 | 3 | 2 | 1 |
| CO5 | 2 | 3 | 2 | 1 | 1 |
| CO6 | 2 | 2 | 3 | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CEP4451** | **Course Title:** **Chemical Process Equipment Design & Drawing** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 60** | **0** | **0** | **4** |
| **List of Prerequisite Courses** | | | | | |
| | Structural Mechanics (EST4151), Materials Science and Engineering, Engineering Graphics (ESP4152), Chemical Project Economics (CET4358), Chemical Process Development and Engineering (CET 4451) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Knowledge of chemicals and chemical producing equipment and plants are essential for professional Chemical engineer and Technologist. This subject will help students to understand use of basics of applied science in the form of mechanics, strength of materials, selection of materials and suitable manufacturing techniques and the details of operating conditions of equipment and its design procedure. This will help Chemical engineer to understand process equipment and their design concept and section of proper equipment for the designed functions of the plats. It will help them to understand various design codes used for fabrication of these equipment and the various types of destructive and non-destructive tests performed on equipment before and after assembly of equipment defining its capacity, reliability, and its life. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Basic design concepts, use of standards and design stresses and factor of safety, selection of materials, working conditions, corrosion and its effects on equipment's. Standard design codes | | 6 | | |
| 2 | Design of pressure vessels: stresses acting on pressure vessels, operating conditions, selection of materials, pressure vessel codes, design stress and design criteria's, Design of Shell, Head, Nozzle, Flanged joints for heads and nozzles | | 6 | | |
| 3 | Design of Storage vessels: Storage of various types of fluids and liquids in tanks, Loss mechanism of storage of volatile and non-volatile liquids and gases, Types of storage vessels, Vessels for storing of gases, method of storage of gases, Design of rectangular and cylindrical tank with components such as shell, bottom plate, self-supporting roof design, types of roofs, | | 6 | | |
| 4 | Testing of process equipment, various | | 4 | | |
| 5 | Mechanical Design of Reaction Vessels.<br>Design of shells subjected to internal and external pressures.<br>Types of Jackets /Coils used for heating and cooling in reaction vessels and their design.<br>Type of agitators and their design.<br>Design of agitator system components such as shafts, stuffing box etc. | | 14 | | |
| 7 | Mechanical Design of Heat Exchangers<br>Components of shell and tube type heat exchangers.<br>Design of various components of heat exchangers such as Fixed tube sheet type, U tube, Floating head etc.<br>Various codes for heat exchangers. | | 12 | | |
| 8 | Mechanical design of distillation columns<br>Various components of columns such as trays, packings, downcomers, bubble cap etc<br>Design of shell for various stress conditions.<br>Tray supports and their design | | 12 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Process equipment Design By V V Mahajani, S. B. Umarji | | | | |
| 2 | Equipment Design by Dawande | | | | |
| 3 | Process equipment Design by Young | | | | |
| 4 | Welding Technology by O.P. Khanna, Welding Technoloy by Little | | | | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand general design procedure for chemical process equipment. | K2 |
| CO2 | Design and draw pressure vessels and its parts subjected to internal pressure. | K6 |
| CO3 | Design and draw reactors and its parts subjected to internal and external pressure. | K6 |
| CO4 | Design and draw shell and tube type of heat exchangers. | K6 |
| CO5 | Design and draw tray columns and its parts. | K6 |
| CO6 | Understand different types of supports for chemical process equipment. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Process Equipment Design & Drawing: CEP4451**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 2 | 3 | 3 | - | - | 1 | 1 | 1 |
| CO2 | 3 | 1 | 1 | 2 | 2 | 3 | 3 | - | - | 2 | 2 | 2 |
| CO3 | 3 | 1 | 2 | 1 | 1 | 2 | 2 | - | - | 1 | 1 | 1 |
| CO4 | 3 | 1 | 1 | 1 | 2 | 2 | 3 | - | - | 2 | 2 | - |
| CO5 | 2 | 1 | 1 | - | 2 | 2 | 2 | - | - | 1 | 2 | - |
| CO6 | - | - | - | - | 1 | 1 | 1 | - | - | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Process Equipment Design & Drawing: CEP4451**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 3 | 1 | - |
| CO2 | 1 | 2 | 3 | 3 | 1 |
| CO3 | 2 | 3 | 3 | 2 | 2 |
| CO4 | 1 | 2 | 3 | 3 | 3 |
| CO5 | 2 | 3 | 2 | 2 | 2 |
| CO6 | 3 | 1 | - | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **RM** | **Course Code:** **CEP4452** | **Course Title:** **Literature Review (Research Methodology: I)** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 30** | **1** | **0** | **2** |
| **List of Prerequisite Courses** | | | | | |
| | NA | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Design and Analysis Experiments (CEP4453), Design Project - I (CEP4461), Thesis (CEP4474 and CEP4475) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The formal exposure to various elements of research methods such as problem formulation, literature search, planning of various activities, documentation, budgeting, purchase, report/thesis compilation, manuscript writing, patent drafting, is critical for polishing the naïve research attitude and aptitude in the PG students of the programme. The course is designed to formally introduce various concepts of research methodology in stepwise manner to the students. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Introduction of Course<br>Academic Honesty Practices<br>General philosophy of science & Arguing About Knowledge<br>Case studies in science history | | 3 | | |
| 2 | Motivation and Background<br>Motivation/Demotivation for Research, Building Background for Research and How to read research papers | | 3 | | |
| 3 | Time Management (Academic and Non-academic time), Effort Management, Plan execution, Energy Management Issue, Role and expectation of research supervisor and student | | 4 | | |
| 4 | Finding and Solving Research Problems<br>What is Research, how to start? Approaches to find research problems and psychological experiments.<br>Literature survey, Textbooks, Review, and research papers<br>How to ask Questions<br>What is worthwhile research problem, Analytical and synthetic research approach | | 4 | | |
| 5 | Finding and Solving Research Problems<br>What is Research, how to start? Approaches to find research problems and psychological experiments.<br>Literature survey, Textbooks, Review and research papers, critical review of research papers, how to write literature survey report, how to ask Questions, formulating research questions, | | 4 | | |
| 6 | What is worthwhile research problem, Analytical and synthetic research approaches?<br>How to solve research problems, designing work plan, importance of objectives, activity and strategizing research work. Design of timeline for work plan (Gnatt Chart etc), Grant Writing Guidelines | | 4 | | |
| 7 | Experimental Research, Inventory Management, Material Management<br>Learning required skills for research, Documentation and lab notebook guidelines,<br>Safety aspects in chemical/biological research | | 4 | | |
| 8 | Methods and Tools used in Research: Qualitative studies; Quantitative studies; Simple data organization; Descriptive data analysis; Limitations and sources of error; Inquiries in form of Questionnaire, Opinionnaire or by interview; Statistical analysis of data including Variance, Standard deviation, Students ‘t’ test and Analysis of variance (ANOVA), Correlation data and its interpretation, Computer data analysis | | 6 | | |
| 9 | Scientific Writing<br>Skeleton of research paper, author guidelines, proficient writing skills, importance of discussion, Macro-level discussion.<br>Structure of the documents. General issues of presentability. Micro-level discussion.<br>Stylistic issues.<br>Examples of bad and good writings. | | 6 | | |

| | | |
|---|---|---|
| 10 | Publishing and Reviewing<br>Publication process, how to publish papers, where to submit, Review process and reacting to a review report.<br>Reviewing scientific papers | 4 |
| 11 | Scientific Norms and Conventions<br>Authorship.<br>Plagiarism. Simultaneous submissions. Reviewing norms. Referring to other papers. Use of data. Collaborative Research Work | 3 |
| | **Total** | **30** |
| **List of Textbooks/ Reference Books** | | |
| 1 | Menzel, D.; Writing a Technical Paper; McGraw-Hill, United States (1961). | |
| 2 | Best, J. W., Kahn, J. V., Jha, A. K.; Research in Education; 10th ed.; Pearson, New Delhi, India (2005) | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Understand the basic concepts of research and the components therein, formally | K2 |
| CO2 | Understand and appreciate the significance of statistics in Chemical Technology, Pharmacy and Chemical Engineering | K2 |
| CO3 | Understand and apply importance of literature survey in research design and understand an in-depth knowledge on the documentation in research | K3 |
| CO4 | Evaluate importance of various parts of a research report/paper/thesis in presentation of research results | K5 |
| CO5 | Understand the significance of several types of IPRs in research | K1 |
| CO6 | Create a model research project | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Literature Review (Research Methodology: I): CEP4452**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 2 | 3 | 1 | - | - | 2 | - | - | 3 | 1 | - |
| CO2 | 2 | 3 | 2 | 1 | - | - | 1 | - | - | 2 | 1 | - |
| CO3 | - | 3 | 3 | - | 1 | - | 1 | - | - | 3 | 2 | - |
| CO4 | - | 3 | 3 | 2 | - | - | 2 | - | - | 3 | 2 | - |
| CO5 | 2 | 2 | 2 | 2 | 1 | - | 1 | - | - | 3 | 2 | - |
| CO6 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | - | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Literature Review (Research Methodology: I): CEP4452**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 3 | - | - |
| CO2 | 3 | 1 | 2 | - | - |
| CO3 | 2 | 2 | 2 | - | - |
| CO4 | 3 | 2 | 2 | 2 | - |
| CO5 | 2 | 2 | 1 | 3 | 1 |
| CO6 | 1 | 2 | 2 | 3 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **RM** | **Course Code:** **CEP4453** | **Course Title:** **Design and Analysis of Experiments (Research Methodology: II)** | **Credits = 2** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 30** | **1** | **0** | **2** |
| **List of Prerequisite Courses** | | | | | |
| | Literature Review (CEP4452), Applied Mathematics I (MAT4151 and MAT4152) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | This course is required for graduating engineers to function effectively in Industry, Academia, and other professional spheres. This course is in Semester VIII | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Modern day manufacturing activities and R&D activities need decisions taken with a scientific rigor and should be well-supported by 'statistics. Chemical engineering graduates who will serve industry as well as postgraduate research students who will serve industry, R&D organizations, or academic research should have a good background of statistical decision making. This also involves extraction of meaningful data from well-designed minimal number of experiments at the lowest possible material costs. This course will also help the students in all domains of their life by imparting them a vision for critical appraisal and analysis of data. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Fundamental principles of classical design of experiments<br>Strategy of Experimentation, Typical applications of Experimental design, Basic Principles, Guidelines for Designing Experiments. | | 4 | | |
| 2 | Review of Probability and basic statistical inference:<br>Concepts of random variable, probability, density function cumulative distribution function. Sample and population, Measure of Central tendency; Mean median and mode, Measures of Variability, Concept of confidence level. Statistical Distributions: Normal, Log Normal & Weibull distributions, Hypothesis testing. | | 3 | | |
| 3 | Experiments with a Single Factor: The Analysis of Variance<br>Fixed effect model and Random effect model, Model adequacy checking, Contrasts, Orthogonal contrasts, Regression Models and ANOVA, Violation of Normality Assumption: Kruskal-Wallis test. Randomized block designs, Latin square designs, Balanced Incomplete Block Designs | | 6 | | |
| 4 | Factorial designs:<br>Definition, estimating model parameters, Fitting response curves and surfaces. | | 3 | | |
| 5 | The $2^k$ Factorial Design, Blocking and Confounding in the 2k Factorial Design; Focus of $2^2$ and $2^3$ designs, Blocking and Confounding in the $2^k$ Factorial Design. | | 6 | | |
| 6 | Plackett Burman methods, Central Composite Design (CCD) | | 3 | | |
| 7 | Descriptive Statistics, Probability Distribution and testing of Hypothesis using R | | 4 | | |
| 8 | Regression techniques, diagnostic checks, ANOVA using R and implementation of contrasts. | | 4 | | |
| 9 | Construction of Balanced Incomplete Block Designs and data analysis using R | | 4 | | |
| 10 | Analysis of factorial designs using R, understanding output and interpretation. | | 4 | | |
| 11 | Factorial designs, Data analysis and interpretation. | | 4 | | |
| | **Total** | | **30** | | |
| **List of Text Books / Reference Books** | | | | | |
| 1 | Douglas C. Montgomery, Design and Analysis of Experiments, 8th Edition, John Wiley & Sons, Inc. 2013 | | | | |
| 2 | Box, G. E., Hunter, W.G., Hunter, J.S., Hunter, W.G., Statistics for Experimenters: Design, Innovation, and Discovery, 2nd Edition, Wiley, 2005. | | | | |
| 3 | John Lawson, Design and Analysis of Experiments with R, CRC Press, 2015 | | | | |
| 4 | Dieter Rasch, Jürgen Pilz, Rob Verdooren, Albrecht Gebhardt Optimal Experimental Designs with R. CRC Press, 2011. | | | | |
| 5 | José Unpingco, Python for Probability, Statistics, and Machine Learning, Springer, 2019 | | | | |
| 6 | Response Surface Methodology: Process and Product Optimization using Designed Experiments: R. H. Myers, D. C. Montgomery. | | | | |

| | | |
|---|---|---|
| 7 | Introduction to Statistical Quality Control: D. C. Montgomery. | |
| 8 | Design of Experiments in Chemical Engineering: Živorad R. Lazić. | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Students should be able to understand basic principles of design of experiments. | K2 |
| CO2 | Students should be able to perform statistical analysis of single experiments and do post hoc analysis. | K4 |
| CO3 | Students should be able to conduct experiment and analyze the data using statistical methods. | K5 |
| CO4 | Students should be able to choose an appropriate design given the research problem. | K4 |
| CO5 | Students should be able to perform statistical analysis of different designs using R and interpret the results. | K6 |
| CO6 | Students should be able to identify and apply the basic principles of experimental design, including randomization, replication and control. | K4 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Design and Analysis of Experiments (Research Methodology: II): CEP4453**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | - | - | 2 | 1 | - |
| CO2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | - | - | 3 | 2 | - |
| CO3 | 3 | 2 | 1 | - | 2 | 2 | 1 | - | - | 2 | 1 | - |
| CO4 | 1 | 1 | 1 | 1 | - | 1 | 1 | - | - | 3 | 1 | - |
| CO5 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 3 | 1 | - |
| CO6 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | - | - | 3 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Design and Analysis of Experiments (Research Methodology: II): CEP4453**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 2 | - |
| CO2 | 2 | 2 | 2 | 1 | - |
| CO3 | 2 | 1 | 2 | 1 | - |
| CO4 | 3 | 1 | 2 | 1 | - |
| CO5 | 1 | 2 | 3 | 2 | - |
| CO6 | 3 | 2 | 2 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **Project** | **Course Code: CEP4461** | **Course Title: Design project: I** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 120** | **0** | **0** | **8** |
| **List of Prerequisite Courses** | | | | | |
| | All | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Home Paper II | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course enables students to integrate all the subjects that they have learnt and design plants / processes from Chemical Engineering Principles. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Every student will be required to solve a problem in design, which will be set by one or more of the teachers in the institution. The design will have to be submitted in the form of a standard-type report. Every student will be orally examined. The student will be assessed based on the progress made during the semester. There would be two submissions: (i) Process selection and PFD, (ii) Material and Energy Balance. The submissions will be presented to a panel of faculty members / examiners. There will be a weightage of 60% for the submissions and 40% for the presentation.<br>Additional details may be given to the students from time to time by the coordinator. | | **120** | | |
| | **Total** | | **120** | | |
| **List of Text Books/ Reference Books** | | | | | |
| | | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Identify market requirement related to a particular chemical | | K2 | | |
| CO2 | Draw a process block diagram from a given process description. | | K6 | | |
| CO3 | Select a site for the project | | K5 | | |
| CO4 | Develop a PFD based on block diagram | | K6 | | |
| CO5 | Do material and energy for all the equipment in PFD. | | K6 | | |
| CO6 | Identify needs and constraints of product development system and create a prototype model 5. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Design project: I: CEP4461**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 2 | 2 | 3 | 2 | - | - | - | 1 | 1 | - |
| CO2 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | - |
| CO3 | - | - | 2 | - | 1 | 1 | 2 | - | - | 1 | 1 | - |
| CO4 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | - | 2 | 2 | 2 | - |
| CO5 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | - | - | 3 | 2 | - |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 3 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Design project: I: CEP4461**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| CO1 | 2 | 2 | 3 | 3 | 2 |
| CO2 | 1 | 2 | 2 | 3 | 3 |
| CO3 | 1 | 2 | 3 | 3 | 2 |
| CO4 | 1 | 2 | 2 | 3 | 2 |
| CO5 | 2 | 1 | 3 | 3 | 3 |
| CO6 | 2 | 2 | 2 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Fourth Year

# Semester-VIII

| Semester VIII | | | | | |
|---|---|---|---|---|---|
| **IPT** | **Course Code: CEP4474** | **Course Title: IPT (4-6 Months)** | **Credits = 12** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VIII** | **Total contact hours: 180** | **0** | **0** | **40** |
| **List of Prerequisite Courses** | | | | | |
| | All | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | All | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| | This course enables students to integrate all the subjects that they have learnt and design plants / Process from Chemical Engineering Principles | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | IPT | | 180 | | |
| | **Total** | | **180** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| | | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Identify market requirement related to a particular chemical | | K2 | | |
| CO2 | Draw a process block diagram from a given process description | | K6 | | |
| CO3 | Select a site for the project | | K5 | | |
| CO4 | Develop a PFD based on block diagram | | K6 | | |
| CO5 | Do material and energy for all the equipment in PFD | | K6 | | |
| CO6 | Students will be knowledgeable about the application of IPT theory and practice with a variety of presenting problems and groups. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**IPT: CEP4474**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | 3 | 2 | 1 | 1 | 2 | 2 | 1 | - | 1 | 3 | 2 |
| CO2 | 3 | 2 | 1 | 2 | - | 1 | 2 | - | - | 1 | 2 | 1 |
| CO3 | - | 1 | 1 | 2 | 1 | 1 | - | - | 2 | 2 | 1 | 2 |
| CO4 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 2 | 3 |
| CO5 | 2 | 2 | 1 | 2 | 1 | 2 | 3 | - | - | 2 | 3 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**IPT: CEP4474**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 3 | 3 | 3 |
| CO2 | 3 | 3 | 2 | 2 | 2 |
| CO3 | 2 | 2 | 2 | 3 | 2 |
| CO4 | 1 | 2 | 3 | 2 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| CO5 | 1 | 2 | 2 | 3 | 1 |
| CO6 | 2 | 2 | 3 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Fifth Year

# Semester-IX

| Semester IX | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CET4551** | **Course Title:** **Advanced Transport Phenomena** | **Credits = 3** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 45** | **2** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Fluid Flow (CET4251), Momentum Transfer (CET4352), Applied Mathematics (MAT4151 and MAT4151), Applied Physics (PHT4151), Applied Chemistry (CHT4151), Chemical Engineering Operation (CET4254), Separation Processes (CET4356), Process Simulation Lab-I and II (CEP4255 and CEP4256) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Multiphase Reactor Engineering (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course introduces advanced concepts of momentum transfer and heat transfer to students. Various concepts such as pressure, momentum, energy, heat transfer, heat exchangers and their design are introduced. Laws related to conservation of momentum; energy are taught. Applications of these laws to various engineering situations and process equipment is explained with the help of several problems. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Turbulent flow: basics, Reynolds average Navier-Stokes equations, closure problem, Boussinesques hypothesis, Prandtl mixing length theory, turbulence models, energy spectrum, turbulent boundary layer, universal velocity profile | | 10 | | |
| 2 | Gas-liquid and solid-liquid fluidized beds: Characteristics of particles, Principle of fluidization and mapping of various regimes, two phase theory of fluidization, Bubbles in fluidized bed, Entrainment and Elutriation, Fast fluidized bed, Mixing, segregation and gas dispersion, Heat and mass transfer in fluidized bed, Solid-liquid fluidized bed and three phase fluidized bed, Design of fluidized bed reactors | | 10 | | |
| 3 | Forced and natural convective heat transfer, analogies of momentum and heat transfer, Heat transfer with phase change | | 10 | | |
| 4 | Design aspects of shell-and-tube heat exchangers (NTU-epsilon method; Bell-Delaware method), plate heat exchangers and spiral heat exchangers; Flow-stream analysis, Design of compact heat exchangers, Design aspects of condensers, reboilers, and evaporators | | 10 | | |
| 5 | Radiation heat transfer concepts, Angle factor calculations, Radiation calculation through gases and vapors, design methods for furnaces. | | 5 | | |
| | **Total** | | **45** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Transport Phenomena, R.B. Bird, W.E. Stewart, E.N. Lightfoot | | | | |
| 2 | Transport Phenomena, R.S. Brodkey | | | | |
| 3 | Momentum, Heat and Mass Transfer, Bennet and Myers | | | | |
| 4 | Fluid Mechanics, Pijush K. Kundu | | | | |
| 5 | Turbulent Flows: Fundamentals, Experiments and Modeling by G. Biswas, V. Eswaran | | | | |
| 6 | Heat Transfer: Jack P. Holman | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Calculate pressure drop in pipelines and equipment for different situations such as single- and two-phase flow, fixed and fluidized beds | | K3 | | |
| CO2 | Describe and discuss equation of motion for turbulent flows | | K2 | | |
| CO3 | Design various components of Heat transfer equipment | | K5 | | |
| CO4 | Compare various heat transfer equipment and select an appropriate equipment for a particular situation | | K5 | | |
| CO5 | Use information from balance equations to calculate engineering quantities like drag force, rate of heat and mass transfer, and pressure loss. | | K4 | | |
| CO6 | Analyze transport problems in simple and complex geometries using simulation software. | | K4 | | |

| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating |
|---|

| **Advanced Transport Phenomena: CET4551**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 2 | 1 | - | 1 | 1 | - | - | 1 | 1 | - |
| CO2 | 3 | 1 | 1 | 2 | - | - | - | - | - | 2 | 2 | - |
| CO3 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO4 | 2 | 1 | 1 | 2 | 1 | - | 1 | - | - | 2 | 1 | - |
| CO5 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | - | - | 2 | 2 | - |
| CO6 | 3 | 2 | 1 | 1 | - | - | - | - | - | 2 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Advanced Transport Phenomena: CET4551**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 2 | 3 | 3 | 3 | - |
| CO2 | 1 | 2 | 2 | 3 | - |
| CO3 | 1 | 2 | 3 | 2 | 2 |
| CO4 | 1 | 1 | 2 | 2 | 1 |
| CO5 | 1 | 2 | 3 | 3 | 1 |
| CO6 | 2 | 3 | 2 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IX | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CET4552 | Course Title: Advanced Separation Processes | Credits = 3 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 45 | 2 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Chemical Engineering Operation (CET4254), Separation Processes (CET4356) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Advanced Mass transfer Operations (CET4554), Multiphase Reaction Engineering (Hon.) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This is a course further built up on and in continuation with undergraduate level course on mass transfer and separation process. Advanced separation process such as membrane-based separation, adsorption, etc. are covered in detail. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Revision of basic concepts of Distillation, Design Aspects of multi-component distillation. Principles of azeotropic and extractive distillation processes, Residue Curve Maps. Use of ternary diagrams for azeotropic and extractive distillation. Designing separation strategy based on Residue Curve Maps. | | 9 | | |
| 2 | Revision of basic concepts of liquid extraction. Several types of extraction equipment and their design aspects. Liquid-liquid extraction; stage wise calculations for multicomponent with multiple feed streams using reflux and mixed solvents. Basic concepts and design calculations of Reactive extraction. Basic concepts and calculations of separation factor for dissociation extraction. | | 12 | | |
| 3 | Membrane Processes: Transport processes involved in various membrane separation processes such as ultrafiltration, nano-filtration, gas separation, reverse osmosis. Calculations of flux, separation factor, and design aspects of various membrane processes such as ultrafiltration, nano-filtration, gas separation, reverse osmosis. | | 12 | | |
| 4 | Adsorption and Ion Exchange: Thermodynamic aspects of adsorption and ion exchange equilibria. Design aspects of fixed bed adsorption, ion exchange processes, analysis, and models for breakthrough curves. | | 12 | | |
| | Total | | 45 | | |
| List of Textbooks/ Reference Books | | | | | |
| 1 | Separation Process Principles, Authors: J.D. Seader, E.J. Henley | | | | |
| 2 | Principles of Mass Transfer and Separation Processes, B.K. Dutta | | | | |
| Course Outcomes (students will be able to….) | | | | | |
| CO1 | Describe and discuss principles of various advanced separation processes based on membranes, chromatography, distillation, extractions | | K2 | | |
| CO2 | Design various components of equipment used in advanced separation processes | | K5 | | |
| CO3 | Compare various options and select an appropriate process for a particular separation | | K5 | | |
| CO4 | Apply advanced computational techniques to Chemical Engineering systems. | | K3 | | |
| CO5 | Gain an appreciation of formal problem-solving methodologies. | | K4 | | |
| CO6 | Appreciate through group-based assignments, an understanding of the design process involving ethical conduct, teamwork spirits, leadership and the need for attention to detail. | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Advanced Separation Processes: CET4552<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | - | - | 1 | 1 | - |
| CO2 | 3 | 2 | 1 | 2 | 3 | 1 | 2 | - | - | 1 | 2 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | 1 | 2 | 2 | 1 | 1 | 1 | - | - | - | 2 | 1 | - |
| CO4 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO5 | 2 | 3 | 2 | 1 | 1 | 1 | - | - | - | - | 2 | 1 |
| CO6 | 2 | 3 | 1 | 2 | 3 | 1 | - | - | - | - | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Advanced Separation Processes: CET4552**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 2 | 3 | 3 | 2 | 2 |
| CO3 | 1 | 2 | 3 | 3 | 1 |
| CO4 | 2 | 3 | 3 | 2 | 2 |
| CO5 | 3 | 4 | 1 | 2 | 1 |
| CO6 | 2 | 3 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IX | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CET4553** | **Course Title:** **Advanced Reaction Engineering** | **Credits = 3** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 45** | **2** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Physics (PHT4151), Applied Chemistry (CHT4151), Applied Mathematics (MAT4151 and MAT4152), Chemical Reaction Engineering (CET4351), Material Energy Balance and Calculation (CEP4151); Process Simulation Lab-I and II (CEP4255 and CEP4256) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NA | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Advanced Reaction Engineering is concerned with the utilization of chemical reactions on a commercial scale. This course is truly relevant but not limited to the following industries: Pharmaceuticals, Petrochemical, Fine chemicals, etc. Advanced concepts related to design, analysis and modelling of chemical reactors are covered in this course. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Design of ideal reactors with heat effects, multiple steady states and reactor stability | | 12 | | |
| 2 | Non-ideal flow in reactors; RTD, Estimation of dispersion/back mixing, dispersed plug flow and tanks in series model, design aspects of reactors with non-ideal flow, micro and meso mixing in reactors | | 9 | | |
| 3 | Kinetics of solid-catalyzed fluid phase reactions: Mechanisms of Catalytic Reactions, Development of rate equations for solid catalyzed fluid phase reactions, Diffusion with reaction in porous catalyst, Estimation of kinetic parameters External/internal mass and heat transfer resistances in catalyst particles. Design aspects of solid catalyzed reactions | | 12 | | |
| 4 | Fluid: Fluid Reactions: Mass transfer with chemical reaction (regimes and examples), model contactors, design aspects of fluid: fluid reactors | | 12 | | |
| | **Total** | | **45** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Chemical Reaction Engineering, O. Levenspiel | | | | |
| 2 | Elements of Chemical Reaction Engineering, H. Scott Foggler | | | | |
| 3 | Heterogeneous Reactions vol. I and II, L.K. Doraiswamy, M.M. Sharma | | | | |
| 4 | Mass Transfer with Chemical Reaction, G. Astarita | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Describe and discuss principles of various types of reactors | | K2 | | |
| CO2 | Calculate rates of reactions based on given reaction scheme | | K3 | | |
| CO3 | Design various components of reactors used in industrial practice | | K5 | | |
| CO4 | Compare various reactors and select an appropriate reactor for a given situation | | K5 | | |
| CO5 | Design and analyze reactor systems using numerical methods and commercial software and synthesize advanced reactor designs for industrial applications. | | K6 | | |
| CO6 | Analyze the importance of catalysis in heterogeneous catalysis, photocatalysis, and biocatalysis systems, and determine rate limiting steps in catalytic systems. | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Advanced Reaction Engineering: CET4553**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | - | - | 1 | - | - |
| CO2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | - | - | - | - | - |
| CO3 | 2 | 2 | 3 | 2 | 3 | 1 | 2 | - | - | - | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO4 | 2 | 3 | 1 | 2 | 2 | 1 | 2 | - | - | - | - | - |
| CO5 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 1 | 1 | - |
| CO6 | 2 | 3 | 2 | - | 2 | 2 | - | - | - | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Advanced Reaction Engineering: CET4553**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 3 | 1 | - |
| CO2 | 2 | 2 | 2 | 2 | - |
| CO3 | 1 | 2 | 3 | 2 | 2 |
| CO4 | 2 | 3 | 1 | 1 | 2 |
| CO5 | 2 | 3 | 3 | 2 | 1 |
| CO6 | 2 | 3 | 2 | - | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IX | | | | | |
|---|---|---|---|---|---|
| **PCC** | **Course Code:** **CET4554** | **Course Title:** **Advanced Mass transfer** | **Credits = 3** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 45** | **2** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Fluid Flow (CET4251), Momentum Transfer (CET4352), Applied Mathematics (MAT4151 and MAT4151), Applied Physics (PHT4151), Applied Chemistry (CHT4151), Chemical Engineering Operation (CET4254), Separation Processes (CET4356) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Multiphase Reaction Engineering (Hon.) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This is a course further built up on and in continuation with undergraduate level course on mass transfer. Modeling of mass transfer process with or without chemical reaction is explained in this course. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Thermodynamic, kinetic and hydrodynamic physical phenomena governing interfacial mass transfer and generation of interfacial transfer area. | | 10 | | |
| 2 | Shell balances to set up lumped parameter models and more sophisticated differential equation-based models to describe mass transfer under various commonly encountered industrial situations. | | 10 | | |
| 3 | The Stefan-Maxwell Unified approach to mass transfer. | | 5 | | |
| 4 | Standard algorithms for multicomponent counter current mass transfer and their applicability. | | 8 | | |
| 5 | Mass Transfer equipment of Industrial significance and their quantitative characterization. | | 12 | | |
| | **Total** | | **45** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| 1 | Principles of Mass Transfer and Separation Processes, B.K. Dutta | | | | |
| 2 | Mass Transfer Operations, R.E. Treybal | | | | |
| 3 | Chemical Engineering, Volume 2, J.M. Coulson, J.F. Richardson | | | | |
| 4 | Transport Processes and Unit Operations, C.J. Geankoplis | | | | |
| 5 | Transport Processes and Separation Process Principles, C.J. Geankoplis | | | | |
| 6 | Separation Processes, C.J. King | | | | |
| 7 | Separation Process Principles, J.D. Seader, E.J. Henley | | | | |
| 8 | Equilibrium Stage Separation Operations in Chemical Engineering, E.J. Henley, J.D. Seader | | | | |
| 9 | Unified Approach to Mass Transfer: Krishna and Wesselingh | | | | |
| 10 | Diffusion: Mass Transfer in Fluid Systems, E.L. Cussler | | | | |
| 11 | Perry's Chemical Engineer's Handbook (latest editions VIII) | | | | |
| 12 | Albrights' Handbook of Chemical Engineering | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Describe and discuss principles of various mass transfer operations | | K2 | | |
| CO2 | Calculate Mass transfer rates for given mass transfer operation | | K3 | | |
| CO3 | Design various components of equipment used in mass transfer operations | | K5 | | |
| CO4 | Compare various options of mass transfer operations and equipment and select an appropriate equipment / operation for a particular situation | | K5 | | |
| CO5 | To understand the mechanisms of heat transfer under steady and transient conditions. | | K2 | | |
| CO6 | Apply test equipment's in electrical projects. | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Advanced Mass transfer: CET4554<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | - | - | 1 | 1 | - |
| CO2 | 3 | 2 | 1 | 2 | 2 | 1 | 2 | - | - | 2 | 1 | - |
| CO3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | - | - | 1 | 2 | - |
| CO4 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 2 | 1 | - |
| CO5 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | 1 | - |
| CO6 | 2 | 3 | 2 | 2 | 1 | - | - | - | - | 1 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Advanced Mass transfer: CET4554<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 1 | 1 | - |
| CO2 | 2 | 1 | 2 | 1 | 1 |
| CO3 | 1 | 2 | 3 | 2 | 2 |
| CO4 | 1 | 3 | 2 | 3 | 1 |
| CO5 | 2 | 3 | 3 | 2 | 1 |
| CO6 | 2 | 3 | 1 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester IX | | | | | |
|---|---|---|---|---|---|
| **Research** | **Course Code: CEP4563** | **Course Title: Thesis** | **Credits = 10** | | |
| | | | **L** | **T** | **P** |
| | **Semester: IX** | **Total contact hours: 150** | **0** | **0** | **40** |
| **List of Prerequisite Courses** | | | | | |
| | All | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | All | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The research project is concerned with details and critical analysis of literature related to a topic of research.<br>Develop of research hypothesis<br>Identification of novel topic<br>Performing control and critical analyses to test the research hypothesis.<br>A report to e made and submitted as Thesis as per the guidelines (provided separately) | | | | | |
| **Course Contents (Topics and subtopics)** | | | **Reqd. hours** | | |
| | Research | | **150** | | |
| | **Total** | | **150** | | |
| **List of Textbooks/ Reference Books** | | | | | |
| | All | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Identify the Problem and Evaluate the solution by hypothesis | | K5 | | |
| CO2 | Performing the Experiments to collect the data | | K6 | | |
| CO3 | Presentation of data and optimization to satisfy the results | | K6 | | |
| CO4 | Graphical representation and modelling along with simulation | | K6 | | |
| CO5 | Evaluate and estimate the experimental data | | K6 | | |
| CO6 | Report making and representing | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Thesis: CEP4563**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 2 | 2 | 3 | 2 | - | - | 1 | 1 | 2 | 2 |
| CO2 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |
| CO3 | 3 | - | 2 | - | 1 | 1 | 2 | - | - | 1 | 1 | 1 |
| CO4 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | - | 2 | 2 | 3 | 2 |
| CO5 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | - | 1 | 3 | 2 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Thesis: CEP4563**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 1 | 2 | 3 | 2 | 2 |
| CO2 | 2 | 3 | 3 | 3 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| CO3 | 1 | 2 | 3 | 3 | 2 |
| CO4 | 1 | 3 | 2 | 3 | 3 |
| CO5 | 1 | 3 | 3 | 3 | 2 |
| CO6 | 2 | 3 | 3 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Fifth Year

# Semester-X

| Semester X | | | | | |
|---|---|---|---|---|---|
| **Research** | **Course Code:** **CEP4564** | **Course Title:** **Thesis** | **Credits = 22** | | |
| | | | **L** | **T** | **P** |
| | **Semester: X** | **Total contact hours: 330** | **0** | **0** | **40** |
| **List of Prerequisite Courses** | | | | | |
| | All | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | All | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The research project is concerned with details and critical analysis of literature related to a topic of research.<br>Develop of research hypothesis<br>Identification of novel topic<br>Performing control and critical analyses to test the research hypothesis.<br>A report to made and submitted as Thesis as per the guidelines (provided separately) | | | | | |
| **Course Contents (Topics and subtopics)** | | | **Reqd. hours** | | |
| | Research | | **330** | | |
| | **Total** | | **330** | | |
| | **List of Textbooks/ Reference Books** | | | | |
| | All | | | | |
| **Course Outcomes (students will be able to….)** | | | | | |
| CO1 | Identify the Problem and Evaluate the solution by hypothesis | | K5 | | |
| CO2 | Performing the Experiments to collect the data | | K6 | | |
| CO3 | Presentation of data and optimization to satisfy the results | | K6 | | |
| CO4 | Graphical representation and modelling along with simulation | | K6 | | |
| CO5 | Evaluate and estimate the experimental data | | K6 | | |
| CO6 | Report making and representing | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Thesis –CEP4564**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 2 | 2 | 3 | 2 | - | - | 1 | 1 | 2 | 2 |
| CO2 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |
| CO3 | 3 | - | 2 | - | 1 | 1 | 2 | - | - | 1 | 1 | 1 |
| CO4 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | - | 2 | 2 | 3 | 2 |
| CO5 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | - | 1 | 3 | 2 | 2 |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Thesis –CEP4564**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 1 | 2 | 3 | 2 | 2 |
| CO2 | 2 | 3 | 3 | 3 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| CO3 | 1 | 2 | 3 | 3 | 2 |
| CO4 | 1 | 3 | 2 | 3 | 3 |
| CO5 | 1 | 3 | 3 | 3 | 2 |
| CO6 | 2 | 3 | 3 | 3 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Honors Syllabus

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Biochemical Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Chemical Reaction Engineering (CET4351), Introduction to Biological Sciences and Bioengineering, Chemistry (CHT4152), Material and Energy Balance Calculations (CEP4151), Chemical Engineering Thermodynamics (CET4353), Chemical Engineering Operations (CET4254) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Multiphase Reactor Engineering, Environmental Engineering and Process Safety (CETxxx), Chemical Process Development and Engineering (CET4451) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This course integrates biological sciences and chemical engineering and a requisite for Biobased Industry | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Introduction to Biotechnology: Role of chemical engineers in biotechnology | | 3 | | |
| 2 | Basic of Genetic Engineering and Tissue Culture: Recombinant DNA technology | | 3 | | |
| 3 | Structure function relations of enzymes; Classification, | | 3 | | |
| 4 | Mechanism of Enzyme action, Enzyme kinetics, inhibition, and regulation | | 3 | | |
| 5 | Enzyme purification and characterization, Coenzymes, cofactors | | 3 | | |
| 6 | Enzyme reactors, thermos-stabilization, immobilization of enzymes | | 3 | | |
| 7 | Enzymes as industrial catalysts- Examples | | 2 | | |
| 8 | Plant and animal cell cultures to produce biochemicals, Immobilized cells. | | 4 | | |
| 9 | Kinetics of microbial growth, models and simulations, Batch and continuous culture, Mixed microbial culture | | 8 | | |
| 10 | Biochemical process development and bioreactors using biological catalysts | | 8 | | |
| 11 | Integration of downstream processing with bioprocessing | | 4 | | |
| 12 | Transport phenomena in bioreactions and bioreactors | | 4 | | |
| 13 | Fundamentals of fermentation-submerged fermentation, Fermenter design and basic biochemical engineering aspects of fermentation | | 4 | | |
| 14 | Reactor design for biochemical reactions and scale up, Process Design for bioproducts, Bioreactor design, Scale up of bioreactions/reactors, | | 8 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Biochemical Engineering Fundamentals, Bailey and Olis, Wiley | | | | |
| 2 | Biotransformation and Bioprocesses, Doble, Anilkumar and Gaikar, Marcel Dekker | | | | |
| | | | | | |
| | | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | Calculate microbial/enzymatic kinetics parameters | | K5 | | |
| CO2 | Design enzyme reactors and scale up fermenters | | K6 | | |
| CO3 | Calculate biomass production/substrate requirements | | K5 | | |
| CO4 | Decide process parameters | | K5 | | |
| CO5 | Estimate energy equipment/oxygen requirements | | K5 | | |
| CO6 | Estimate bio-reactor size/time for a given microbial/enzymatic process. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| HONORS: Biochemical Engineering<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 1 | 1 | 2 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO2 | 2 | 2 | 1 | 1 | - | 1 | 3 | - | - | 2 | 2 | - |
| CO3 | 1 | 1 | 2 | 1 | - | - | - | - | - | 2 | 2 | - |
| CO4 | - | 2 | 3 | 1 | - | 3 | 3 | - | - | 1 | 1 | - |
| CO5 | 3 | 1 | 2 | 2 | 1 | 1 | 2 | - | - | 1 | 1 | - |
| CO6 | 1 | 1 | - | 1 | 2 | 1 | - | - | - | 1 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| HONORS: Biochemical Engineering<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 1 | 2 | 3 | 2 | - |
| CO2 | 2 | 3 | 3 | 3 | 1 |
| CO3 | 1 | 2 | 3 | 2 | 2 |
| CO4 | 2 | 2 | 3 | 2 | 2 |
| CO5 | 1 | 2 | 3 | 3 | 1 |
| CO6 | 1 | 2 | 2 | 3 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Multiphase Reaction Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Heat Transfer (CET4252), Chemical Engineering Operations (CET4254), Separation Processes (CET4356), Chemical Engineering Thermodynamics (CET4353) | |
| **List of Courses where this course will be prerequisite** | | |
| | NA | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| This course integrates reaction engineering and chemical engineering and a requisite for chemical and biochemical Industry | | |
| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
| 1 | Classification of multiphase reactors, qualitative description, examples of industrial importance | 8 |
| 2 | Hydrodynamics, scale-up, process design and performance of the following major classes of multiphase reactors, case studies and problems, w.r.t: | |
| 2a | Stirred tank reactors, | 10 |
| 2b | Bubble columns, packed bubble columns, sectionalized bubble columns, | 10 |
| 2c | Internal loop and external loop air-lift reactors, jet loop reactors, | 8 |
| 2d | Fluid-fluid reactors such as spray columns, packed columns, plate columns, static mixers, rotating disc contactors | 8 |
| 2e | Fixed bed reactors, trickle bed reactors, | 8 |
| 2f | Solid-liquid and gas-solid fluidized bed reactors, solid-gas transport reactors | 8 |
| | **Total** | **60** |
| **List of Textbooks/ Reference Books** | | |
| 1 | Heterogeneous Reactions, Vol. I and II: L. K. Doraiswamy, M. M. Sharma | |
| 2 | Fluid Mixing and Gas Dispersion in Stirred Reactors: G. B. Tatterson | |
| 3 | Bubble Column Reactors: W. D. Deckwer | |
| 4 | Fluidisation: D. Kunni and O. Levenspiel | |
| 5 | Gas Liquid Reactions: P. V. Danckwerts | |
| 6 | Fluidisation: J. F. Davidson and D. Harrison | |
| 7 | Random Packings and Packed Tower Design: R. F. Strigel | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Calculate operating regime for a given reaction. | K5 |
| CO2 | Calculate intrinsic kinetics from the data on model contactors. | K5 |
| CO3 | Calculate conversion / selectivity / size / temperature / pressure / power required for conducting a given multiphase reaction equipment. | K5 |
| CO4 | Ability to solve problems of mass transfer with reaction in solid catalyzed reactions | K4 |
| CO5 | sign and sizing of industrial scale reactor on the basis of kinetic data obtained at lab scale | K6 |
| CO6 | Designing experiments involving chemical reactors, and analyzing and interpreting data | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**HONORS: Multiphase Reaction Engineering**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 1 | 2 | 1 | 3 | - | - | 1 | 1 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO2 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | - | - | 2 | 2 | - |
| CO3 | 3 | 1 | 1 | 2 | 2 | 1 | 2 | - | - | 2 | 2 | - |
| CO4 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | - | - | 2 | 2 | - |
| CO5 | 2 | 3 | 2 | 3 | 2 | - | - | - | - | 3 | 2 | 1 |
| CO6 | 2 | 3 | 2 | 3 | 1 | 2 | 3 | 1 | - | - | 2 | 3 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**HONORS: Multiphase Reaction Engineering**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 1 | 2 | 3 | 2 | 1 |
| CO2 | 2 | 1 | 3 | 3 | 2 |
| CO3 | 1 | 2 | 3 | 2 | 2 |
| CO4 | 2 | 2 | 3 | 3 | 2 |
| CO5 | 1 | 2 | 3 | 1 | - |
| CO6 | 2 | 3 | 2 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Mathematical Methods & Optimization in Chemical Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 2 | 0 | 4 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Applied Mathematics: I (MAT4151) and Applied Mathematics II (MAT4152), Momentum Transfer (CET4352), Chemical Engineering Operations (CET4254), Chemical Engineering Thermodynamics (EST4253), Heat transfer (CET4252), Chemical Reaction Engineering (CET4351) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Transport Phenomena, Chemical Process Control (CET4354), Optimization of Chemical Engineering Systems | |

