Draft Model Curriculum for
UG Degree Course
in
Chemical Engineering
(Engineering & Technology)

ALL INDIA COUNCIL FOR TECHNICAL EDUCATION
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Concept of Minor Degree

All branches of Engineering and Technology shall offer Elective Subjects in the Emerging/ Multidisciplinary/ Region Specific Areas as specified in the Approval Process Hand book (APH).

a. Undergraduate Degree Subjects in Emerging / Multidisciplinary/ Region Specific Areas shall be allowed as specialization from the same department. The minimum additional Credits for such areas shall be in the range of 18-20 (including credit transferred from the SWAYAM platform) and the same shall be mentioned in the degree certificate, as specialization in that particular area. For example, doing extra credits for Cyber Security in Computer Science and Engineering shall earn B.E./B.Tech. (Hons.) Computer Science and Engineering with specialization in Cyber Security.

b. Minor specialization may be allowed in any Undergraduate Degree Courses where a student of another Department shall take the