**Description of relevance of this course in the Int. M. Tech. Program**

In this course advanced mathematical tools are covered which will help students to solve complex problems in Chemical Engineering. This course will serve as a bridge between the applied mathematics courses and their application to Chemical Engineering problems. Specifically, the techniques learnt in this course will help problem formulation and solution in Chemical Reaction Engineering, Chemical Process Control, Heat Transfer and Transport Phenomena. Many Chemical Engineering problems encounter trade-offs between two or more parameters and thus formulation and solution of an optimization problem helps a Chemical Engineer to obtain the best solution.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Vector algebra: scalar & vector product (application to fluid flow problems) and Linear algebra. | 12 |
| 2 | PDEs: Types, solution (penetration theory, 2D conduction, counter-current heat exchanger, reaction-diffusion, dispersion model, etc.) | 8 |
| 3 | Fourier series, transforms (diffusion equations), Laplace, Z transform | 8 |
| 4 | Equation scaling, normalization, convergence | 4 |
| 5 | Integer, linear and quadratic programming (simple scheduling, simple production planning, fuel blending, data fitting, optimal control) | 10 |
| 6 | Nonlinear programming (Reflux ratio optimization, consecutive reaction, reactor-separator recycle systems) | 6 |
| 7 | Mixed integer linear programming (flowsheet optimization, supply chain optimization) | 6 |
| 8 | Multi-objective optimization (design and operation of chemical processes) | 6 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Kreyszig, E. Advanced Engineering Mathematics. | |
| 2 | Pushpavanam, S. Mathematical Methods in Chemical Engineering | |
| 3 | Collette, Y. and Siarry, P. Multi-objective optimization | |
| 4 | Vanderbei, R.J. Linear programming: Foundations and extensions | |
| 5 | Jenson, V.G. and Jeffreys, G.V. Mathematical Methods in Chemical Engineering | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Formulate a Chemical Engineering problem into a mathematical problem | K4 |
| CO2 | Solve (analytically or numerically) ODE and PDE equations encountered in Chemical Engineering Applications | K5 |
| CO3 | Assess stability of Chemical Engineering systems | K3 |
| CO4 | Formulate a Chemical Engineering problem into an optimization problem | K4 |
| CO5 | Solve (analytically or numerically) optimization problems encountered in Chemical Engineering Applications | K5 |
| CO6 | Provide knowledge of advanced numerical methods and their applications to chemical engineering problems | K3 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| HONORS: Mathematical Methods & Optimization in Chemical Engineering<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO2 | 3 | 2 | 1 | 1 | 1 | 2 | 2 | - | - | 2 | 2 | - |
| CO3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | - | - | 2 | 2 | - |
| CO4 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | - | - | 1 | 1 | - |
| CO5 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO6 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | - | - | 1 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| HONORS: Mathematical Methods & Optimization in Chemical Engineering<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 1 | 2 | 3 | 2 | 1 |
| CO2 | 2 | 3 | 2 | 2 | - |
| CO3 | 3 | 2 | 1 | 2 | 1 |
| CO4 | 2 | 3 | 1 | 3 | 2 |
| CO5 | 1 | 2 | 3 | 2 | 1 |
| CO6 | 2 | 3 | 3 | 3 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Refinery Science and Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Material Balance and Energy Balance Calculations (CEP4151), Chemical Reaction Engineering (CET4351), Heat Transfer (CET4252), Chemical Engineering Operations (CET4254) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | NA | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| In this course will learn to apply their knowledge of mass transfer, heat transfer, equipment design and chemical reaction engineering to complex processes of petroleum refineries. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | World oil scenario and future of oil, Petroleum pricing and economics | | 4 | | |
| 2 | Fundamentals of crude distillation | | 4 | | |
| 3 | Refinery products and properties, refining chemistry, role of catalysis | | 6 | | |
| 4 | Refinery processes - thermal cracking, fluid catalytic cracking, hydrotreating, catalytic reforming, refinery alkylation, isomerization | | 10 | | |
| 5 | Integration of petrochemical processes with refinery | | 6 | | |
| 6 | Material selection in refinery technology | | 4 | | |
| 7 | Treatment processes, gas cleaning | | 4 | | |
| 8 | Safety, health and environment issues | | 4 | | |
| 9 | Renewable and alternative fuels | | 4 | | |
| 10 | Biorefineries | | 4 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | W. C. Edmister, Applied Hydrocarbon Thermodynamics Vol I and Vol II Gulf Publishing Co. | | | | |
| 2 | Joseph Hilyard, International petroleum encyclopedia 2008 (3 Volume). | | | | |
| Course Outcomes (students will be able to….) | | | | | |
| CO1 | To understand refining trends, challenges, and key issues | | K2 | | |
| CO2 | To analyze the role of refining processes in the world energy challenge | | K4 | | |
| CO3 | To propose feasible solutions for energy security in India | | K5 | | |
| CO4 | To understand all the basics about crude oil, including its physical/chemical properties and composition | | K2 | | |
| CO5 | To explain step-by-step the processes of refining | | K3 | | |
| CO6 | Understand the flow diagrams of refineries and understand the refinery products and their characteristics. | | K2 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**HONORS: Refinery Science and Engineering**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | - |
| CO2 | - | 1 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | 2 | - |
| CO3 | - | 1 | 2 | 1 | 2 | 3 | 3 | - | - | 2 | 2 | - |
| CO4 | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 1 | 1 | 2 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | 1 | 2 | 3 | 2 | 1 | 2 | - | - | - | - | 1 | 1 |
| CO6 | 2 | 2 | 1 | 3 | 2 | - | - | - | 2 | 2 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**HONORS: Refinery Science and Engineering**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | - | - |
| CO2 | 2 | 3 | 2 | 2 | 1 |
| CO3 | 2 | 2 | 3 | 2 | 2 |
| CO4 | 2 | 2 | 2 | 2 | 1 |
| CO5 | 2 | 3 | 1 | 2 | 1 |
| CO6 | 3 | 2 | 2 | 1 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Catalytic Science and Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Applied Chemistry (CHT4151), Chemical Reaction Engineering (CET4351) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NA | |

**Description of relevance of this course in the Int. M. Tech. Program**

In this course will learn to apply their knowledge of catalysis process and it's engineering along with synthesis process and characterization for the catalytic process. This course will also deal the several applications of catalyst and their process as well.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Relevance and examples, Atom economy and green chemistry concepts, Homogenous and heterogeneous catalysis | 10 |
| 2 | Fundamentals of homogeneous catalysis and mechanisms and kinetics, Fundamentals of adsorption, isotherms, energetics, structural and dynamic considerations, | 10 |
| 3 | Mechanisms, models and kinetics of surface reactions, Fractal models, Determination of surface structure though modern methods, Significance of Pore structure and models | 10 |
| 4 | Catalysts Characterization methods: Surface area and pore volume determinations, XRD, various Spectroscopic techniques, Temperature programmed reduction & oxidation, Electron microscopy. | 10 |
| 5 | Solid and surface chemistry of catalysis, Quantum mechanical, molecular mechanical and hybrid models, Catalyst design through artificial intelligence and computer modelling | 5 |
| 6 | Poisoning, promotion, deactivation and selectivity, Catalytic process engineering, Measurement of catalytic rates and kinetic parameters, Types of reactors | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | G. Ertl, H. Knozinger and J. Weitkamp, "Handbook of Heterogeneous Catalysis" Vol 1-5, Wiley - VCH. | |
| 2 | J.J. Carberry, "Chemical and catalytic reaction Engineering", Dover Publications. | |
| 3 | C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley-VCH. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand synthesis, characterization, activity and deactivation of heterogeneous catalyst | K2 |
| CO2 | Understand the mechanisms of homogeneous catalysis | K2 |
| CO3 | Understand the role of catalysis in industrial processes | K2 |
| CO4 | To plan, develop and test catalyst for given application | K3 |
| CO5 | Suggest strategies for catalyst development | K3 |
| CO6 | Select and design multiphase catalytic reactors | K4 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| HONORS: Catalytic Science and Engineering<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO2 | 2 | 1 | 2 | 1 | 1 | 1 | 3 | - | - | 2 | 2 | - |
| CO3 | 1 | 2 | 3 | 1 | 3 | 2 | 3 | - | - | 2 | 2 | - |
| CO4 | 1 | 3 | 1 | 2 | 2 | 1 | 1 | - | - | 1 | 1 | - |
| CO5 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | - | - | 1 | 1 | - |
| CO6 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | - | - | - | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| HONORS: Catalytic Science and Engineering<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 1 | 2 | - |
| CO2 | 2 | 2 | 2 | 1 | - |
| CO3 | 3 | 1 | 1 | 1 | 1 |
| CO4 | 3 | 2 | 1 | 2 | - |
| CO5 | 1 | 2 | 3 | 1 | - |
| CO6 | 1 | 2 | 1 | 2 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PCC | Course Code: CETxxxx | Course Title: Statistical Thermodynamics | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Applied Mathematics especially probability, vectors and linear algebra, Computer Programming especially working with arrays and vectors (MAT4151) and (MAT4152), Chemical Engineering Thermodynamics (CET4353) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NA | |

**Description of relevance of this course in the Int. M. Tech. Program**

In this course will learn to apply their knowledge of statistical mechanics and its application in engineering thermodynamics and their problem solution.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction to statistical mechanics: a first look at the Canonical Ensemble. Introduction to the Boltzmann Distribution | 4 |
| 2 | Introduction to the microcanonical, PVT and Grand Canonical Ensembles | 4 |
| 3 | Macroscopic Thermodynamic Quantities as Functions of Ensembles with particular emphasis on the microscopic level difference between Heat Transfer and Work Transfer. | 4 |
| 4 | a) Derivation of the Ideal Gas Law using Schrodinger's Equation applied to Particle-in-a-box and extended to many particle systems using statistical mechanics<br>b) Derivation of Pressure for an Ideal Gas and introduction to the Virial Theorem | 8 |
| 5 | Introduction to the pair interaction energy, pair correlation function (radial distribution function) and determination of macroscopic thermodynamic quantities including derivation of the van der Waals equation of state. | 10 |
| 6 | Introduction to Importance Sampling, detailed balance and the Metropolis Monte Carlo Algorithm | 4 |
| 7 | Writing a code for Monte Carlo simulations in 1D using periodic boundary conditions | 4 |
| 8 | Phase Space, the Liouville Theorem and Molecular Dynamics Simulations | 6 |
| 9 | Symplectic integrators and writing a code for molecular dynamics simulations in 1D using periodic boundary conditions | 4 |
| 10 | Fluctuation Dissipation theorem and the Green Kubo relations to determine transport properties from MD simulations.<br>Writing code to determine thermodynamic and transport properties of a system from fluctuations and autocorrelations thereof. | 8 |
| 11 | Introduction to Transition State Monte Carlo Simulations for Phase Equilibria | 4 |
| | **Total** | **60** |

| List of Textbooks/ Reference Books | | |
|---|---|---|
| 1. | An Introduction to Statistical Thermodynamics by Terrence Hill (Dover Books) | |
| 2. | Understanding Molecular Simulations by Daan Frenkel and Berend Smit (Academic Press) | |
| 3. | Classical Dynamics of Particles and Systems S.T. Thornton and J. B. Marion (Cengage Learning) | |
| 4. | Statistical Mechanics D. A. McQuarrie (University Science Books) | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Student would be able to understand and use the concept of microcanonical, canonical, grand-canonical and PVT ensembles and the partition functions thereof | K3 |
| CO2 | Student would be able to relate macroscopic thermodynamic quantities like entropy and free energy to the partition functions | K4 |
| CO3 | Student would be able to understand the algorithms behind Monte Carlo simulations and write a simple Monte Carlo Simulation | K4 |

| | | |
|---|---|---|
| CO4 | Student would be able to understand the algorithms behind Molecular Dynamics Simulations and write a simple MD simulation | K4 |
| CO5 | Student would be able to understand and use the fluctuation dissipation theorem in conjunction with Monte Carlo simulations to determine transport coefficients using the Green Kubo relations. | K4 |
| CO6 | Students can learn to derive vibrational and translational partition functions, and to derive and compute thermodynamic functions from partition functions. | K6 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**HONORS: Statistical Thermodynamics**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 2 | - |
| CO2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | - | - | - | 1 | - |
| CO3 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | - | - | - | 2 | - |
| CO4 | 2 | 1 | 2 | 1 | 2 | 2 | - | - | - | - | - | - |
| CO5 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | - | - | 1 | 1 | - |
| CO6 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | - | - | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**HONORS: Statistical Thermodynamics**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 2 | - |
| CO2 | 3 | 3 | 2 | 3 | 1 |
| CO3 | 3 | 2 | 3 | 2 | 2 |
| CO4 | 3 | 1 | 2 | 1 | 1 |
| CO5 | 3 | 2 | 1 | 2 | 2 |
| CO6 | 3 | 2 | 3 | 2 | 2 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

# Electives Syllabus

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4751** | **Course Title:** **Process Intensification** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | Momentum transfer (CET4352), Chemical Engineering operations (CET4254), Heat transfer (CET4252), Chemical reaction engineering (CET4351), Advanced mass transfer (CET4554), Advanced transport phenomena (CET4551) | |
| **List of Courses where this course will be prerequisite** | | |
| | Thesis (CEP4563 and CEP4564) | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| The course is intended to be useful for students in applying intensified reactor and/or separator systems in chemical industries. The course will cover some intensified technologies, with particular emphasis on their application in chemical processes. | | |
| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
| 1 | Introduction on Process Intensification: History, Philosophy and Concept, Principle Features, Strategies and domain based techniques. | 6 |
| 2 | Mechanism involved in the process intensification: Intensification by fluid flow process, Mechanism of Intensification by mixing, Intensification in Reactive system | 4 |
| 3 | Role of Process intensification in sustainable development: Problems leading to sustainable development, Concept, Issues and Challenges, Strategies in process design | 4 |
| 4 | Process intensification by cavitation: Introduction and Mechanism of Cavitation-based PI, Acoustic cavitation, Hydrodynamic cavitation, Cavitation Reactor Configurations, Application of cavitation in reaction, wastewater treatment, crystallization, emulsification etc., | 10 |
| 5 | Process intensification by micro-reactors: Introduction to microprocess technology, Types of Micro-reactors, Hydrodynamics, and transport in microchannel based microreactor, Application of micro-reactors in reaction, nanomaterial synthesis etc. | 10 |
| 6 | Microwave-assisted process intensification technique, Applications of microwaves in extraction, reaction and nanomaterials. | 10 |
| 7 | Process intensification by membrane: Introduction to membrane and its principles, Membrane engineering in process intensification | 6 |
| | **Total** | **60** |
| **List of Textbooks/ Reference Books** | | |
| 1. | Process Intensification in Chemical Engineering Design Optimization and Control, by Juan Gabriel Segovia, Hernández Adrián and Bonilla Petriciolet, 2016, Springer. | |
| 2. | Process Intensification: Engineering for efficiency, sustainability and flexibility, by David Reay, Colin Ramshaw, and Adam Harvey, 2nd edition, 2013, Elsevier. | |
| 3. | 3. The Fundamentals of Process Intensification by Andrzej Stankiewicz, TomVan Gerven and Georgios Stefanidis, 2019, Willey VCH. | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Contemplate new design concepts and analyze design alternatives for any process | K3 |
| CO2 | Propose improvements in a process by integration of unit operations, | K4 |
| CO3 | Apply their knowledge to the design and implementation of green processing technologies based on process intensification principles. | K5 |
| CO4 | Improve processes without sacrificing product quality by increasing efficiency, reducing energy consumption, costs, volume, and waste as well as improving safety. | K4 |
| CO5 | Identify process intensification for the enhancement of chemical processes | K2 |
| CO6 | Solve process challenges using intensification technologies and analyze scale up issues in the process industries. | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

| Chemical Engineering Elective: CET4751Process Intensification<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 3 | 2 | 1 | 2 | 1 | - | - | 1 | - | 1 |
| CO2 | 2 | 3 | 2 | 3 | 2 | 1 | - | - | - | 2 | - | - |
| CO3 | 1 | 2 | 3 | 2 | 1 | - | - | - | - | 1 | 2 | 2 |
| CO4 | 2 | 3 | 3 | 2 | 2 | 1 | 1 | - | - | 1 | 1 | 1 |
| CO5 | 2 | 3 | 1 | 2 | 2 | - | - | - | 1 | 2 | 1 | 1 |
| CO6 | 2 | 2 | 1 | 2 | 2 | 1 | - | - | - | 1 | 2 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: CET4751Process Intensification<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 3 | 2 | 3 | 1 | - |
| CO2 | 3 | 2 | 2 | 3 | 2 |
| CO3 | 2 | 1 | 3 | 3 | 3 |
| CO4 | 3 | 2 | 3 | 3 | 2 |
| CO5 | 2 | 1 | 2 | 1 | 2 |
| CO6 | 2 | 2 | 1 | 1 | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4752 | Course Title: Chemical Safety and Risk Management | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Process Safety (CET4255), Process Development and Engineering (CET4451) | |
| **List of Courses where this course will be prerequisite** | | |
| | NA | |

**Description of relevance of this course in the Int. M. Tech. Program**

This curse aims - to list principles of safety, risk management and material hazards, to define safety principles, procedures, standards, and regulations, - to describe safety aspects related to chemicals, fires, electricity, pathogens etc., - to apply SHE principles and its management in the industry, - to assess the risks and environmental impact of projects and processes - to perform tasks such as hazard identification or plant layout etc.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | **Introduction to Safety and Risk Management**: Major industrial disasters and evolution of safety and risk management<br>**Basic OSH**: Occupational hygiene basics<br>**Material hazard** - GHS MSD - physical hazard, toxic hazard, and eco-toxicity MSDS (Material Safety Data Sheet), 16-point MSDS, uniformity in MSDS, details of MSDS, LD50 & LD10 dosage values; TLV, STEL, Flash, Vapour pressure; Globally Harmonized System (GHS), R&S phrases<br>**Hazardous Chemicals**: Classification of Hazardous chemicals | 12 |
| 2 | **PSM elements:** Why PSM; Overview of 14 elements<br>**Hazard evaluation techniques:** What-If, Checklist, HAZOP, FEMA etc. Overview of each of HAZOP & HAZAN Analysis; Cause and Consequence Analysis; FEMA; LOPA; Fault Tree Analysis; QRA<br>**Hazard identification and assessment:** 1. Basic Hazard identification, assessment & measures<br>**Flammability and fire safety-extinguishers:** Fire types, Types of fire extinguishers, Agents for firefighting, Fire hydrant | 12 |
| 3 | **Plant layout based on process safety & fire safety-fire hydrant system design**: Solvent yard, warehouse, and plant layout with design of fire safety system.<br>**Human elements in safety-behavior safety:**<br>**Basics of laboratory safety**<br>**Compliance to statutory safety audits**: Overview of safety audits based on ISO standards (14000) | 12 |
| 4 | **Management Practice in SHE in Plant Operation:** Man-management, organization management, policy management; Fundamentals of safety management systems for occupational safety, job hazard analysis (confined space, height safety, hot jobs); Chemical and plant security; Cyber security as applicable to Chemical Projects; Management of change; Incident reporting and investigation; Human elements in safety, ergonomics and behavioural safety<br>**Hazard assessment:** 2. Process safety, thermal safety, dust explosion etc. Inherent safety concepts for processes and unit operations; Powder handling hazards - dust explosion<br>**Safety in utilities:** Safety in electrical power generation units including nuclear, steam boilers, boiler feed water, thermic fluids, transformers.<br>**Storage, handling and transportation of hazardous substances:** Safety provisions during transport of petroleum products including LNG and other hazardous materials by ship, rail, air cargo and roads; transport emergency; isolated storage; warehouses; color coding of pipelines; inventory management; packaging and labelling. | 12 |
| 5 | **Environmental Impact Assessment**: Environmental impact and risk assessment (EIRA), risks of projects, process related, risks, measurement, and monitoring tools<br>**Emergency response plan:** Hazard identification and elements of emergency response plan; OHC categorization, control banding and precautions while handling substances; GMP principles | 12 |

| | | |
|---|---|---|
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Chemical Process Safety: Fundamentals with Applications: Daniel A. CROWL and Joseph F. LOUVAR | |
| 2 | Guidelines for Process Safety Management, Environment, Safety, Health, and Quality: Centre for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | |
| 3 | Chemical Process Safety Learning from Case Histories: Roy E. SANDERS | |
| 4 | Guidelines for Process Safety Documentation: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Identify hazards in a given process and assess the same and provide solutions for operating safely. | K3 |
| CO2 | Specify safety requirements for storage and handling of a given chemical. | K4 |
| CO3 | Apply fundamental principles, implement safety and risk management in practice, and demonstrate management skills. | K3 |
| CO4 | Recognize hazards, assess risks, minimize and manage risks, and prepare for emergencies. | K5 |
| CO5 | To learn about chemical classification, toxicology, labeling, handling, storage, and transportation. | K2 |
| CO6 | To learn the fundamentals of chemical process safety and hazards management and discuss important components of a risk management plan. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective - CET4752 Chemical Safety and Risk Management**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - | 2 | 3 | - | 3 | 1 | - | - |
| CO2 | 2 | 3 | 3 | 2 | - | 2 | 3 | 1 | 2 | 2 | - | - |
| CO3 | 3 | 2 | 2 | 1 | - | 2 | 3 | 1 | 2 | 2 | - | - |
| CO4 | 2 | 3 | 1 | 2 | 1 | 2 | 2 | - | - | 1 | 1 | 2 |
| CO5 | 1 | 1 | 1 | - | - | - | - | - | 1 | 2 | 1 | - |
| CO6 | 1 | 2 | 1 | 2 | - | - | - | - | - | 1 | - | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective - CET4752 Chemical Safety and Risk Management**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | 3 | 2 | 2 | 1 | - |
| CO2 | 2 | 3 | 1 | 2 | 1 |
| CO3 | 3 | 2 | 2 | 1 | 1 |
| CO4 | 2 | 3 | 2 | 1 | - |
| CO5 | 2 | 1 | 2 | 2 | - |
| CO6 | 2 | 3 | 1 | - | 1 |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester VII | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4753** | **Course Title: Environmental Engineering and Chemical Process Safety** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester: VII** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Material Balance & Energy Balance Calculations (CEP4151), Chemical Reaction Engineering (CET4351), Chemical Engineering Operations (CET4254), Momentum transfer (CET4352), Biochemical Engineering, Chemical Engineering Thermodynamics (EST4353), Process Safety (CET4255), Environmental Sciences (CET4258), Biochemical Engineering (Hon.) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Biochemical Engineering (Hon.) | | | | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course 'Environmental Engineering and Process Safety' is highly relevant in all fields of activities, and process industry. The above clearly highlights the necessity and significance of the course. This course will certainly add value to our chemical engineering graduates.

A chemical engineer working in any function of process industry should have working knowledge of all the prevailing safety, environment, and health standards, and may be involved in / responsible for any or all of the following:

- site process safety, environmental affairs
- assisting the Health Safety Environment (HSE) team
- employee safety observations and pre-job risk assessments
- implementation of HSE policies and guidelines to help ensure that all employees, contractors, and visitors enjoy high levels of safety, health and environmental protection; this reduces company's liability exposure.
- improvement of process safety performance and reduction of risk by facilitating Process Hazard Analyses Layer of Protection Analyses
- incident investigations for process safety and environmental incidents
- recognising information that would be pertinent to process safety documentation and follow through with site personnel to ensure information is well documented
- developing and updating site Policies and Procedures related to process safety and environmental.
- capital and other project teams to identify and resolve regulatory issues, analyse process and property hazards, and establish protective measures to mitigate risks to a tolerable level.
- assisting the plant with government interfaces and inspections.
- training using internal and external resources; provides guidance to site management for implementation of programs or controls to comply with environmental requirements.
- managing site environmental programs including but not limited to waste management, spill prevention & response, etc.
- preparation and submission of reports to appropriate agencies to assure compliance with federal, state and local regulations. Responds to corporate requests in a timely manner.
- obtaining new or revised environmental permits that provide operational flexibility within the schedule established for new projects. Ensure that the operating units can meet all provisions and provide tools to enable compliance.
- providing environmental guidance; develop procedures and training, and HSE support as needed.
- participate in site objectives in the areas of community relations.

| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
|---|---|---|
| 1 | Introduction to all prevailing international standards of Health, Safety, and Environment (HSE); Environmental laws and regulations; Standards (air quality, noise, water), ISO 14000+ | 4 |
| 2 | Environmental impact assessment, Life cycle assessment (LCA) | 4 |
| 3 | Pollution prevention in chemical manufacturing<br>Industrial wastewater treatment: characterization of effluents (COD and BOD), treatment levels (primary, secondary and tertiary) and strategies (physical, chemical and biological), sludge treatment and effluent valorisation, | 4 |
| 4 | Wastewater treatment; Groundwater and surface water pollution, removal of specific water contaminants; Solid waste; Hazardous waste, Details of the effluent treatment plant and | 6 |

| | | |
|---|---|---|
| | machines, chemical pipelines and storage condition, segregation of waste streams (high COD and low COD), Current practices in wastewater treatment: examples and case studies | |
| 5 | Management of municipal solid waste, waste-to-energy strategies, refuse-derived fuel, hazardous waste, E-waste, battery waste, plastic waste | 2 |
| 6 | Air pollution; Air pollutants: sources (specific pollutants), effects, and dispersion modelling, air pollution, air quality, pollutants minimisation and control, fugitive emissions (source and control), Methods (absorption, adsorption, oxidation and reduction) and equipment (scrubbers, dust management systems) for the control of gaseous pollutants from the industry, Catalytic technologies for air pollution control | 4 |
| 7 | Noise pollution | 6 |
| 8 | Inherent safety; Major disasters (e.g. Flixborough, UK; Bhopal, India; Seveso, Italy; Pasadena, Texas; Texas City, Texas; Jacksonville, Florida; Port Wentworth, Georgia), | 6 |
| 9 | Toxicology; Industrial hygiene | 4 |
| 10 | Prevention and control of accidental release of contaminants, plume behaviour<br>Source models; Toxic release and dispersion models | 4 |
| 11 | Fires and explosions; Concepts to prevent fires and explosions | 2 |
| 12 | Chemical reactivity | 4 |
| 13 | Reliefs and reliefs sizing; Hazard identification; Risk assessment | 4 |
| 14 | Safety procedures and designs, Process hazards, design and control: safe design of process vessels, safety systems, colour coding, earthing, safety-related equipment<br>Risk-based process safety, inherently safer design | 4 |
| 15 | Some case histories | 2 |
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Chemical Process Safety: Fundamentals with Applications: Daniel A. CROWL and Joseph F. LOUVAR | |
| 2 | Guidelines for Process Safety Management, Environment, Safety, Health, and Quality: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | |
| 3 | Environmental Engineers' Handbook: Irene LIU (Editor) | |
| 4 | Chemical Process Safety Learning from Case Histories: Roy E. SANDERS | |
| 5 | Guidelines for Process Safety Documentation: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE) | |
| 6 | Environmental and Health and Safety Management: A Guide to Compliance: Nicholas P. CHEREMISINOFF, Madelyn L. GRAFFA | |
| 7 | Environmental Pollution Control Engineering: C. S. Rao | |
| 8 | Environmental Engineering: H. S. Peavy | |
| | | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Calculate BOD / COD for a given composition of effluent stream, Estimation of bio-Kinetics | K5 |
| CO2 | Calculate adiabatic lapse rate and determine conditions for suitability of atmospheric dispersion, effective stack height, chimney design | K5 |
| CO3 | Calculate concentrative of pollutant at any point in the neighbourhood of emission given atmospheric conditions like wind, dispersion, environmental factors etc. | K5 |
| CO4 | Calculate size/time/power required for primary clarifier, secondary treatment, tertiary treatment, sizing of different types of biological treatments etc. | K5 |
| CO5 | Identify hazards in a given process and assess the same and provide solutions for operating safely. | K4 |
| CO6 | Specify safety requirements for storage and handling of a given chemical. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

| Chemical Engineering Elective V: Environmental Engineering and Chemical Process Safety: CET4753<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | 3 | 2 | 1 | 1 | 2 | 2 | 3 | 1 | 3 | - | 1 | - |
| CO2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | - | 2 | - | 2 | - |
| CO3 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | - | 3 | - | 1 | - |
| CO4 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | - | 3 | - | 1 | - |
| CO5 | 1 | 2 | 1 | - | - | 2 | 1 | - | 3 | - | 2 | - |
| CO6 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | - | 2 | - | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective V: Environmental Engineering and Chemical Process Safety: CET4753<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | 1 | 2 | 3 | 3 | - |
| CO2 | 2 | 1 | 2 | 3 | 1 |
| CO3 | 1 | 2 | 3 | 3 | - |
| CO4 | 1 | 3 | 3 | 3 | |
| CO5 | 2 | 2 | 2 | 2 | - |
| CO6 | 3 | 2 | 1 | 1 | - |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4754 | Course Title: Perspectives of Society, Science and Technology | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | NIL | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | This course is needed to understand the sustainable development | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| The course is the relationship between technology, science and society can be understood from different perspectives, such as historical, sociological, philosophical, economic, political, ethical, and environmental. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | History of Science and Technology and its relevance in the respective era | | 4 | | |
| 2 | Recent developments in technology (chemical, biotechnology energy, telecommunications, etc.) and their influence on society | | 6 | | |
| 3 | Economics and Sustainable Development | | 4 | | |
| 4 | Value system and Ethics in the profession of Technology, Science and Engineering. Problems before the World and India. Various approaches in solving them. | | 6 | | |
| 5 | Integrating Issue: Society and Science | | 6 | | |
| 6 | Industrial disasters and their effect on science and technology and society | | 4 | | |
| 7 | Environmental degradation, global warming and their effect on science and technology and society | | 6 | | |
| 8 | IPR issues and their relevance to science and technology and society | | 6 | | |
| 9 | Some aspects of future of Society, Technology, Science and Engineering. | | 4 | | |
| 10 | Interdependence of Theology and Science | | 4 | | |
| 11 | Impact of climate change on the nexus of water, energy and water Technology and World Peace Role of Innovation and R&D | | 6 | | |
| 12 | Industry-Academia Interaction to Enhance Standard of Living | | 4 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Science, Technology and Society: An Encyclopedia by Sal Restivo, Oxford University Press 2005 | | | | |
| 2 | Science, Technology and Society: A Sociological Appraoach by Wenda K. Bauchspies, Jennifer Croissant, Sal P. Restivo | | | | |
| 3 | Vision of STS: Counterpoints in Science Technology and Society Studies by Stephan H. Cutcliffe, Carl Mitcham, Sunny Press 2012 | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | Enable students to understand science as a socio-cultural product in specific socio-historical contexts. | | K2 | | |
| CO2 | Expose students to philosophical, historical and sociological perspectives to look at science as a practice deeply embedded in culture and society. | | K3 | | |
| CO3 | Emphasizes the dynamic nature of the relations between wider cultural practices on one hand and scientific practices on the other. | | K3 | | |
| CO4 | Attempt to equip students with an understanding indispensable for an in-depth study of science-technology-society dynamics. | | K4 | | |
| CO5 | Explore and understand the many ways that modern science and technology shape modern culture, values, and institutions, and how modern values shape science and technology. | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Chemical Engineering Elective: Perspectives of Society, Science and Technology: CET4754<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Perspectives of Society, Science and Technology: CET4754<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4755** | **Course Title: Optimization Techniques** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Mathematics 4151 and Mathematics 4152 | |
| **List of Courses where this course will be prerequisite** | | |
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The purpose of optimization techniques course is to achieve the "best" design relative to a set of prioritized criteria or constraints. These include maximizing factors such as productivity, strength, reliability, longevity, efficiency, and utilization.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Review of local maximum/minimum | 10 |
| 2 | Method of Lagrange Multipliers and KKT methods | 10 |
| 3 | One dimensional Optimization Techniques: Fibonacci search method, Golden section method and interpolation method. | 10 |
| 4 | Direct Search unconstrained optimization: Powell's method, Nelder-Mead (simplex) method Gradient Search Optimization Methods: Steepest Descent Method, Newton's Method, Conjugate gradient methods | 10 |
| 5 | Linear Programming: Simplex Method, Revised Simplex Method and other Advanced Methods, Integer Programming | 10 |
| 6 | Modern Optimization Techniques; Genetic Algorithms, Simulated Annealing, Ant Colony Optimization | 10 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | |
|---|---|
| 1 | S. S. Rao, Engineering Optimization: Theory and Practice, Wiley, 2008. |
| 2 | K. Deb, Optimization for Engineering design algorithms and Examples, Prentice Hall, 2 Nd edition 2012. |
| 3 | C.J. Ray, Optimum Design of Mechanical Elements, Wiley, 2007. |
| 4 | R. Saravanan, Manufacturing Optimization through Intelligent Techniques, Taylor & Francis Publications, 2006. |
| 5 | D. E. Goldberg, Genetic algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Longman Publishing, 1989. |
| 6 | An Introduction to Optimization, Edvin K. P. Chong & Stanislab H. Zak, Wiley Publication |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Comprehend the techniques and applications of Engineering optimization. | K3 |
| CO2 | Analyze characteristics of a general linear programming problem. | K4 |
| CO3 | Apply basic concepts of mathematics to formulate an optimization problem. | K3 |
| CO4 | Analyse various methods of solving the unconstrained minimization problem. | K4 |
| CO5 | Analyze and appreciate variety of performance measure for various optimization problems. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Optimization Techniques CET4755**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Optimization Techniques CET4755**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4756** | **Course Title: Machine Learning** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Mathematics 4151 and Mathematics 4152, MATLAB/SCILAB, Python | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Design projects (CEP4461), Optimization (MATXXXE) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course will provide a solid introduction to machine learning. In particular, upon successful completion of this course, students will be able to understand, explain and apply key machine learning concepts and algorithms, including:<br>Probability review<br>Introduction to different types of machine learning and supervised learning<br>Decision trees algorithm<br>Naïve Bayes algorithm<br>Logistic Regression algorithm<br>Machine learning concepts such as regularization, overfitting, and Laplace smoothing | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Machine Learning Concepts: Mean Square Error (MSE), Training Error, Test Error, Bias-variance trade-off, Measuring the quality of fit, Regression Diagnostics, Understanding the concept of model flexibility and prediction accuracy, Universal behaviour of Training and Test MSE. Case study of linear regression with K-nearest neighbour regression | | 15 | | |
| 2 | Model Selection and Regularization: Validation set approach, Leave-One-Out-Cross-Validation, K-fold cross validation, best subset selection, Forward Selection, Backward selection, Hybrid selection, shrinkage methods: Ridge regression, Lasso, least angle regression. | | 15 | | |
| 3 | Decision Trees, Bagging and Boosting, Random Forests, Gradient Boosting, Artificial Neural Network | | 10 | | |
| 4 | Classification problem: Logistic Regression, Support Vector Machines, Receiver operating characteristic (ROC) curves, Area under the curve (AUC) and other related accuracy measures | | 10 | | |
| 5 | Multivariate methods: Principal Component Analysis, Factor Analysis, Principal component regression, K-means clustering, Hierarchical Clustering, Multi-dimensional scaling | | 10 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Review of local maximum/minimum | | | | |
| 2 | Method of Lagrange Multipliers and KKT methods | | | | |
| 3 | One dimensional Optimization Techniques: Fibonacci search method, Golden section method and interpolation method. | | | | |
| 4 | Direct Search unconstrained optimization: Powell's method, Nelder-Mead (simplex) method | | | | |
| 5 | Gradient Search Optimization Methods: Steepest Descent Method, Newton's Method, Conjugate gradient methods | | | | |
| 6 | Linear Programming: Simplex Method, Revised Simplex Method and other Advanced Methods, Integer Programming | | | | |
| 7 | Modern Optimization Techniques; Genetic Algorithms, Simulated Annealing, Ant Colony Optimization | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Understand different types of machine learning and map problems to different classes of machine learning algorithms. | | K3 | | |
| CO2 | Describe and apply machine-learning algorithms including decision trees, naïve Bayes, and logistic regression. | | K4 | | |

| | | |
|---|---|---|
| CO3 | Understand subtleties and application scenarios for different supervised classification algorithms discussed above. | K3 |
| CO4 | Explain and apply machine-learning concepts such as regularization, overfitting, and Laplace smoothing to design efficient machine learning models. | K4 |
| CO5 | Develop an appreciation for what is involved in learning from data. | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Machine Learning CET4756**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Machine Learning CET4756**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4757 | Course Title: Biomaterials: Biodegradable Materials for Biomedical Applications | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | 10+2 Biology | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course will provide a knowledge about biomaterials that play an integral role in medicine today—restoring function and facilitating healing for people after injury or disease. Biomaterials may be natural or synthetic and are used in medical applications to support, enhance, or replace damaged tissue or a biological function.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction of Biomaterials | 6 |
| 2 | Biomaterials Surfaces: Structure and Properties, Surface Energy<br>Adsorption and Reconstruction at Surfaces, | 6 |
| 3 | Protein-Surface Interactions<br>Proteins: Structure, Properties, Functions, Protein Adsorption: Complex Phenomena, Measurement | 6 |
| 4 | Cell-Surface Interactions: Host Response to Biomaterials: Cell adhesion mechanism, coagulation cascade, immune response | 6 |
| 5 | Surface Characterization: AES, XPS, AFM, Contact Angle | 6 |
| 6 | Quantifying Cell Behavior: Cell Culture, Cellular Assays<br>Biosensors and Diagnostic devices | 6 |
| 7 | Drug Delivery: Controlled Release, Diffusion Controlled and Membrane based devices, Mechanical Pumps | 6 |
| 8 | Biomaterial for Organ Replacement<br>Mechanical Properties, Bone Substitutes | 6 |
| 9 | Introduction of Tissue Engineering: Cell, Scaffold design, Artificial liver, pancreas, cartilage | 6 |
| 10 | Regulatory overview | |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Schoen, F. J., Ratner, B. D., Hoffman, A. S., Lemons, J. E. (2004). Biomaterials Science: An Introduction to Materials in Medicine. Netherlands: Elsevier Science. | |
| 2 | Hench, L. L., Ethridge, E. C. (1982). Biomaterials: an interfacial approach. United Kingdom: Academic Press. | |
| 3 | Bronzino, J. D. (2000). The Biomedical Engineering Handbook. Germany: CRC Press.. | |
| 4 | Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine. 2nd ed. Burlington, MA: Academic Press, 2004. ISBN: 9780125824637 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand common use of biomaterials as metals, ceramics and polymers and its chemical structure, properties, and morphology. | K3 |
| CO2 | Understand and account for methods for categorization of biomaterials. | K4 |
| CO3 | Explain methods to modify surfaces of biomaterials and choose material for desired biological response. | K3 |
| CO4 | Describe interactions between biomaterials, proteins and cells. | K4 |
| CO5 | Understand the interaction between biomaterial and tissue for short term and long term implantation, distinguish between reactions in blood and in tissue. | K5 |

| | | |
|---|---|---|
| CO6 | Explain the types of material used to replace different organs & tissues of human body. | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Biomaterials: Biodegradable Materials for Biomedical Applications CET4757**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Biomaterials: Biodegradable Materials for Biomedical Applications CET4757**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4758 | Course Title: Advanced Membrane Separations | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemical Engineering Operation ((CET4254), Separation Process (CET4356) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Advanced Separation Process (CET4552) | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course is intended to familiarize the students of chemical engineering with the new, emerging and nontraditional separation techniques and their potential applications in chemical and allied process industries. The course will provide exposure to membrane-based techniques, chromatographic separation, super critical fluid extraction and various other technologies.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction: classification and definitions | 12 |
| 2 | Membrane Processes and their applications: Microfiltration, Ultrafiltration and micelle-enhanced ultrafiltration, Nanofiltration, Reverse osmosis, Dialysis, piezo dialysis, electrodialysis, Pervaporation and membrane distillation, Gas permeation, Liquid membranes, Ion exchange membranes<br>Transport mechanisms, and mathematical modelling | 12 |
| 3 | Membranes: Design of membranes, Characterization | 12 |
| 4 | Polarisation and fouling: Polarisation phenomena and fouling concentration polarization, Characteristic flux behaviour in pressure driven membrane operation, Membrane fouling, Methods to reduce fouling | 12 |
| 5 | Process design: modules and configurations: Capillary, hollow fibre, tubular, Plate and frame, Spiral wound Membrane reactors and their applications in biotechnology | 12 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | |
|---|---|
| 1 | Mulder, M.H.V. Membrane Separations, Springer. |
| 2 | Philip, R., Wankat, C. Rate-Based Separations, Springer. |
| 3 | Transport Processes and Separation Process principles, Christie J Geankoplis Prentice-Hall of India Private Ltd, New Delhi, 4th Edition 2006. |
| 4 | Nunes, S.P., Peinemann, K.V. Membrane Technology in the Chemical Industry, Wiley. |
| 5 | Rautanbach and R. Albrecht, Membrane Processes, Wiley. |
| 6 | Crespo, J.G., Bodekes, K.W. Membrane Processes in Separation and Purification, Kluwer Academic Publications. |
| 7 | Geankoplis, C.J. Transport Processes and Unit Operations, Prentice-Hall |
| 8 | Separation Process Principles, J.D. Seader and E.J.Henley, Wiley, 2nd Edition 2004 |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Ability to identify an appropriate separation technique for intended problem. | K3 |
| CO2 | Understand the principle of membrane separation for various aqueous systems. | K4 |
| CO3 | To conceptualize the reactive and catalytic distillation. | K3 |
| CO4 | Ability to recognize the selection criteria between advanced separation techniques and conventional separation techniques. | K4 |
| CO5 | Evaluate which membrane materials and morphologies are most suitable for a membrane separation/purification system. | K5 |
| CO6 | Able to design a suitable membrane separation process for a given separation system | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Advanced Membrane Separations CET4758<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Advanced Membrane Separations CET4758<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4759 | Course Title: Process Design of Heat and Mass Transfer Equipment | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Chemical Engineering Operation ((CET4254), Heat Transfer (CET4252) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Advanced Separation Process (CET4552) | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course provides the basics of major heat and mass transfer operations. The objective of this course is to impart knowledge on design of heat and mass transfer equipment. In addition, it also imparts knowledge on optimization of the cost of heat transfer operations used in bioprocess industries.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Advanced Process design aspects of various process equipment will be considered through several case studies; and will cover hydrodynamic characteristics, heat and mass transfer characteristics, selection criteria, etc.<br>The topics will include some of the following equipment (but not limited to):<br>(1) Equipment for heat transfer: plate heat exchangers, plate fin exchangers, finned tube exchangers, thermo-siphon reboilers, evaporators, condensers, etc.<br>(2) Equipment for Unit operations: plate and packed columns, spray towers, etc.<br>(3) Equipment for Multiphase reactions: Stirred tanks, gas inducing reactors, bubble columns / modified bubble columns, air-lift reactors, packed and plate columns, trickle bed reactors, ejectors, etc. | 60 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | A. Suryanarayana, "Mass Transfer Operations", 1st edition, New - Age, International, 2006. | |
| 2 | McCabe, W.L. Smith J.C. and Harriot P., "Unit Operations of Chemical Engineering", 7th edition, McGraw Hill, 2004. | |
| 3 | D. Q. Kern, "Process Heat Transfer", McGraw-Hill, 2001. | |
| 4 | C. J. King, "Separation Processes", 2nd edition, McGraw Hill, 2014. | |
| 5 | P.M. Doran, "Bioprocess Engineering Principles", 2nd edition, Academic Press, 2012. | |
| 6 | R.E. Treybal, "Mass Transfer Operations", 3rd edition, Mc-Graw Hill, 2012. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand the basic modes of heat and mass transfer. | K2 |
| CO2 | Apply principles of heat and mass transfer to predict transfer coefficients | K3 |
| CO3 | Analyze working of various heat transfer equipment | K4 |
| CO4 | Design heat and mass transfer equipment. | K6 |
| CO5 | Evaluate no. of stages required for given mass transfer problem. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Process Design of Heat and Mass Transfer Equipment CET4759**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Process Design of Heat and Mass Transfer Equipment CET4759<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4760** | **Course Title:** **CFD applications in chemical processes** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | NIL | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Design Project (CEP4461) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The course provides brief introduction of Computational Fluid Dynamics along with chemical engineering application specifically, analysis of fluid mechanics and heat transfer related problems. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Derivation of equations of momentum and energy for turbulent flows.<br>Finite volume technique<br>One dimensional heat conduction and flow<br>Grid generation<br>Space and time discretization<br>Pressure velocity coupling (simple, simpler & SIMPLEC)<br>Open FOAM software, simulation of pipe flow, backward step, flow past cylinder<br>Commercial software, simulation of pipe flow, backward step, flow past cylinder, stirred vessel, bubble column, cyclone separator, spray dryer etc. | | 60 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Versteeg and Malalasekera, “An introduction to computational fluid dynamics. The finite volume method”, (2007) | | | | |
| 2 | Patankar S., “Numerical heat transfer and fluid flow”, (1980) | | | | |
| 3 | P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw-Hill (1998). | | | | |
| 4 | Muralidhar, K., and Sundararajan, T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House (1995). | | | | |
| 5 | P. Niyogi, P. Chakrabarty, S.K. and Laha, M.K., Introduction to computational fluid dynamics, Pearson education (2006). | | | | |
| 6 | LI J., G. H. Yeoh, C Liu. A Computational Fluid Dynamics, ELSEVER (2008) | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Comprehensive Understanding: Gain a comprehensive understanding of the principles underlying fluid dynamics, numerical methods, and the application of Computational Fluid Dynamics in the domain of chemical engineering. | | K2 | | |
| CO2 | Application Proficiency: Develop proficiency in applying CFD techniques to simulate and analyze various fluid flow scenarios, including multiphase flows, heat transfer, and reacting flows. | | K3 | | |
| CO3 | Problem-Solving and Optimization: Apply optimization and sensitivity analysis in CFD simulations for improved design and performance within chemical engineering applications | | K4 | | |
| CO4 | Technological Integration: Explore and utilize emerging technologies, such as machine learning, to enhance predictive analysis and innovation in CFD simulations. | | K5 | | |
| CO5 | Professional Development: Gain exposure to industrial challenges, best practices, and emerging trends in CFD, fostering readiness for practical applications and future advancements within the chemical engineering field. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Chemical Engineering Elective: CFD applications in chemical processes CET4760<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: CFD applications in chemical processes CET4760<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4761 | Course Title: Process Systems Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | NIL | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Design Project (CEP4461) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This course gives a general background on problems, methods, and tools for process systems engineering. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | **Introduction to Systems Engineering:** Systems and their origin, examples of problems in Systems Engineering | | 5 | | |
| 2 | **Foundations of Systems Engineering:** Scope and Formulation of Engineering Problems, Goals, Objectives, Specifications and Constraints, Types of Models; Hierarchical decomposition of systems, Types of Problems: Forward solution and inversion of models | | 5 | | |
| 3 | **Structural Analysis of Systems:** Graphs and digraphs: Representation of systems, Partitioning and Precedence Ordering of systems, Structural analysis of modelling equations, Structural controllability and observability of systems, Applications to engineering problems | | 10 | | |
| 4 | **Steady State Analysis of Systems:** Formulating steady-state models and simulations, Degrees of freedom and design specifications, The Sequential-Modular Strategy, The Equation-Oriented Strategy, Applications to engineering problems | | 10 | | |
| 5 | **Optimization of Systems:** Theory and Algorithms: Basic concepts and definitions, Linear programming, Unconstrained nonlinear optimization, Nonlinear Programming, Combinatorial optimization, Applications to engineering problems | | 10 | | |
| 6 | **Simulation of Dynamic Systems:** Basic concepts: Systems described by ODEs and DAEs, formulating dynamic simulations; consistent initialization, Numerical integration of ODEs and DAEs, Modelling-simulation of hybrid Discrete/Continuous systems, Applications to engineering systems | | 10 | | |
| 7 | **Model-Based Process Control:** The nature of feedback control, The concept of model-based control systems, Design and analysis of model-based control systems applications | | 10 | | |
| | **Total** | | **60** | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Versteeg and Malalasekera, “An introduction to computational fluid dynamics. The finite volume method”, (2007) | | | | |
| 2 | Patankar S., “Numerical heat transfer and fluid flow”, (1980) | | | | |
| | | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | The students will know how to establish simple and large-scale process models, and how to perform analysis of these models. | | K2 | | |
| CO2 | The student will further have knowledge of the working principles of the most common numerical simulation algorithms and be able to implement basic versions of them in a programming language (e.g. python). | | K3 | | |
| CO3 | The student will know how to use state-of-the-art python tools to solve important problems from Process Systems Engineering. | | K4 | | |
| CO4 | The student will be able to understand and apply tools for adjusting model parameters to experimental data and have basic knowledge of data-driven models such linear static models and neural networks. | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Chemical Engineering Elective: Process Systems Engineering CET4761<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Process Systems Engineering CET4761<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4762** | **Course Title:** **Project Management: Case Study Approach** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | NIL | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Design Project (CEP4461) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Case Study Based Project Management course is an introductory course to project management. It is designed to lay down the foundations for a more in-depth study of project management through a basic overview of key concepts. In addition to being exposed to these key concepts, participants will be provided with an opportunity to recognize how these key concepts are crucial in ensuring project success. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning. | | 10 | | |
| 2 | Project execution as conglomeration of technical and non-technical activities.<br>Detailed Engineering activities. | | 10 | | |
| 3 | Pre project execution main clearances and documents<br>Project team: Role of each member. Importance<br>Project site: Data required with significance.<br>Project contracts. Types and contents.<br>Project execution<br>Project cost control.<br>Bar charts and Network diagram.<br>Project commissioning: mechanical and process | | 40 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | | | | | |
| 2 | | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Define a project and explain project life cycle and project constraints | | K2 | | |
| CO2 | Explain the key elements of project initiation and develop project estimate and plan | | K3 | | |
| CO3 | Identify project stakeholders and develop communication plan | | K4 | | |
| CO4 | Manage project schedule | | K3 | | |
| CO5 | Identify and manage key sources of conflict in projects | | K3 | | |
| CO6 | Manage project change and explain tasks require to close a project | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

**Chemical Engineering Elective: Project Management: Case Study Approach CET4762**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Project Management: Case Study Approach CET4762<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4763** | **Course Title: Advanced Materials** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Applied Physics (PHT4151), Introduction to Material Technology (SMT4351), | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Material Processing (SMT4354) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| This course provides to learn the principles of material testing and characterization and to apply them for various engineering applications. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Nanostructured Materials: Metal nano particles, their structure and properties , Carbon nano tubes: manufacture, properties and applications. Nano materials in catalysis. | | 10 | | |
| 2 | Composite Materials: Polymer composites, metal-metal composites, polymer-metal composites, metal- ceramic composites. | | 10 | | |
| 3 | Superconducting Materials: Principles of superconductivity, properties, advantages and limitations of superconductors. Applications, superconductors | | 10 | | |
| 4 | Smart Materials: Shape memory alloys, Auxetic materials and Biomimicking materials. Stimuli for sensors and actuators | | 30 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Physical Chemistry, Atkins and de Paula (any recent edition) | | | | |
| 2 | Inorganic Chemistry, 5th edition by P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Understand how intermolecular forces determine colloidal behaviour, surfactant and surface phenomena. | | K2 | | |
| CO2 | Understand the application of statistical thermodynamics to describe the behaviour of gases, simple liquids, as well as phase (gas-liquid) equilibrium and liquid mixtures. | | K3 | | |
| CO3 | Develop an understanding of the relationship between structure, local crystal chemistry and function in the solid state. | | K4 | | |
| CO4 | Implement the theory developed in the lecture course through the practical component. | | K3 | | |
| CO5 | Work to a professional level of skills in a chemical laboratory demonstrating effective laboratory safety and etiquette, especially in the areas of handling of chemicals and usage of lab-based glassware and equipment. | | K3 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Chemical Engineering Elective: Advanced Materials CET4763<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Advanced Materials CET4763**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4764** | **Course Title: Plant Utilities** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | NIL | |
| **List of Courses where this course will be prerequisite** | | |
| | Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256) | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | |
| Chemical engineer must ensure smooth and proper operation of utilities and auxiliaries' plants such as steam, compressed air, instrumental air, inert gases, DM water and chilled water. These utilities are essential for manufacturing different chemical products. Use of concept of energy efficiency and green chemistry are necessary for energy conservation in chemical plant for producing materials of desired quality and to maintain plant safety. Hence the course has been design to develop these competencies and its associated cognitive and effective domain learning outcomes. | | |
| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
| 1 | Role of Process Utilities in process industries. Impact on Project economics | 8 |
| 2 | Water, its characteristics and its conditioning and treatment for process industries e.g. boiler feed water, cooling water. Recycling aspects of water from blow downs. | 8 |
| 3 | Application of steam systems in chemical process plants, design of efficient steam heating systems, condensate utilization, flash steam, steam traps. | 8 |
| 4 | Characteristics properties, classification, selection and industrial applications | 8 |
| 5 | Characteristics of air and air receivers, instrument air. Inert gas generation | 8 |
| 6 | Vacuum system engineering.<br>Electrical Power: HT/LT | 5 |
| 7 | Area classification,<br>Motors/drives selection accordingly. | 5 |
| 8 | Single line diagram.<br>Emergency Drives Identification<br>Emergency power. Inverters, DG sets. Etc. | 5 |
| 9 | Estimation of utilities<br>Utilities Audit | 5 |
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Physical Chemistry, Atkins and de Paula (any recent edition) | |
| 2 | Inorganic Chemistry, 5th edition by P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong. | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | Student will be able to interpret the usage of water as utility across various applications in an industry. | K2 |
| CO2 | Knowledge of utilization of air and various form of air utilization in industry. | K3 |
| CO3 | Understanding of application and means of generation of steam in industry | K4 |
| CO4 | Understanding of refrigeration systems and its utilization in an industry. | K3 |
| CO5 | Knowledge of implementing a venting system and vacuum system in an industry | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

| **Chemical Engineering Elective: Plant Utilities CET4764**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Plant Utilities CET4764**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4765** | **Course Title: Fuels Engineering** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Introduction to Petroleum Technology (SPT4351) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | Petrochemicals Technology (SPT4355), Refinery engineering (SPT4354), Reservoir Technology (SPT4353) | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| Fuel is a substance that produces useful energy either through combustion or through nuclear reaction. Energy should be released in a controlled manner and can be harnessed economically for domestic and industrial purposes. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Classification of fuels: G/L/S , Automotive Fuels Bharat Standards IV | | 8 | | |
| 2 | Gaseous Fuels: Natural Gas: Processing for pipeline specs, CO2/H2S/COS Removal, Gas dehydration, Gas compression for pipeline transport, Coal bed methane, Bio Gas (methane) | | 8 | | |
| 3 | CNG: As auto fuel, Compression, CNG stations | | 8 | | |
| 4 | LNG: Liquefaction of NG JT effect, closed & open cycle, Storage of LNG, Transportation of LNG, vessels / truck, terminal, Gasification of LNG to NG for pipeline transport | | 8 | | |
| 5 | Liquid Fuels: Refinery sources, Reforming for fuels, LPG: Domestic and Auto LPG Storage and handling, Manufacture and Storage (Partly in I&EC) Petrol, Diesel, Aviation Turbine Fuel, HSD, LDO. Furnace oil, Fuel oil, LSHS. Biofuels: bioethanol, biodiesel | | 8 | | |
| 6 | Solid Fuels: Characterization, Coal, Biomass, Residue from Refinery, Plastic waste, Municipal domestic waste | | 5 | | |
| 7 | Combustion of Fuels: Basic equation, air requirement norms for excess air, Heating value: GHV/LHV Calculations for mixture of components, Wobbe number for Gaseous Fuels definition and significance, Burners: Gas/Liquid/Hydrogen, Flue gas composition, Dew point calculations, Treatment of flue gas to meet local standards, Carbon Credit | | 5 | | |
| 8 | Gasification of Coal, Indian Coal, Biomass, Refinery Heavy Residue, Power generation, combined cycle, cogeneration | | 10 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | S. Sarkar, “Fuels and combustion”, 3rd Edition, Universities Press, 2009. | | | | |
| 2 | S.P. Sharma and C. Mohan, “Fuels and combustion”, Tata McGraw-Hill, 1984 | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Differentiate between various fuels. | | K2 | | |
| CO2 | Analyse exhaust and flue gases | | K4 | | |
| CO3 | Understand design considerations of burners, Gasification of coal, differents types of fuel | | K3 | | |
| CO4 | Control of emissions in combustion | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Chemical Engineering Elective: Fuels Engineering CET4765 Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |

| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; |
|---|

| **Chemical Engineering Elective: Fuels Engineering CET4765**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4766 | Course Title: Advanced topics in Polymer Chemistry/Physics Characterization/Analysis of Polymers | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | 10+2 Physics, Applied Physics (PHT4151), | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Introduction to Material Technology (SMT4351), Polymer Science and Technology- I (SMT4352), Synthesis and Characterization of Resins and Polymers (SMP4351), Polymer Science and Technology- II (SMT4353) | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This course introduces advanced methods of polymerization and to the characterization of macromolecules in solution. The course is made of flipped classrooms and projects. All topics are not necessarily covered each year.<br>Part A: After recalling the basics of chain polymerization methods, the different current synthetic strategies will be studied (anionic, cationic, standard radical, controlled radical and coordinative polymerization methods). The scope and limitations of each method will be systematically discussed. Mechanistic and kinetic features will be then studied for each polymerization method. Special emphasis will be finally placed on the control of macromolecular architectures.<br>Part B discusses the notions of ideal and real chains, the size of macromolecules in solution, the notions of excluded volume and second virial coefficient, the thermodynamic properties of polymer solutions, and different techniques of characterization of polymers in solution (osmometry, viscometry, size exclusion chromatography, static light scattering). | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Structure/property relationship: Morphology & Crystallinity Mechanical and Chemical properties | | 10 | | |
| | Structure/Rheology relationships<br>Rheology, elasticity, Viscoelasticity, yield and fracture chemical resistance<br>Properties of commercial polymers. PE, PP, Acrylic, amides & peptides phenolic & Urethane resins | | 15 | | |
| 2 | Role of Additives: Type of additives and their role in altering the properties | | 10 | | |
| 3 | Polymer composites: Carbon filled; fibre filled etc. Reinforced polymers | | 10 | | |
| 4 | Analysis of polymer solubility, thermodynamics and phase equilibrium of polymer solutions, End group analysis, Colligative property measurement, Light scattering, Solution viscosity and molecular size and wt. distribution. Spectroscopic methods, microscopy, thermal analysis. | | 15 | | |
| 5 | Selection of polymers, domestic and engineering usage | | 10 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | S Introduction to polymers- R.J.Young & P.A.Lovell, Chapman & Hall, London. second edition. Wiley online library 1991. | | | | |
| 2 | Textbook of Polymer Science- Fred W. Billmeyer, J.R.John Wiley & Sons, New York. Third edition. Wiley online library 1994. | | | | |
| 3 | Principles of Polymer Systems- F. Rodrignek, McGraw Hill, N.Y. 2nd edition. Wiley online library 1981. | | | | |
| 4 | Polymer Chemistry- Seymour & Carreher, Marcel Dekkar, NY. Library of congress. | | | | |
| 5 | Fundaments of Polymer Science and Engineering- Anil Kumar & S.K.Gupta, Tata McGraw Hill, New Delhi. 1978. | | | | |
| 6 | Principle of polymer science-P Bahadur, N.V Sastry 2nd edition Narosa Publishing House. 2002. | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | Realize the basic concept of chemical reactions and polymerization reactions involved in the Macro molecules and micro molecular reactions | | K2 | | |

| | | |
|---|---|---|
| CO2 | Become fully aware of the stereo chemistry and physical status of polymer molecules, molecular weight, stereo specificity and stability of polymer compounds. | K4 |
| CO3 | Understand the study of methods of polymerization reaction and their properties, advantages, disadvantages, modifications and applications. | K3 |
| CO4 | Understand the various methods and techniques of polymerization reactions, their chemistry, mechanism, structures, properties and applications. | K2 |
| CO5 | Understand the structure of monomers, functionality, and classification of polymers based on source, composition, conditions, molecular weight, geometry, and Nomenclature of polymers. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Advanced topics in Polymer Chemistry/Physics Characterization/Analysis of Polymers CET4766**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Advanced topics in Polymer Chemistry/Physics Characterization/Analysis of Polymers CET4766**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4767 | Course Title: Polymer Reactor Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | NIL | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | Synthesis and Characterization of Resins and Polymers (SMP4351), Polymer Science and Technology- II (SMT4353) | | | | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course provides a complete overview of current and future aspects in polymer engineering. The finished polymer product properties are usually determined during the production process and hence it very essential to understand all the fundamentals and chemistry behind the polymerization process. Various terms such as reaction initiation, propagation, termination, reaction kinetics, thermal kinetics, molecular weight, and physical features such as microstructures, morphology, tensile and fractural strength etc. will be discussed in this course. The general polymerization concepts, principles, kinetics and methodology will be discussed through various examples.

The course will be helpful for polymer and chemical engineer, students and industries for the advancement in the concepts related to polymer reaction engineering.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Kinetic modelling, concept of reactor design, optimisation and control of polymerisation process, isolation and separation of monomers/catalyst/by products etc for Bulk polymerisation, Solution polymerisation, Emulsion polymerisation, suspension polymerisation with case studies | 10 |
| 2 | Bonding forces in polymers, Molecular weight and its distribution, control of polymer synthesis; thermodynamic and kinetic control, diffusion control, polymer end chain control & polymerization process, control strategies | 10 |
| 3 | Interpretation of batch reactor data; Kinetic equations for unimolecular & bimolecular irreversible different order reaction such as second order& nth order, Half -life, varying and constant volume reaction system, Design equations for ideal reactors, namely batch, CSTR, plug flow, design equation for single reaction systems using batch and semi batch, CSTR, PFR, Multiple reactor system; reactor in series and parallel, Preference of type of reactor used, Best arrangement in ideal reactors | 10 |
| 4 | Recycle reactor, auto catalytic reactions, Design for multiple reactions: Parallel and series reactions, quantitative and qualitative treatment of product distribution and of reactor size for different types of ideal reactors, selectivity and yield, reactors in series and parallel for single reaction system, related problems<br>Problems; related to reaction kinetics, series and parallel reaction and multiple reactor systems, Reaction engineering of step growth polymerization: Basic properties & Examples of commercially important polymers, Reactivity of functional groups Kinetics of step polymerization, Self-Catalysed Polymerization, External Catalysis of Polymerization, Effect of Non-equivalence of Functional Groups, Accessibility of functional groups, Equilibrium considerations, Cyclization versus linear polymerization | 10 |
| 5 | Step growth polymerization; Molecular weight control in linear polymerization, Molecular weight distribution in linear & non-linear polymerization, Introduction to radical chain polymerization, Basic concepts of resonance, Comparison between radical and step polymerization, Comparison between radical and ionic chain polymerization, Thermodynamic and kinetic aspect of Radical Chain Polymerization, Effect of Substituents, Modes of Propagation of Monomer Units, Experimental Facts from Literature, Synthesis of Head-to-Head Polymers, Polymerization Sequence: Initiation, Propagation, Termination | 10 |
| 6 | Radical chain polymerization; Rate Expression, Cage Efficiency, Determination of Rate of polymerization, Precipitation of Polymer, Polymer and Process Analysis for polymerization, Initiation, Stability and Half Life of Initiators, Dependence of Polymerization Rate on Initiator, Dependence on Monomer, Initiation in aqueous media, | 10 |

| | | |
|---|---|---|
| | Redox Initiation (cont.), Initiation in non-aqueous media, Rate of Redox polymerization, Photochemical Initiation<br>Photosensitizer, Mechanism of Photo-initiation, Rate of Photo-polymerization, Absorbed light Measurement, Initiation by Ionizing Radiation, Other initiation techniques, Electrolytic polymerization, Plasma polymerization, Sonication, Kinetic Chain Length and other important terms, Heterogenous Polymerization: Precipitation, Suspension | |
| 7 | Heterogenous Polymerization: Precipitation, Suspension (cont.) & Emulsion Polymerization; microstructural feature, factors affecting the emulsion polymerization, process of emulsion polymerization, mechanism kinetic and thermodynamics, Model, surface active agents, process, population balance, Physical properties and phase equilibrium calculations | 9 |
| 8 | Emulsion Polymerization: particle nucleation, morphology, types of reactors used for emulsion polymerization, performance of emulsion, polymerization reactors, Population balance, Implementation of emulsion polymerization, Ionic Chain Polymerization: Comparison between radical and ionic chain polymerization, Living and Dormant polymers and polymerizable<br>Ionic Chain Polymerization: classification of ionic species, effect of solvents, conductance studies, initiation and propagation in ionic polymerization, effect of solvating agent, Heat and Entropy of dissociation of ionic pairs, types of ions, cationic polymerization, Chain | 9 |
| 9 | Kinetic modelling of co-polymerisation processes | 9 |
| | **Total** | **60** |
| **List of Text Books/ Reference Books** | | |
| 1 | Odian G., 2002, “Principles of Polymerization”, John Wiley & Sons. | |
| 2 | Billmayer, F. W., Textbook of Polymer Science 3rd Edition, Willey 1984 Inter Science, New York | |
| 3 | Pauer, Werner (Ed.), 2018, Polymer Reaction Engineering of Dispersed Systems, Springer publications\| ISBN 978-3-319-96436-2 | |
| 4 | José M. Asua, 2007, Polymer Reaction Engineering, Blackwell Publishing Ltd | |
| 5 | Thierry Meyer and Jos Keurentjes, 2005, Handbook of polymer Reaction engineering, Wiley-VCH | |
| 6 | Beisenberger J. A. and Sebastian D.H.; “Principles of Polymerization Engineering”, John Wiley& Sons | |
| **Course Outcomes (students will be able to…..)** | | |
| CO1 | To Study the methods of measuring the molecular weight, polymerization kinetics and Copolymerization and polymer processing technologies. | K2 |
| CO2 | To understand all the fundamentals and chemistry behind the polymerization process. | K4 |
| CO3 | Understand the kinetic modelling of co-polymerisation processes | K3 |
| CO4 | Understand the various terms such as reaction initiation, propagation, termination, reaction kinetics, thermal kinetics, molecular weight, and physical features such as microstructures, morphology, tensile and fractural strength etc. | K2 |
| CO5 | Understand the general polymerization concepts, principles, kinetics and methodology will be discussed through various examples. | K2 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Polymer Reactor Engineering CET4767**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Polymer Reactor Engineering CET4767<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4768 | Course Title: Polymer Processing | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Polymer science and Technology I (SMT4352), Structural Property Relationship (SMT4355), Introduction to Material Technology (SMT4351) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Material Processing (SMT4354) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course provides a generalized understanding to the polymer process engineering. First, a brief introduction about several polymers, their classification, and characterization techniques is provided. Then, the deep insight on the thermodynamic, rheological, heat and mass transfer, as well as reaction engineering perspective of the polymers is explained. Finally, the student will get to learn about the polymer processing, preparation processes, and industrial testing methods. To better understand the engineering perspective, the application of polymers in electronic sectors and building engineering is also discussed with examples.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Plastic Technology: Moulding, (injection, blow) extrusion, cold-not and vacuum forming multipolymer systems. Equipment design and operating conditions | 10 |
| 2 | Fibre Technology: Textile processing, fibre spinning and after treatment. Equipment design and operating conditions | 10 |
| 3 | Elastomer Technology: Vulcanisation, Reinforcement compounding Equipment- design & operating conditions, environmental impact | 10 |
| 4 | Recycle of polymers: Reprocessing techniques and limitations | 10 |
| 5 | Selection of polymers: domestic & engineering usage | 10 |
| 6 | Rheological and mechanical measurements concept of solution viscosity | 10 |
| | **Total** | **60** |

**List of Text Books/ Reference Books**

| | |
|---|---|
| 1 | Richard G. Griskey Ph.D., P.E. (auth.) - Polymer Process Engineering-Springer Netherlands (1995) |
| 2 | James J. Licari, Laura A. Hughes - Handbook of Polymer Coatings for Electronics_ Chemistry, Technology and Applications (Materials Science and Process Technology Series)-William Andrew (1991) |
| 3 | Yoshihiko Ohama - Handbook of polymer-modified concrete and mortars_ properties and process technology-Noyes Publications (1995) |
| 4 | Roger Brown - Handbook of polymer testing - physical methods-CRC Press (1999) |
| 5 | Werner Pauer - Polymer Reaction Engineering of Dispersed Systems_ Volume I (2018, Springer International Publishing) |
| 6 | George Odian - Principles of Polymerization (2004, Wiley-Interscience) |
| 7 | Jose Asua - Polymer Reaction Engineering (2007, Wiley-Blackwell) |

**Course Outcomes (students will be able to…..)**

| | | |
|---|---|---|
| CO1 | Isolate the key design features of a product which relate directly to the material(s) used in its construction | K2 |
| CO2 | Indicate how the properties of polymeric materials can be exploited by a product designer. | K4 |
| CO3 | Pursue lifelong learning that addresses, from concept to commercialization, the design and manufacture of plastic products. | K3 |
| CO4 | Realize basic elements in optical fibres, different modes and configurations | K2 |
| CO5 | Analyze the transmission characteristics associated with dispersion and polarization techniques. | K4 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Polymer Processing CET4768<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Polymer Processing CET4768<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4769 | Course Title: Introduction to Polymer Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Polymer science and Technology I (SMT4352) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | Material Processing (SMT4354) | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course provides a generalized understanding about polymer engineering is commonly an engineering area that designs, analyses, and modifies polymers. It covers aspects of the petrochemical industry, polymerization, shape and polymer characterization, and properties. Also, it includes polymer processing and description, and structure–property concerning applications.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction to Polymers: Classification based on application and history, Natural and synthetic polymers and types e.g. fibres, rubbers, adhesives, resins, plastics, etc. | 15 |
| 2 | Classification based on properties/structures: Thermoplastic, thermosetting, crystalline, amorphous, molecular weights status, transitions, glass transition temperature | 15 |
| 3 | Polymer formation/modification: Functionality and reactions, chain, ionic, condensation, co-ordination, complex polymerisation, Kinetic schemes, Orders of reactions, Cross-linking, Co-polymerisation, Heat effects | 15 |
| 4 | Polymerisation Processes and methods of manufacture: Bulk, Solution, Suspension and emulsion polymerisation with examples, polystyrene, polyethylene/propylene, styrene-Butadiene, poly urethane, Epoxy, PET, Kinetics, reaction rates, diffusional limitations, Biodegradable polymers | 15 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Paul C. Painter and Michael M. Coleman, Essentials of Polymer Science and Engineering, Destech Publications, Inc., 2008. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Students will be able to understand the relationships between polymer molecular weight, molecular weight distribution, and the properties of polymeric materials. | K2 |
| CO2 | Students will demonstrate an ability to distinguish different polymerization reactions and their mechanisms/kinetics and learn how actual polymerization is performed in the laboratory. Students will also be able to analyze polymerization data and predict the conversion and molecular weight, which will lead to critical thinking about how to improve the setup for better polymerization. | K3 |
| CO3 | Students will be able to determine polymer molecular weights and molecular weight distributions from different types of experiments. Students will learn about polymer solvent interaction and the effect of the solvents on the dimensions of the polymers in solution. | K4 |
| CO4 | Students will improve and expand their skills in performing and analysing the thermal and mechanical properties of polymers and demonstrate an ability to predict how the molecular weight will affect these properties. | K4 |
| CO5 | Students will be able to describe the viscoelastic behaviour of polymers with respect to their chemical structures and molecular weights, and to construct a corresponding master curve from the experimental data, which can be used to predict the material response at different temperatures, times, and/or frequencies. | K5 |
| CO6 | Students will be able to run extrusion and injection moulding machines, and to collect and analyze data. This will help them to make connections between the polymer molecular weight, viscoelastic properties, and processing conditions. | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Introduction to Polymer Engineering CET4769<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Introduction to Polymer Engineering CET4769<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4770 | Course Title: Downstream Processing in Biochemical Industry | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Introduction to Biological Science (BST4251) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The purpose of downstream processing is to isolate, purify and concentrate the previously synthesized drug substance or other product from the complex bulk matrix. Downstream processing may also include formulation activities, signifying the transition from drug substance to drug product (DP).

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Separation processes in biochemical industry, Separation processes for bulk chemicals and proteins, special needs, Unit operations on biochemical industry, such as filtration, centrifugation, heat and mass transfer, | 10 |
| 2 | Solvent extraction: liquid-liquid extractions, phase diagrams, thermodynamics of liquid - liquid extraction, physical vs reactive extraction, liquid ion exchangers, design of extractors, two phase flow in extractors, modelling and simulation of extractors, | 10 |
| 3 | Aqueous two-phase extraction, affinity partitioning, dye ligand partitioning, Reverse micellar extraction of proteins and enzymes, | 10 |
| 4 | Adsorption: physical and chemical adsorption, theories of adsorption, ion exchange resins and polymeric adsorbents, adsorption of small molecular weight bioproducts such primary and secondary metabolic products of cells, | 10 |
| 5 | Protein purifications, precipitation, affinity precipitation, adsorptive and chromatographic separations of proteins, design of adsorption columns, Methods of operation., | 10 |
| 6 | Gel permeation chromatography, metal ligand chromatography, dye ligand chromatography, affinity chromatography, expanded bed chromatography, | 5 |
| 7 | Applications in biochemical industry | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Belter, P.A. E.L. Cussler And Wei-Houhu – "Bioseparations – Downstream Processing For Biotechnology, Wiley Interscience Pun. (1988). | |
| 2 | Sivasankar, B. "Bioseparations : Principles and Techniques". PHI, 2005. | |
| 3 | R.O. Jenkins, (Ed.) – Product Recovery In Bioprocess Technology – Biotechnology By Open Learning Series, Butterworth-Heinemann (1992). | |
| 4 | J.C. Janson And L. Ryden, (Ed.) – Protein Purification – Principles, High Resolution Methods and Applications, VCH Pub. 1989 | |
| 5 | R.K. Scopes – Protein Purification – Principles And Practice, Narosa Pub. (1994). | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Upon success completion of this course, the students will be able to Understand the methods to obtain pure proteins, enzymes and in general about product development R & D | K3 |
| CO2 | Able to Define the fundamentals of downstream processing for product recovery | K3 |
| CO3 | Able to Understand the requirements for successful operations of downstream processing | K3 |
| CO4 | Able to Describe the components of downstream equipment and explain the purpose of each | K2 |
| CO5 | Able to Understand the process of isolation, purification, product formulations and finishing operations involved in bioproduct production | K4 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Downstream Processing in Biochemical Industry CET4770<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Downstream Processing in Biochemical Industry CET4770<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4771 | Course Title: Advanced Biochemical Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Introduction to Biological Science (BST4251) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course provides the basic principles of reactor design for bioprocess and biotechnology applications. Biochemical engineers are key players in the greatest biomedical challenges that lie ahead including: can we make medicines more cheaply and quickly. how to make food more efficiently and with less energy.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Separation processes in biochemical industry, Separation processes for bulk chemicals and proteins, special needs, Unit operations on biochemical industry, such as filtration, centrifugation, heat and mass transfer, | 10 |
| 2 | Solvent extraction: liquid-liquid extractions, phase diagrams, thermodynamics of liquid - liquid extraction, physical vs reactive extraction, liquid ion exchangers, design of extractors, two phase flow in extractors, modelling and simulation of extractors, | 10 |
| 3 | Aqueous two-phase extraction, affinity partitioning, dye ligand partitioning, Reverse micellar extraction of proteins and enzymes, | 10 |
| 4 | Adsorption: physical and chemical adsorption, theories of adsorption, ion exchange resins and polymeric adsorbents, adsorption of small molecular weight bioproducts such primary and secondary metabolic products of cells, | 10 |
| 5 | Protein purifications, precipitation, affinity precipitation, adsorptive and chromatographic separations of proteins, design of adsorption columns, Methods of operation., | 10 |
| 6 | Gel permeation chromatography, metal ligand chromatography, dye ligand chromatography, affinity chromatography, expanded bed chromatography, | 5 |
| 7 | Applications in biochemical industry | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | "Principle of Fermentation Technology", P.F. Stanbury and A. Whitaker; Pergamon Press. | |
| 2 | "Basic Biotechnology", J. Bu'lock, B. Kristiansen, Academic Press. | |
| 3 | "Biochemical Engineering Fundamentals" by J.E. Bailey and D.F. Ollis, McGraw-Hill Book Co., New York. | |
| 4 | Bioprocess Engineering Basic Concepts. 2nd edition.. Michael L. Shuler and Fikret Kargi, Prentice Hall, Upper Saddle River, NJ. | |
| 5 | Bioprocess Engineering Principles Pauline Doran, Academic Press, London. | |
| 6 | T Panda, Bioreactors analysis and design, Tata McGraw Hill, New Delhi, New York, 2011 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Apply chemical engineering principles e.g. fluid flow, mixing, heat transfer and mass transfer principles to bioreactors. | K3 |
| CO2 | Assess the performance of bioreactors and troubleshoot operational problems. | K3 |
| CO3 | Demonstrate an understanding of the socio-economic context of advanced biotechnology applications, such as regulatory and ethical responsibilities, in assessing complex problems. | K3 |
| CO4 | Solve open-ended problems by investigating emerging trends in the field and identifying and proposing creative processes. | K2 |
| CO5 | Collaborate effectively with others by utilising your team's diverse abilities and perspectives. | K4 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Advanced Biochemical Engineering CET4771<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Advanced Biochemical Engineering CET4771<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4772** | **Course Title:** **Adsorptive Separations** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Chemical Engineering Operations (CET4254), Separation Processes (CET4356) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NIL | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The course will cover the basic principles of adsorption and adsorption separation processes including both equilibrium and dynamic modelling and a brief overview of representative industrial processes. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Separation Processes: overview, alternative separation techniques, Mass separating agents | | 10 | | |
| 2 | Adsorbents: Molecular sieves activate carbon, zeolites alumina, silica ion exchangers, Polymeric adsorbents | | 10 | | |
| 3 | Physical and Reactive adsorption: Selectivity engineering in catalysis, Gaseous and liquid adsorption, Thermodynamics of adsorption, Statistical thermodynamics of adsorption phenomena, Surface excess, theories of adsorption. Separations: Bulk separation, purifications, Concentration and recovery from dilute solutions: metals, organic chemicals, microelectronics | | 10 | | |
| 4 | Design of adsorbers: Gaseous and liquid phase adsorption | | 10 | | |
| 5 | Theoretical analysis of diffusion in relation to adsorption in micropores | | 10 | | |
| 6 | Chromatographic separations: Bulk chemicals separations, Purification, refining operations, Biochemical applications | | 5 | | |
| 7 | Novel separation techniques using adsorbents, Industrial examples | | 5 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Principles of Adsorption and Adsorption Processes, 1984. Ruthven D.M. - Wiley. | | | | |
| 2 | Pressure Swing Adsorption, 1994. Ruthven D.M., Farooq S., Knaebel K.S. - Wiley. | | | | |
| 3 | Diffusion in Zeolites and other Microporous Solids, 1992. Kärger J., Ruthven D.M. - Wiley. | | | | |
| 4 | Adsorbents Fundamentals and Applications, 2003. Yang R.T., Wiley. | | | | |
| 5 | Adsorption by Powders & Porous Solids, 1999. Rouquerol F., Rouquerol J., Sing K. - Academic Press. | | | | |
| 6 | Perry's Chemical Engineers' Handbook. 7th Ed., 1997. Perry R.H. and Green D.W., McGraw-Hill.. | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | An understanding of the fundamental equilibrium and transport properties in adsorption. | | K3 | | |
| CO2 | A capability to model transient adsorption processes. | | K3 | | |
| CO3 | An understanding of the basic design of adsorption systems. | | K3 | | |
| CO4 | To understand the adsorption equilibrium (including both single and multicomponent systems) and adsorbent materials (with emphasis on zeolites and activated carbon);. | | K2 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Chemical Engineering Elective: Adsorptive Separations CET4772**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Adsorptive Separations CET4772**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4773 | Course Title: Interfacial Science and Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | NIL | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | NIL | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| This course outlines the principles and techniques of physics and chemistry of surfaces, which are critical in engineering and fabricating process. Physical phenomena occurring at interfaces will be addressed. Key concepts of interfacial phenomena are discussed, including surface tension, surfactants, interfacial thermodynamics, emulsions and wettability of surface. Students will be encouraged to apply the principles of surface and interfacial engineering in developing new functional materials and solving engineering problems. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Definitions: Chemical and physical properties of interfaces, Introduction to surface mechanisms and thermodynamics, capillarity, meniscus shapes, contact angle, surface tension and its measurement, Laplace Equation, Young's equation, Kelvin Equation, Gibbs equation, equilibrium criteria, dividing surface, monolayers and films, mobile and fixed interfaces Interfacial areas and degrees of wetting, aerosols, liquid liquid and particulate dispersions, Bubbles, and drops aprons. | | 10 | | |
| 2 | Microphases: Definitions and dynamics, Micelle formation surfactants CMC, structures of micelles, swollen micelle and microemulsions models, phase diagrams, Macroemulsions, Mechanical vs thermodynamic stability, HLB, Bancroft rule and other systems, Foams Colloids, Film elasticity, drainage, association, Langmuir Blodgets film production. | | 10 | | |
| 3 | Experimental techniques of measurement of relevant properties: surface tension, solubilization, thermodynamic properties, spectroscopic techniques<br>Rheological aspects of two phase (involving microphases) flow and transport, visco elasticity of surfactant solutions. | | 10 | | |
| 4 | Solubilization and catalysis by microphases: Models, theories and data, surface potential and equations of state, double layer theory, layer Debye□Huckel theory, Thermodynamics of solubilization, Hydrotropy | | 10 | | |
| 5 | Emulsification and Demulsification, foam breakage, theories of coalescence, and agglomeration, Brownian motion, shear and other models. | | 10 | | |
| 6 | Applications: Adsorption, foam fractionation, froth floatation Enhanced oil recovery, Novel separation processes, Coagulation, Flocculation, Microelectronics, surface vapour deposition, other applications with techniques<br>Monte Carlo simulation for molecular dynamics of structures, graphics software for structural display., | | 5 | | |
| 7 | Diffusion on the surface and in microphases | | 5 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | “Physics and Chemistry of Interfaces” by Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl John Wiley & Sons. | | | | |
| 2 | “Advanced Techniques for Surface Engineering”, by W. Gissler and H.A. Jehn, | | | | |
| 3 | “Surfactants and Interfacial Phenomena”, Milton J. Rosen, Joy T. Kunjappu, John Wiley & Sons. | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | To control the fundamental concepts of surface and interfacial Engineering | | K3 | | |
| CO2 | To interpret the phenomena of the interface between two phases | | K3 | | |
| CO3 | To understand electron-transfer kinetics and electric double layer effects | | K3 | | |

| | | |
|---|---|---|
| CO4 | To be familiar with the nature phenomena and learn from the nature to solve engineering problems | K2 |
| CO5 | To use the surface reactions to produce new materials. | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Interfacial Science and Engineering CET4773**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Interfacial Science and Engineering CET4773**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4774 | Course Title: Colloid and Interfacial Science | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course will aim at introducing the basic concepts and tools for the analysis of colloidal and interfacial properties. Behaviour and interactions together with brief introduction to some advanced topics such as self-assembly, meso-patterning of soft materials, functional materials, nanocomposites, super-hydrophobicity, super-glue, etc. which have attracted increasing attention recently. The overall aim of this course is to develop a broad background in colloids and interfaces which will enable students to: 1. Appreciate and understand much of the otherwise specialized contemporary published research in nanoparticles and surfaces. 2. Apply these themes to their own research and development problems effectively. This course will be very useful to undergraduate students, post-graduate students, teachers and practitioners from a wide variety of backgrounds: chemical, mechanical, civil, materials and electrical engineering; chemistry and physics; and materials science.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Capillarity: Definition, Existence of surface tension/surface free energy, Laplace equation, Young Equation, Capillarity rise phenomena, Measurement of surface tension, Contact angle Wetting characteristics | 10 |
| 2 | Surface Thermodynamics: Surface thermodynamic properties, Kelvin Eqn. Gibbs eqn, Surface Excess, Monolayer phase | 10 |
| 3 | Adsorption: Localised vs Mobile adsorption, Adsorption isotherms  Langmuir, Freundlich, BET etc., Potential theory, Adsorption from solution, Electrical Diffuse Double layer theory, Debye Huckel theory scaled particle theory, Stern layer, Surfactant adsorption | 10 |
| 4 | Micelles: Classes of surfactants, synthesis of surfactants, Micelle structures, Determination of HLB, Models for micelle formation, Swollen micelles, Hydrotropy | 10 |
| 5 | Solubilization in micelles: Location of solubilization in micelles, Measurement of solubilization, Spectroscopic methods: MR, Fluorescence, IR etc, Detergency, selective solubilization | 10 |
| 6 | Emulsions: Micro and macro emulsions, Stability of emulsions (Mechanical vs. thermodynamic), Bancroft rule, de-emulsification, HLB for emulsion, multiple emulsions, applications | 5 |
| 7 | Foams: Gibbs triangle, Film elasticity, drainage of films, Foam, defoaming, applications of foams | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Principles of Colloid and Surface Chemistry, Paul C. Hiemenz, Marcel Dekker, any edition starting with the 2nd edition, 1986. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understanding of basic nomenclature, concepts and tools of colloid and interface science and engineering; multi-phase nano-systems; mechanics and thermodynamics on small scales. | K2 |
| CO2 | A clear understanding of differences between the surface and bulk dominated regimes and behaviour and exploitation of nano-behaviour. | K2 |
| CO3 | Appreciation of how these concepts and tools translate into a variety of applications from processes to materials. | K4 |
| CO4 | Study of colloids and interfaces is highly multidisciplinary in nature combining both the concepts and applications from such diverse domains as chemical engineering and manufacturing. | K4 |
| CO5 | A few problems will be solved to illustrate the concepts clearly and updated reviews and research papers will also be referred in addition to the standard textbooks. | K5 |

| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating |
|---|

| **Chemical Engineering Elective: Colloid and Interfacial Science CET4774<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Colloid and Interfacial Science CET4774<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4775 | Course Title: Catalytic Green Science and Technology | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The need for enhanced education in catalysis is common to many countries. Dramatic progress in catalysis fundamental science and technology occurred in the last two decades enables teaching and learning of catalysis based on a unified approach in which catalysis including all its subdisciplines is taught in a logically consistent way using the organic chemistry reaction mechanism, namely the main chemistry conceptual methodology with its unique usefulness as predictive and creative tool. Selected lessons from the past are taken into account along with new insight on the role of catalysis and green chemistry in chemistry education based on systems thinking.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Green synthesis and heterogeneous catalysis, Metal and supported metal catalysis, metal-support interaction, Metal oxides and determination of acidity and basicity, Nature and type of supports, Solid acid catalysis, Solid base catalysis, | 10 |
| 2 | Catalyst design, preparation and activation, Clay and modified clays, Ion exchange resins, Zeolites and zeotypes , Heteropoly acids, Inorganic-organic catalysts, Immobilised enzymes, zeozymes, complexes, | 10 |
| 3 | Electrochemical catalysis, Photocatalysis, Microwave catalysis, Ultrasound catalysis, Synergistic catalysis, Important examples from, | 10 |
| 4 | Refinery industry -FCC, reforming, platforming, hydroforming, polymerisation, alkylation, isomerisation; hydrodesulfurization, hydro-nitrogenation, Pharmaceutical and fine chemical industry, | 10 |
| 5 | Dyestuff and intermediate industries, Perfume and flavour industry, Polymer industry, Textile industry, Paint industry, | 10 |
| 6 | Edible oil industry, Food industry, | 5 |
| 7 | Waste water treatment, Catalysis for auto-exhaust pollution abatement, DeNox, DeSOx technologies | 5 |
| | **Total** | **60** |

**List of Text Books/ Reference Books**


| | | |
|---|---|---|
| 1 | IUPAC (1987) Compendium of Chemical Terminology, Gold V, Loening KL, McNaught AD, Sehmi P (Ed.s), Blackwell Scientific Publications: Oxford | |
| 2 | Wisniak J (2010) The History of Catalysis. From the Beginning to Nobel Prizes. Educ. quím. 21:60–69 | |
| 3 | Kennema M, Shaping the future of catalysts, Heterogeneous Catalysts for Sustainable Industry, Royal Society of Chemistry, Burlington house, London, 25 November 2019 | |
| 4 | Szekely G, de Sousa MCA, Gil M, Ferreira FC, Heggie W (2015). Chem Rev 115:8182–8229 | |


**Course Outcomes (students will be able to…..)**

| | | |
|---|---|---|
| CO1 | Demonstrate knowledge of the principles and key applications of catalysis | K2 |
| CO2 | Explain the relation and differences between catalysis various subdisciplines | K2 |
| CO3 | Explain the interdisciplinary connection of catalysis with materials and surface science | K4 |
| CO4 | Explain different catalyst preparation methods | K4 |
| CO5 | Explain use of quantum chemistry in catalysis, and modern catalyst characterization methods | K5 |
| CO6 | Identify and understand the latest knowledge connected to catalysis research | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Catalytic Green Science and Technology CET4775<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Catalytic Green Science and Technology CET4775<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4776 | Course Title: Homogeneous Catalysis | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | NIL | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | NIL | | | | |
| Description of relevance of this course in the Int. M. Tech. Program | | | | | |
| The global objective of the course is to provide the student with an advanced training in Catalysis including the principles, mechanisms and applications of the different types of catalysts that operate both in homogeneous phase, such as organometallic catalysts and organo-catalysts, and in heterogeneous phase. | | | | | |
| | Course Contents (Topics and subtopics) | | Reqd. hours | | |
| 1 | Examples, Single phase and multiphase catalytic reactions, | | 10 | | |
| 2 | Acid--base catalysis, Transition metal catalysis, | | 10 | | |
| 3 | Bio-catalysis: Microbes and enzymes, Phase transfer catalysis, Micellar catalysis, | | 10 | | |
| 4 | Microemulsion catalysis, Electron transfer catalysis, Heteropoly acid catalysis, | | 10 | | |
| 5 | Homogeneous polymer catalysis, Heterogenisation of homogeneous catalysts, | | 10 | | |
| 6 | Catalysis by microwaves and ultrasound, | | 5 | | |
| 7 | Catalyst recovery and reuse | | 5 | | |
| | Total | | 60 | | |
| List of Text Books/ Reference Books | | | | | |
| 1 | Eric V. Anslyn and Dennis A. Dougherty: Modern Physical Organic Chemistry, University Science Books, 2006, selected chapters. | | | | |
| 2 | Homogeneous Catalysis: Understanding the Art, W.N.M. van Leeuwen | | | | |
| 3 | Catalysis: An Integrated Textbook Ulf Hanefeld, Leon Lefferts | | | | |
| 4 | Catalysis: Concepts and Green Applications, Gadi Rothenberg | | | | |
| Course Outcomes (students will be able to…..) | | | | | |
| CO1 | The student must identify the importance of catalysis in the development of sustainable chemicals processes. | | K2 | | |
| CO2 | The student must know the different types of catalysts, their mode of action, advantages and disadvantages, as well as their principal applications. | | K2 | | |
| CO3 | The student must identify key reactions in organometallic catalysis. | | K4 | | |
| CO4 | The student must know the main homogeneous reactions catalyzed by transition metal complexes and their reaction mechanisms. | | K4 | | |
| CO5 | The student should describe the different types of heterogeneous catalysts and the different strategies of immobilisation of molecular catalysts. | | K5 | | |
| CO6 | The student should describe the different types of organocatalyzed reactions and its applications. | | K6 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| Chemical Engineering Elective: Homogeneous Catalysis CET4776<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Homogeneous Catalysis CET4776**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4777 | Course Title: Fundamentals of Catalytic Science and Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The global objective of the course is
➢ To provide a brief review to chemical kinetics, catalysis and applications ➢ To provide insight to the surface chemistry and diffusion fundamentals in catalytic reactions ➢ To give a wholesome picture on catalytic reactions and catalytic reactors and modelling ➢ To give details on catalyst synthesis, characterization and instrumentation involved

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Relevance and examples, Atom economy and green chemistry concepts, Homogenous and heterogeneous catalysis, | 10 |
| 2 | Fundamentals of homogeneous catalysis and mechanisms and kinetics, Fundamentals of adsorption, isotherms, energetics, structural and dynamic considerations, Mechanisms, models and kinetics of surface reactions, Fractal models, | 10 |
| 3 | Determination of surface structure though modern methods, Significance of Pore structure and models, Solid and surface chemistry of catalysis, | 10 |
| 4 | Quantum mechanical, molecular mechanical and hybrid models, Catalyst design through artificial intelligence and computer modelling, | 10 |
| 5 | Poisoning, promotion, deactivation and selectivity, Catalytic process engineering, | 10 |
| 6 | Measurement of catalytic rates and kinetic parameters, Types of reactors | 5 |
| 7 | Catalyst recovery and reuse | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | H. S. Fogler, “Elements of Chemical Reaction Engineering”, 3rd Ed, New Delhi-Prentice Hall, 2001. | |
| 2 | O. Levenspiel, “Chemical Reaction Engineering” Willey Eastern, 3rd Ed. 2000. | |
| 3 | J. M. Smith, “Chemical Engineering Kinetics”, 3rd Ed., McGraw- Hill, 1988 | |
| 4 | Krijn P. de Jong, “Synthesis of Solid Catalysts”, Wiley, 2009 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Explain the general characteristics of catalysts and the principle behind the catalytic activity | K2 |
| CO2 | Outline appropriate preparative method for a catalyst | K2 |
| CO3 | Apply the basic concepts and theory for characterization of catalysts | K3 |
| CO4 | Identify various industrial catalysts | K4 |
| CO5 | Analyze catalyst deactivation | K5 |
| CO6 | Describe modern trends in catalyst technology | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Fundamentals of Catalytic Science and Engineering CET4777**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Fundamentals of Catalytic Science and Engineering CET4777**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4778** | **Course Title: Refinery Science and Engineering** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | Refinery engineering (SPT4354), Petroleum refining processes (SPT4352) | |
| **List of Courses where this course will be prerequisite** | | |
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The petroleum refining training course covers the technology aspects you need to know about refineries from the properties and composition of crude oil to the core refining processes including atmospheric and vacuum crude oil distillation, hydrotreating, catalytic reforming, FCC, alkylation, hydrocracking, delayed coking, amine treating and Sulphur recovery and gasoline/diesel blending.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Terminology, Origin, Kerogen, Occurrence, Recovery, Classification, Composition, Evaluation, | 10 |
| 2 | Fractionation, Identification, Asphaltic constituents, Refining chemistry, Refining distillation | 10 |
| 3 | Thermal cracking, Catalytic cracking, Hydro processing, | 10 |
| 4 | Reforming, Treatment processes, | 10 |
| 5 | Gas cleaning, Products, | 10 |
| 6 | Petrochemicals | 5 |
| 7 | Petroleum economics, Policy framework for Indian oil and gas. | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Petroleum refining, Technology and Economics by J H Gary and G E Handwork | |
| 2 | The Chemistry and Technology of Petroleum by James G Speight, | |
| 3 | Composition and properties of Petroleum by H J Neumann, B P Lahme and B Severin | |
| 4 | Modern Petroleum Technology : G D Hobson and W Pohl | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand all the basics about crude oil, including its physical/chemical properties and composition | K2 |
| CO2 | Understand and discuss major refinery processes | K2 |
| CO3 | Describe all the refinery units | K3 |
| CO4 | Understand the flow diagrams of refineries | K4 |
| CO5 | Explain step-by-step the processes of refining | K5 |
| CO6 | Understand the refinery products and their characteristics. | K6 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Refinery Science and Engineering CET4778**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | | | | | | | | | | | | |
| CO6 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Refinery Science and Engineering CET4778**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| CO6 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4779** | **Course Title:** **Flow Though Porous Media** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |
| **List of Prerequisite Courses** | | | | | |
| | Chemical engineering operations (CET4254) | | | | |
| **List of Courses where this course will be prerequisite** | | | | | |
| | NIL | | | | |
| **Description of relevance of this course in the Int. M. Tech. Program** | | | | | |
| The course discusses the various applications of flow through porous media in fields such as geophysical or geochemical flow, hydrology, and hydrocarbon recovery. It delves into mass continuity in porous media, explaining theories of flow and how to measure porosity and permeability. Derivation of the continuity equation and the diffusion equation for single phase flow in the reservoir. Introduction to the concepts of heterogeneity and anisotropy. Steady state, pseudo steady state and unsteady state flow regimes. Definition of productivity index of wells for various well geometries and fluid types during single phase flow. Introduction to two phase flow. Definition of mobility and mobility ratio. The fractional flow curve. The displacement process in porous media and the Buckley-Leverett Equation. | | | | | |
| | **Course Contents (Topics and subtopics)** | | **Reqd. hours** | | |
| 1 | Relevance of pore structure in science and technology, Examples from oil reservoirs, catalysis, soil science, membranes, aquifers, foods, polymers, biology, etc., | | 10 | | |
| 2 | Pore structures and their determination, Capillarity and wettability, Models of pore structure, | | 10 | | |
| 3 | Wettability and flow histories, Single phase flow, Multiphase flow, Percolation processes and network models, beds, Ultrafiltration, Models of catalyst poisoning and deactivation, Geo-statistics | | 10 | | |
| 4 | Fractal models, Simulations of macroscopic properties, | | 10 | | |
| 5 | Pore level mechanisms of flow, | | 10 | | |
| 6 | Diffusion and dispersion in porous media, Membrane transport, | | 5 | | |
| 7 | Analysis of trickle and packed | | 5 | | |
| | **Total** | | **60** | | |
| **List of Text Books/ Reference Books** | | | | | |
| 1 | Scheidegger A.E. The Physics of Flow through Porous Media, University of Toronto Press, 1974 | | | | |
| 2 | Dullien F.A.L. Porous Media: Fluid Transport and Pore Structure, Academic Press 1979 | | | | |
| 3 | Bear J. Dynamics of Fluids in Porous Media, Dover Civil and Mechanical Engineering 1988 | | | | |
| 4 | Civan F. Porous Media Transport Phenomena Wiley 2011 | | | | |
| **Course Outcomes (students will be able to…..)** | | | | | |
| CO1 | Formulate mathematical models representing flow of single phase fluids in porous media | | K2 | | |
| CO2 | Describe the various flow regimes observed in the reservoir | | K2 | | |
| CO3 | Describe the effects of rock and fluid properties on the flow of fluids in porous media | | K3 | | |
| CO4 | Obtain the solutions to the diffusion equation for various boundary conditions | | K4 | | |
| CO5 | Describe oil-water flow in the reservoir | | K5 | | |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | | | | |

| **Chemical Engineering Elective: Flow Though Porous Media CET4779**<br>**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Flow Though Porous Media CET4779**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4780 | Course Title: Enhanced Oil Recovery | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Refinery engineering (SPT4354), Petroleum Reservoir Engineering | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course discusses the various applications of flow through porous media in fields such as geophysical or geochemical flow, hydrology, and hydrocarbon recovery. It delves into mass continuity in porous media, explaining theories of flow and how to measure porosity and permeability. Derivation of the continuity equation and the diffusion equation for single phase flow in the reservoir. Introduction to the concepts of heterogeneity and anisotropy. Steady state, pseudo steady state and unsteady state flow regimes. Definition of productivity index of wells for various well geometries and fluid types during single phase flow. Introduction to two phase flow. Definition of mobility and mobility ratio. The fractional flow curve. The displacement process in porous media and the Buckley-Leverett Equation.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Residual oil and tracer studies, Defining enhanced oil recovery, Basic equations for fluid flow in porous media, | 10 |
| 2 | Petrophysics and petrochemistry, Phase behaviour and fluid properties, Efficiency of waterflooding, Pore level mechanisms, Mobility control, capillary number, bond number correlations, | 10 |
| 3 | Heterogeneity of pore structure and reservoirs, Thermal methods, Steam stimulation, steam flooding and hot water drive, Combustion- forward and reverse, | 10 |
| 4 | Ancillaries in thermal methods, Miscible flooding, Surfactant flooding, Microemulsion flooding, | 10 |
| 5 | Foam flooding, Polymer flooding, Micellar-polymer flooding, Alkaline flooding, | 10 |
| 6 | Carbon dioxide flooding, Inert gas injection, | 5 |
| 7 | Reactive gas injection, Microbial recovery | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Mandal, Ajay, and Keka Ojha. Enhanced Oil Recovery: Mechanisms, Technologies and Feasibility Analyses. CRC Press, 2023 | |
| 2 | Green, D.W. and Willhite, G.P., 1998. Enhanced oil recovery (Vol. 6, pp. 143-154). Richardson, TX: Henry L. Doherty Memorial Fund of AIME, Society of Petroleum Engineers. | |
| 3 | Lake, L.W., Johns, R., Rossen, B. and Pope, G.A., 2014. Fundamentals of enhanced oil recovery (Vol. 1, p. 1). Richardson, TX: Society of Petroleum Engineers. | |
| 4 | Donaldson, E.C., Chilingarian, G.V. and Yen, T.F. eds., 1985. Enhanced oil recovery, I: fundamentals and analyses. Elsevier. | |
| 5 | Latil, M., 1980. Enhanced oil recovery. Éditions Technip | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Describe different chemical, miscible, and thermal EOR processes | K2 |
| CO2 | Maximize oil recovery using Mobility Ratio and Capillary Number | K2 |
| CO3 | Apply reservoir characterization and screening actual fields for EOR | K3 |
| CO4 | Understand chemical, miscible, thermal, and hybrid EOR techniques | K4 |
| CO5 | Understand newly developed EOR methods and compare with current ones | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Enhanced Oil Recovery CET4780<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Enhanced Oil Recovery CET4780<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4781 | Course Title: Petroleum Reservoir Engineering | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Refinery engineering (SPT4354) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course Petroleum Reservoir Engineering is designed to help the students to develop a complete understanding of the characteristics of Drive mechanisms; Steady, pseudo-steady and Unsteady fluid flow behaviour through porous media and various water influx models to estimate water encroachment into a reservoir. The course also introduces the concept of Water flooding with emphasis on displacement efficiencies, flooding pattern and role of reservoir geology in the design and operation of water floods.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Energy sources, world scenario, oil pricing, Genesis of petroleum and migration, Composition of petroleum and its classification, Petroleum reservoirs, | 10 |
| 2 | Exploration and drilling technology, Well logging and well completion, Core analysis, Capillarity and wettability, Models of pore structure and multiphase flow , Well stimulation and production strategy, Well pressure behaviour, Gas reservoir engineering | 10 |
| 3 | Fluid displacement and frontal displacement; Buckley-Leverett theory, Material balance, Decline curve analysis, Well patterns and displacement efficiencies, Primary recovery, Gravity drainage, | 10 |
| 4 | Waterflooding, Mechanisms of microscopic and macroscopic flow, | 10 |
| 5 | Transportation of oil and gas, Production rate, reservoir life, Heavy oil and tar sand technologies, | 10 |
| 6 | Residual oil determination, | 5 |
| 7 | Computer modelling of reservoirs, Tertiary recovery methods | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Applied Petroleum Reservoir Engineering by BC Craft and M Hawkins. | |
| 2 | Petroleum Reservoir Rock and Fluid Properties by Abhijit Y Dandekar. | |
| 3 | The reservoir Engineering aspects of Waterflooding by Forrest F Craig (Jr). | |
| 4 | Reservoir Engineering Handbook by Tarek Ahmed. | |
| 5 | Fundamentals of Reservoir Engineering by LP Dake. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | To develop Critical-thinking and problem-solving approach. | K2 |
| CO2 | Understanding of basic oil & gas reservoir characteristics, Drive mechanisms and pressure behaviour in a steady, pseudo-steady and unsteady state reservoir. | K2 |
| CO3 | Ability to design water flooding project for optimum recovery. | K3 |
| CO4 | Water influx models and its uses to analyse water influx behaviour into reservoir. | K4 |
| CO5 | Plan the methods and procedures for avoiding or minimizing environmental impact of petroleum engineering and geo-energy engineering activities | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Petroleum Reservoir Engineering CET4781**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Petroleum Reservoir Engineering CET4781**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4782** | **Course Title: Mixing** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The main objectives of mixing are to create a uniform mixture, promote chemical reactions, and disperse solids or liquids. Various equipment is used for mixing powders, liquids, and semi-solids depending on the application and properties of the substances.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Examples of industrial importance | 10 |
| 2 | Flow pattern, power consumption, classification of impellers, internals | 10 |
| 3 | Mechanism of mixing, Blending in viscous and turbulent system, Suspension of solid particles, | 10 |
| 4 | Heat transfer, Gas-liquid dispersion, Liquid-liquid dispersions, | 10 |
| 5 | Three phase dispersions, Solid-solid mixing, emulsions, pastes, | 10 |
| 6 | Mass transfer at gas-liquid, liquid-liquid, solid-solid and solid-liquid interface | 5 |
| 7 | Process design and scale-up considerations case studies | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Mixing in the Process Industries: Second A W NIENOW, M F EDWARDS, N. Harnby · 1997 | |
| 2 | Foundations of Mixed Methods Research: Integrating Charles Teddlie, Abbas Tashakkori · | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Specific and measurable statements that define the knowledge, skills, and attitudes learners will demonstrate by the completion of a course. | K2 |
| CO2 | Evolve useful methods for mixing processes | K2 |
| CO3 | Use traditional correlations as well as increasingly effective methods both for experiments and for simulation and modelling of complex operations | K3 |
| CO4 | Use improved tools for development of scalable operations. | K4 |
| CO5 | Evaluate and use these technologies effectively in process development and scale-up. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Mixing CET4782**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| **Chemical Engineering Elective: Mixing CET4782**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4783** | **Course Title:** **Statistical Methods in Engineering** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

1. To introduce students about fundamental principles and knowledge of statistics and statistical tools.
2. To develop students' ability to compile statistical data, carry out statistical calculations
3. Understanding of applications of statistical techniques with emphasis to solve practical problems in science and engineering.
4. Understanding of applications of Probability distribution in real-life and production problems.
5. To develop students' ability for Hypothesis testing and it's applications.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Continuous and discrete probability distributions, normal, chi-square, gamma, Poisson distributions. | 10 |
| 2 | Applications. t-Tests, F-Test, Homogeneity tests, Quality Control. | 10 |
| 3 | Acceptance sampling Linear regression and lack of fit Contingency tables. | 10 |
| 4 | Discrete Random Variables and Probability Distributions Discrete random variables Probability mass functions Cumulative distribution functions Mean and variance of a discrete random variable Uniform, binominal, and Poisson distributions | 10 |
| 5 | Joint Probability Distributions Joint and marginal distribution functions Bivariate normal distribution Linear combinations of random variables Error analysis for nonlinear equations | 10 |
| 6 | Multiple Linear Regression Properties of least squares estimation Matrix approach Hypothesis tests and confidence intervals | 5 |
| 7 | Statistical Quality Control Quality control charts Western Electric rules | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Box, G.E.P., W.G. Hunter, and J.S. Hunter, Statistics for Experimenters, 2nd ed., Wiley-Interscience, NY (2005). | |
| 2 | Devore, J.L, Probability and Statistics for Engineering and the Sciences, 5th ed. Pacific Grove, CA (2000). | |
| 3 | Ross, S.M. Introduction to Probability and Statistics for Engineers and Scientists, 2nd ed., Harcourt/Academic, San Diego (2000) | |
| 4 | Montgomery D.C and G.C. Runger, Applied Statistics and Probability for Engineers, 4th ed., John Wiley, NY (2007). | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Comprehension of statistical inferences like Mean, Median, Mode and Dispersion and their applications in real-life situations. | K2 |
| CO2 | Comprehension of statistical inferences like Correlation and Regression and its applications in real-life situations. | K2 |
| CO3 | Comprehension of sampling techniques and Hypothesis testing methods and their applications in real-life situations. | K3 |
| CO4 | Comprehension of Probability distributions and their applications in real-life situations. | K4 |
| CO5 | Comprehension of Nonparametric tests and their applications in real-life situations. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Statistical Methods in Engineering CET4783<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Statistical Methods in Engineering CET4783<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code:** **CET4784** | **Course Title:** **Electrochemical Engineering** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course will provide a broad introduction to Electrochemistry and electrochemical technology. The course will introduce the principles of Electrochemistry and review their application in a wide range of areas such as synthesis, energy systems, materials and surface engineering and water treatment. Special emphasis will be put on the design and engineering aspects behind electrochemical technology.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction to electrochemical engineering. | 20 |
| 2 | Theoretical aspects and special features of electrochemical process. | 20 |
| 3 | Role of mass transfer in a variety of electrochemical processes. | 10 |
| 4 | Some aspects of electrochemical reactor design. Scale-up and optimization of reactors | 10 |
| | **Total** | **60** |

**List of Text Books/ Reference Books**


1. Pletcher D, Walsh FC (1990) Industrial Electrochemistry (2nd Edition), London, Blackie Academic & Professional.
2. Fuller TF, Harb JN (2018) Electrochemical Engineering (1st Edition), Hoboken, John Wiley & Sons.


| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Explain and implement the equations for mass transport in dilute and concentrated electrolytes, and to assess their applicability in specific cases. | K2 |
| CO2 | Explain and implement equations for production and transport of heat in electrochemical systems, and explain the temperature dependence of electrode potentials, electrode kinetics and mass transport properties. | K2 |
| CO3 | Explain and implement models for current distribution in porous electrodes. | K3 |
| CO4 | Set up models for an electrochemical system, based on continuity equations and transport equations for relevant variables, and with necessary boundary conditions. | K4 |
| CO5 | Solve problems of moderate mathematical/ numerical level of difficulty, and to discuss and make conclusions from the results. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Electrochemical Engineering CET4784**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| **Chemical Engineering Elective: Electrochemical Engineering CET4784<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4785 | Course Title: Engineering Aspects of Manufacturers of Organic Chemicals | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course will acquire knowledge about desalination of brackish water and treatment of municipal water. To gain the knowledge of conducting polymers, bio-degradable polymers and fibre reinforced plastics. To learn significance of green chemistry and green synthesis and the synthesis of nano materials.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Special features of process parameters and reactors used for typical organic processes such as hydrogenation, oxidation, alkylation, nitration, sulphonation etc. | 20 |
| 2 | Different strategies of conducting reactions. | 20 |
| 3 | Introduction to a few name reactions such as Friedel Crafts reactions, Sandmeyers reaction, Darzens condensation, etc. | 10 |
| 4 | Typical reaction schemes for the synthesis of medium and low volume chemicals, with an emphasis on the alternative flow sheets of the entire process | 10 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | C.L. Dryden, Outlines of Chemical Technology, Edited and Revised by M. Gopala Rao and S. Marshall, 3rd Edition, Affiliated East West, New Delhi, 1997. | |
| 2 | T.G. Austin and S. Shreve, Chemical Process Industries, 5th Edition, McGraw Hill, New Delhi, 1984. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Study in detail the listed industrial chemicals and gases w.r.t. production, uses, storage and hazards | K2 |
| CO2 | Understand different chemical aspects of pollution. viz: air, water, energy etc | K2 |
| CO3 | Industrial effluents and their treatment methods. | K3 |
| CO4 | Measurement of other water quality parameters--alkalinity, dissolved CO2, chloride ion, sulphate ion | K4 |
| CO5 | Identify the consequences of technology to society and mitigate problems caused by technology | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Engineering Aspects of Manufacturers of Organic Chemicals CET4785**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |

3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;

| **Chemical Engineering Elective: Engineering Aspects of Manufacturers of Organic Chemicals CET4785 Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4786 | Course Title: Industrial Economics | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Basic Principles of Finance & Economics (HUT4156) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The impact of Economics including finance has to be well understood by the students since it has a deep impact on the decision-making ability of an engineer/scientist and also in selecting the best possible alternative out of the ones available to him.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Introduction: Definition of Economics, Nature of Economics problem and working system, relation between science, engineering, technology & economics. Nature and Significance of Economics | 10 |
| 2 | Demand and Revenue Analysis: Meaning, Types, Determinants, law of demand, elasticity of demand, applications of the concept of elasticity of demand, Demand forecasting. | 10 |
| 3 | Production Analysis and Supply: Meaning, factor of production, Long run vs short run, law of variable proportion, return to scale, Market Supply, Law of Supply. | 10 |
| 4 | Cost Analysis: concept of cost, cost function, short & long run cost-output relation, Modern approach to theory of cost. | 10 |
| 5 | Price Determination and Market Structure: Market mechanism, Profit maximizing condition, Meaning, Types and features of Market, Price-output determination in various markets. | 10 |
| 6 | Market failure and Public Good: Growth of Monopoly and Market failure, Imperfect market information, Public good and market failure, Externalities. | 5 |
| 7 | Financial management: Concepts, Financial statement and financial investment analysis, financial decisions, managing components of working capital investment & financing decisions. | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Dwivedi, D.N (2012). Microeconomics: theory and Application, 2nd Edition, Pearson publication. | |
| 2 | Ahuja, H.L (2016), Principles of Microeconomic s, 72nd edition, S Chand Publishing. | |
| 3 | Shrivastava, Rajiv and Anil Mishra (2011), Financial Management, 2nd edition, Oxford University Press. | |
| 4 | Gupta, G.S (2012), Managerial Economics, 2nd Edition, Tata McGraw Hill Education Private Limited. | |
| 5 | Khan, M.Y. and P. K Jain (2017), Financial Management, 7th edition, Tata McGraw Hill Education Private Limited. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | To demonstrate knowledge and understanding of a set of analytical techniques which can be applied to a variety of economic (and non-economic) and financial management issues. It will also be helpful to the student to understand how individuals and firms interact within markets, when markets fail, and how government policy may improve outcomes for society. | K2 |
| CO2 | To help students gain an understanding in certain core concepts of Industrial Economics. | K2 |
| CO3 | To familiarize students with theories in Industrial Economics. | K3 |
| CO4 | To help students understand cost structures and their role and importance in firm decisions. | K4 |
| CO5 | To analyze the performance of the Indian Industrial Economy against the backdrop of contemporary development. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Industrial Economics CET4786<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Industrial Economics CET4786<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4787 | Course Title: Advanced Strength of Materials | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |
| List of Prerequisite Courses | | | | | |
| | Structural Mechanics (EST4151) | | | | |
| List of Courses where this course will be prerequisite | | | | | |
| | NIL | | | | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course examines the main concepts, theories and principles applied for explaining the mechanical behaviour of materials under various states of stress and strain conditions.
It provides you with an in-depth understanding of the major principles used in evaluating the response of construction materials to stresses and deformation.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Analysis of Trusses - Condition for perfect truss, redundancy, stable, unstable truss. Analysis of truss by method of joints, method of sections. | 10 |
| 2 | Torsion of a circular shaft - concept, basic derivation, shear stress distribution, simple problem. | 10 |
| 3 | Short and Long columns (Struts) - Basic concept, crippling load, end conditions. Euler's and Rankine's approach (without derivations) | 10 |
| 4 | Thick and Thin cylinders - concept of radial, longitudinal stresses, behaviour of thin cylinders. Problems on thin cylindrical and spherical shells. Behaviour of thick cylinders (theory only). | 10 |
| 5 | Advance stresses and strains – Representation of stress and strain at a point, Stress stain relationship, plane stress and plane strain. Transformation of stresses and its importance, Principal stresses and strains, maximum shearing stress, Mohr's circle its use and construction. | 5 |
| 6 | Basics of Engineering Design - Steps in the engineering design, Importance of analysis, 1-D, 2-D and 3-D analysis and interpretation of results. Design philosophies, factor of safety, Force displacement relationship, Strain deformation relationship, Introduction to finite element packages. Computer aided analysis and design. | 5 |
| 7 | Composite Materials – Types of composite materials, fillers for composites, polymer composites, fibres and matrix for a composite material, Types of fibres, their properties, woven and non-woven fibres, manufacturing of polymer composite materials. Mechanics of composite materials, Properties and testing of composite materials, Uses of composite materials. | 5 |
| 8 | Advance materials for industrial applications - Advances in materials, Materials used for coatings, anticorrosive coatings, special purpose floorings, water proofing compounds, Various polymers and epoxies used for industrial applications. Different types of performance enhancing and special purpose construction chemicals. Plasticizers and super-plasticizers, air entraining agents, accelerators and retarders, viscosity modifying agents, corrosion inhibitors | 5 |
| | **Total** | **60** |

**List of Text Books/ Reference Books**

| | |
|---|---|
| 1 | Elements of Strength of Materials by Timoshenko and Gere |
| 2 | Advanced Solid Mechanics by LS Srinath |
| 3 | Advanced Mechanics of Materials by Seely and Smith |
| 4 | Strength of Materials by GH Ryder |
| 5 | Mechanics of Materials-I by EJ Hern; Paragaman, New York |

**Course Outcomes (students will be able to…..)**

| | | |
|---|---|---|
| CO1 | Identify different areas of ADVANCED STRENGTH OF MATERIALS. | K2 |

| | | |
|---|---|---|
| CO2 | Find the applications of all the areas in day-to-day life. | K2 |
| CO3 | Determine the stresses in thick cylinders. | K3 |
| CO4 | Analyse the curved beams for stresses with different cross sections. | K4 |
| CO5 | Determine the Strain Energy under various loading conditions. | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Advanced Strength of Materials CET4787**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Advanced Strength of Materials CET4787**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4788 | Course Title: Turbulent Flow and CFD | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

Computational Fluid Dynamics (CFD) course is designed to give the fundamental concepts of the CFD methods and algorithms that enable students to develop their own CFD computer programs or use available public domain or commercial software and interpret the results. The course starts with the mathematical descriptions of fluid flow and the associated phenomena (heat and mass transfer) for incompressible flows at laminar and turbulent flow regimes. Then, the formulation of the numerical solution methodology is discussed in detail using explicit and implicit finite-volume methods. Students will run source codes available in public domain or licensed educational, if available. Homework assignments and a course project will be given.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Derivation of equations of momentum and energy for turbulent flows. Modelling of turbulent flows: kinetic energy, algebraic stress model, Low Reynolds number model, LES model etc. | 10 |
| 2 | Turbulent boundary layer flows and similar solutions | 10 |
| 3 | Grid generation,<br>Conservation Laws (Mass, Momentum, and Energy) of Fluid Flow & Heat Transfer<br>Conservation laws in integral form<br>Conservation laws in differential form<br>The primitive variables (non-conservative) and conservative forms of the governing equations. | 10 |
| 4 | Use of Control volume method, Methods of lines, Finite difference, Finite element and various algorithms (SIMPLE, SIMPLER & SIMPLEC etc) to solve the momentum, energy and mass transfer equations for simulation of some practical problems (Simulation of stirred vessel, Natural convection flow inside a closed chamber etc) | 10 |
| 5 | Solution of Discretized Equations<br>The tri-diagonal matrix algorithm (TDMA)/Thomas algorithm<br>Application of TDMA to two-dimensional and three-dimensional problems | 10 |
| 6 | The Finite Volume Method for Unsteady Flows<br>One-dimensional unsteady heat conduction with explicit and implicit formulations<br>Discretization of unsteady convection-diffusion equation<br>Extension of implicit method to 2-D and 3-D problems<br>The unsteady SIMPLE and pressure implicit with splitting of operators (PISO) algorithms | 5 |
| 7 | Major commercial software packages. Problem solving demonstrations using student version (normally, free). | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Patankar, S.V. (1980), Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Co. | |
| 2 | Versteeg, H.K. and Malalasekera, W. (1995), An introduction to computational fluid dynamics: The finite-volume method, Longman Scientific & Technical (in USA, by John Wiley and Sons Inc.). | |
| 3 | Simple CFD source codes in MATLAB | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Use statistical methods to describe and analyse turbulent flow, | K2 |
| CO2 | Describe and explain the length scale structure of turbulence, and | K2 |

| | | |
|---|---|---|
| CO3 | Use an understanding of turbulence to describe the strengths and weaknesses of common CFD models for turbulent flow. | K3 |
| CO4 | Program and simulate simple CFD problems | K4 |
| CO5 | Understand the CFD role in industrial design applications and its limitations | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Turbulent Flow and CFD CET4788**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Turbulent Flow and CFD CET4788**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4789 | Course Title: Momentum, Heat and Mass Transfer | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Fluid Flow (CET4251), Heat Transfer (CET4252), Chemical Engineering Operations (CET454) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course provides the basics of major heat and mass transfer operations. The objective of this course is to impart knowledge on design of heat and mass transfer equipment. In addition, it also imparts knowledge on optimization of the cost of heat transfer operations used in bioprocess industries.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Derivation of equation of momentum, energy, mass transfer in curvilinear coordinate system, constitutive equation (Newtonian & Non-Newtonian fluids), | 15 |
| 2 | Flow in some simple cases - Flow between two concentric cylinders, flow between two concentric rotating cylinders, hydrodynamics of bearings lubrication, steady flow around a sphere (theory of very slow motion). | 15 |
| 3 | Singular perturbation theory, derivation of bounder layer equations (using singular perturbation theory), similar and non-similar solutions for some forced, mixed and natural convection problems (using bounder layer theory) | 15 |
| 4 | Flow stability, theory of ordinary diffusion in liquids, diffusion with homogenous chemical reaction, diffusion into a falling liquids film (forced convection mass transfer) | 15 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | A. Suryanarayana, "Mass Transfer Operations", 1st edition, New - Age, International, 2006. | |
| 2 | McCabe, W.L. Smith J.C. and Harriot P., "Unit Operations of Chemical Engineering", 7th edition, McGraw Hill, 2004. | |
| 3 | D. Q. Kern, "Process Heat Transfer", McGraw-Hill, 2001. | |
| 4 | C. J. King, "Separation Processes", 2nd edition, McGraw Hill, 2014. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Understand the basic modes of heat and mass transfer. | K2 |
| CO2 | Apply principles of heat and mass transfer to predict transfer coefficients | K2 |
| CO3 | Analyze working of various heat transfer equipment | K3 |
| CO4 | Design heat and mass transfer equipment | K4 |
| CO5 | Evaluate no. of stages required for given mass transfer problem. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Momentum, Heat and Mass Transfer CET4789**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |

| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; |
|---|

| **Chemical Engineering Elective: Momentum, Heat and Mass Transfer CET4789<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4790 | Course Title: Theoretical and Computational Chemistry | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The main objective of computational chemistry is to solve chemical problems by simulating chemical systems (molecular, biological, materials) to provide reliable, accurate and comprehensive information at an atomic level.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Wave character and wave functions, De Broglie equation, normalization and orthogonalization, | 15 |
| 2 | Quantum mechanical operators, Schrodinger equation, particle in an infinite square well potential, quantum mechanical harmonic oscillator, angular momentum operator and rigid rotor, | 15 |
| 3 | Born Oppenheimer approximation, potential energy surfaces, self-consistent field wave functions, | 15 |
| 4 | Computational methods: Molecular mechanics, MO theory, semi empirical and ab initio methods, SCF theory, Hartree Fock method, DFT | 15 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Attila-Szabo, Neil S. Ostlund, "Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory", (Dover Pubns, 1996) | |
| 2 | Wolfram Koch, Max C. Holthausen, "A Chemist's Guide to Density Functional Theory", 2nd Edition, (Wiley, 2001) | |
| 3 | Christopher J. Cramer, "Essentials of Computational Chemistry: Theories and Models", 2nd edition, (Wiley, 2004) | |
| 4 | Michael P. Allen and Dominic J. Tildesley, "Computer Simulation of Liquids", 2nd edition, (Oxford University Press, 2017). | |
| 5 | Daan Frenkel and Berend Smit, "Understanding Molecular Simulation: from Algorithms to Applications", 2nd edition, (Academic Press, 2001). | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Know the main mathematical models that are used in chemistry, mainly the simplest ones. | K2 |
| CO2 | The focus is on the ideas that inspire the models, how they are translated into mathematical equations, and on the comparison with experiments. | K2 |
| CO3 | The student will acquire critical knowledge of the potentials and limitations of computational chemistry methods and programs. | K3 |
| CO4 | A student has a basic knowledge of popular computational methods of quantum chemistry, analyses simple chemical problems and formulates appropriate questions in terms of theoretical chemistry, recognizes theoretical methods suitable for solving these questions. | K4 |
| CO5 | Discuss the applications of DFT in inorganic, organic and physical chemistry | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Theoretical and Computational Chemistry CET4790**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Theoretical and Computational Chemistry CET4790**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4791 | Course Title: Green Chemistry and Catalysis | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

Green chemistry known as sustainable chemistry, is founded on the main principle of reducing or preventing pollution already at the source. This stands in contrast to the field of Environmental Chemistry which encompasses the study of pollutants that are already present in the environment. The term green chemistry was coined by Paul Anastas and introduced at the beginning of the 1990s. It has since established itself as an important philosophy within chemistry over the past decades. One of the objectives of this course is to provide the student knowledge about the principles for Green Chemistry. Central topics will include the reduction of waste, use of renewables, catalysis, substitution of hazardous and dangerous chemicals with more benign alternatives etc. Furthermore, the student will obtain skills and experience through case studies and laboratory exercises.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Concept of Green Chemistry: Twelve principles of green chemistry, E factor, Waste management | 10 |
| 2 | Types of catalysis: Homogeneous and Heterogeneous catalysis. Catalytic cycles<br>Organometallic compounds used as catalysts: Pd, Rh, and Ru in C-C bond formation. Catalytic properties of mononuclear compounds | 10 |
| 3 | Homogeneous catalysis: Hydrogenation, hydroformylation, hydrocyanation, Hydro-silylation, Wilkinson catalysts, Chiral ligands and chiral induction, Ziegler-Natta catalysts | 10 |
| 4 | Mercuration and oxymercuration | 10 |
| 5 | Organopalladium catalysts: Suzuki coupling, Heck coupling and related cross coupling reactions. | 10 |
| 6 | Alkene oligomerization and metathesis. | 5 |
| 7 | Catalytic oxidations and reductions: Epoxidation, dihydroxylations.<br>including carbonylation, decarboxylation, olefin isomerization, arylation<br>Important catalytic reactions: Monsanto acetic acid process, Wacker process, Heck reaction | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Green Chemistry and Engineering Mukesh Doble, Ken Rollins, Anil Kumar | |
| 2 | Green Chemistry and Catalysis, R. A. Sheldon, Isabella Arends, Ulf Hanefeld | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Knowing the 12 principles of Green Chemistry. | K2 |
| CO2 | Be able to describe classes of the most important chemicals (both organic and inorganic) that are hazardous/dangerous for human and animal health, and the environment. | K2 |
| CO3 | Identification of greener solvents and recycling of these including catalysts. | K3 |
| CO4 | Calculate the atomic efficiency and E-factors of chemical reactions and processes. | K4 |
| CO5 | Apply the principles for Green Chemistry in order to make a life cycle assessment for a chemical product including waste treatment (degradation/recycling). | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Green Chemistry and Catalysis CET4791**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Green Chemistry and Catalysis CET4791**<br>**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4792** | **Course Title: Organometallic Chemistry** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | NIL | |
| **List of Courses where this course will be prerequisite** | | |
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The focus of this course is on the synthesis, structure and bonding, properties and reactivity of main group organometallics (including Grignard reagents, organolithium reagents, organophosphorus compounds, etc), organotransition metal chemistry, cluster chemistry, zeolites and metal-organic frameworks, and organo-lanthanoid and -actinoid chemistry. The laboratory component of the course will aim to develop skills in modern synthetic chemistry and the purification of compounds using chromatographic techniques.

| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
|---|---|---|
| 1 | Nature of C-M bond: Metal-carbon bond with main group and transition elements. Factors controlling metal-carbon bond formation. Methods of M-C bond formation. | 10 |
| 2 | Nomenclature and hapticity. Electron counting and 16 and 18 electron rules - applications and exceptions. Stability. Stereochemical nonrigidity in organometallic compounds. | 10 |
| 3 | Structure and bonding of metal alkyls and aryls. Complexes with CO and related ligands, olefins, acetylenes and related unsaturated molecules. Organic transition metal complexes as protective and stabilizing groups for double bond, triple bond, propyl cation and short lives species. Complexes with cyclopentadiene and arenes and other CnHn sandwich and half-sandwich complexes. Hydride, dinitrogen and dihydrogen complexes | 10 |
| 4 | Bimetallic and cluster complexes: Structure and applications in catalysis<br>Basic organometallic reactions: Ligand substitution, oxidative reactions, migratory reactions, migratory insertion, extrusion, oxidative addition, reductive elimination, reductive elimination –mechanism and stereochemistry. | 10 |
| 5 | Nucleophilic regents with C-M bond: Li, Mg, Al, Ti and Ce alkyls; Organicuprates, organic zinc reagents | 10 |
| 6 | Alkyne complexes: Pauson Khand reaction. The use of stoichiometric transition metal complexes in the synthesis of complexes organic molecules - enantioselective synthesis via organometallic compounds. | 5 |
| 7 | Organo silicon compounds, boranes, carboranes and, metallocarboranes, organo platinum complexes, metallocenes<br>Importance of organometallic compounds in Biological systems | 5 |
| | **Total** | **60** |

| **List of Text Books/ Reference Books** | | |
|---|---|---|
| 1 | Alkenes and Aromatics P G Taylor, J M F Gagan | |
| 2 | Principles of Organometallic Chemistry G. E. Coates | |

| **Course Outcomes (students will be able to…..)** | | |
|---|---|---|
| CO1 | Explain and rationalize the synthesis, structure, bonding, properties and reactivity of main group, transition metal, lanthanoid, and actinoid organyls. | K2 |
| CO2 | Work to a professional level in a chemical synthesis laboratory demonstrating effective laboratory safety and etiquette, especially in the areas of chromatographic techniques and spectroscopic characterization. | K2 |
| CO3 | Demonstrate effective report writing, experimental design and data analysis. | K3 |
| CO4 | Understand fundamental reaction types and mechanisms and how to combine these to understand efficient catalytic processes | K4 |
| CO5 | Know important applications of organometallic homogeneous catalysis in the production of large-scale (bulk) and smaller-scale (fine chemicals) production | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

| Chemical Engineering Elective: Organometallic Chemistry CET4792<br>Mapping of Course Outcomes (COs) with Programme Outcomes (POs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| Chemical Engineering Elective: Organometallic Chemistry CET4792<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs) | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4793 | Course Title: Advanced Spectroscopy | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | NIL | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

Modern spectroscopic techniques underpin a wide range of chemical and biological research as well as serving as a valuable analytical tool. This module will introduce some of the key principles, tools and techniques that govern spectroscopic measurements and allow scientists of all disciplines to characterise chemical structure and composition, image biological samples and follow chemical reactions in intricate detail. The module will cover how these techniques can be used for both applied science relevant to biological imaging, as well as more fundamental science for measuring the motion of the atoms and electrons that drive chemical reactivity.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | UV-VIS spectroscopy - Woodward rules, aromatic and heterocyclic compounds | 10 |
| 2 | IR spectroscopy: FT technique, group frequencies, vibrational coupling. NIR spectroscopy. New applications | 10 |
| 3 | Raman spectroscopy: Stokes, anti-Stokes and Releigh scattering, rotational and vibrational transitions. Raman vs IR. | 10 |
| 4 | NMR spectroscopy: Pulse technique, FID, and FT. Relaxation and saturation phenomena, quadrupole relaxation, isotopomers. | 10 |
| 5 | H1 NMR: Chemical shifts and factors affecting the same, spin-spin coupling of different systens, different spin systems, coupling constants.<br>Simplification of complex spectra: Double resonance and decoupling, lanthanide shift reagents, INDOR technique.<br>C13 NMR: Basics, doble resonance,<br>2D NMR: H1-H1- COSY, H1-C13 HETCOR- APT and DEPT, C13-C13 connecticity: INADEQUATE<br>F19 and P31 NMR<br>Through space interactions: NOE and NOESY<br>Solid state NMR and MAS. | 10 |
| 6 | Mass spectrometry: Basics, EI and CI techniques. Isotopic abundance, fragmentation, rearrangement of ions, Maclaferty rearrangement, retrodiels-alder reaction.<br>Hyphenated techniques: GC-MS, LC-MS, LC-MS-MS, GC-IR, GC-AIS, GC-NMR, LC-NMR | 5 |
| 7 | ESR spectroscopy: Theory, experimental technique, Hyperfine splitting<br>Mossbaur spectroscopy<br>Structure elucidation using combined stereoscopic methods<br>Emission: Flame photometry, ICP, Ark-Spark spectra, Phosphorescence, XRF | 5 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Fundamentals of molecular spectroscopy, C.N.Banwell and E.McCasj, Tata McGraw Hill (1994) | |
| 2 | Elements of Nuclear Chemistry H.J. Arnikar, 4th Edn. Wiley Eastern Ltd. | |
| 3 | Introduction of Nuclear and Radiochemistry, G. Friedlaunder, T.W.Kennedy and J.M.Miller, John Wiley and sons 2nd Edn. | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Learn bonding in transition metal complexes, Valence bond theory, Crystal field theory, Molecular orbital theory | K2 |
| CO2 | Study of structural trends, mononuclear oxocomplexes, polyoxometallates, intermediate oxidation states, metal-metal bonded compounds | K2 |

| | | |
|---|---|---|
| CO3 | Understand reaction mechanisms of d-metal complexes, Ligand substitution reactions. classification & theory of redox reactions, photochemical reactions | K3 |
| CO4 | Study of structure, properties, reactions and synthesis of d-block carbonyls, Reactivity of d- and f-block organometallic compounds | K4 |
| CO5 | Introduction, methods of separation and applications of Lanthanides, Actinides | K5 |
| K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating | | |

**Chemical Engineering Elective: Advanced Spectroscopy CET4793**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Advanced Spectroscopy CET4793**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| **PEC** | **Course Code: CET4794** | **Course Title: Statistical Mechanics** | **Credits = 4** | | |
| | | | **L** | **T** | **P** |
| | **Semester:** | **Total contact hours: 60** | **3** | **1** | **0** |

| **List of Prerequisite Courses** | | |
|---|---|---|
| | Applied Physics (PHT4151), Structural Mechanics (EST4151) | |
| **List of Courses where this course will be prerequisite** | | |
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, microcanonical, canonical and grant canonical ensembles; the methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases; selected topics from low temperature physics and electrical and thermal properties of matter are discussed.

| | **Course Contents (Topics and subtopics)** | **Reqd. hours** |
|---|---|---|
| 1 | Basic Statistical Approach to a System | 10 |
| 2 | Applicability of the statistical approach to a system, equilibrium and fluctuations, irreversibility and approach to equilibrium, counting of system states – macrostates and microstates, equiprobability postulate, concept of statistical ensemble, number of accessible states of a system, phase space. | 10 |
| 3 | Ensemble approach to Thermodynamics of Physical Systems<br>Isolated system – microcanonical ensemble, system in contact with a heat reservoir, canonical ensemble, Maxwell-Boltzmann distribution as an example, mean values in a canonical ensemble, partition function for a canonical ensemble, relation to thermodynamics. | 10 |
| 4 | Generalised Interactions<br>Grand canonical ensemble, systems with variable number of particles, chemical potential, partition function for a grand canonical ensemble, relation to thermodynamic variables. | 10 |
| 5 | Applications to Multi-phase Systems | 10 |
| 6 | Stability conditions for a homogeneous system, equilibrium between phases, phase transformations, general relations for a system with several components, general conditions for chemical equilibrium, chemical equilibrium between ideal gases, the equilibrium constants in terms of partition functions. | 10 |
| | **Total** | **60** |

| **List of Text Books/ Reference Books** | | |
|---|---|---|
| 1 | Pathria, R.K., Statistical Mechanics, Butterworth-Heinemann, (1996). | |
| 2 | Reif, F., Fundamentals of Statistical and Thermal Physics, Waveland, (2008). | |
| 3 | Mandl, F. (1998): Statistical Physics, 2nd edition, Wiley | |

| **Course Outcomes (students will be able to…..)** | | |
|---|---|---|
| CO1 | Explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics | K2 |
| CO2 | Apply the principles of statistical mechanics to selected problems | K2 |
| CO3 | Apply techniques from statistical mechanics to a range of situations | K3 |
| CO4 | Use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanation. | K4 |
| CO5 | Use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanation. | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Statistical Mechanics CET4794**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

**Chemical Engineering Elective: Statistical Mechanics CET4794**
**Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
|---|---|---|---|---|---|
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |

| Semester | | | | | |
|---|---|---|---|---|---|
| PEC | Course Code: CET4795 | Course Title: Molecular Quantum Mechanics | Credits = 4 | | |
| | | | L | T | P |
| | Semester: | Total contact hours: 60 | 3 | 1 | 0 |

| List of Prerequisite Courses | | |
|---|---|---|
| | Applied Physics (PHT4151), Structural Mechanics (EST4151) | |

| List of Courses where this course will be prerequisite | | |
|---|---|---|
| | NIL | |

**Description of relevance of this course in the Int. M. Tech. Program**

The course aims to provide fundamental knowledge and introduce selected tools needed to perform quantum mechanical calculations at the molecular level. It addresses students in physics and applied mathematics as well as mathematical- and physical-oriented chemists. It primarily addresses students with a basic understanding of quantum mechanics.

| | Course Contents (Topics and subtopics) | Reqd. hours |
|---|---|---|
| 1 | Revision of Basic Concepts | 10 |
| 2 | Schrodinger equation for the hydrogen atom, solution in terms of radial and angular wavefunctions, significance of quantum numbers, atomic spectra. | 10 |
| 3 | The quantum harmonic oscillator, eigenvalues and eigenfunctions (no detailed derivation), significance of 'zero-point' energy. | 10 |
| 4 | Origin of Molecular Spectra<br>Analysis of diatomic molecule as a rigid rotator, rotational and vibrational energy levels of a simple diatomic molecule. | 10 |
| 5 | Approximation methods in Quantum Mechanics<br>Brief introduction to perturbation theory with simple examples, variational theorem, analysis of helium atom as an example. | 10 |
| 6 | Molecular Quantum Mechanics<br>Molecular orbital and valence bond theories for diatomic molecules, Born-Oppenheimer approximation, LCAO method in H2+ ion and H2 molecule, valence bond method | 10 |
| | **Total** | **60** |

| List of Text Books/ Reference Books | | |
|---|---|---|
| 1 | Molecular Quantum Mechanics Peter W. Atkins, Ronald S. Friedman | |
| 2 | Introductory Quantum Chemistry A. K. Chandra · | |
| 3 | Molecular Quantum Dynamics: From Theory to Applications, Fabien Gatti · 2014 | |

| Course Outcomes (students will be able to…..) | | |
|---|---|---|
| CO1 | Form and use wave functions and operators for many-electron systems | K2 |
| CO2 | Characterise the symmetry of wave functions and thereby understand spectroscopic selection rules | K2 |
| CO3 | Explain strong covalent bonds in terms of wave functions | K3 |
| CO4 | Explain the correlated motions of electrons | K4 |
| CO5 | Perform calculations of approximate wave functions with help of computers | K5 |

K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating

**Chemical Engineering Elective: Molecular Quantum Mechanics CET4795**
**Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO5 | | | | | | | | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | | | | | | | | |

| **Chemical Engineering Elective: Molecular Quantum Mechanics CET4795<br>Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)** | | | | | |
|---|---|---|---|---|---|
| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 |
| CO1 | | | | | |
| CO2 | | | | | |
| CO3 | | | | | |
| CO4 | | | | | |
| CO5 | | | | | |
| 3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution; | | | | | |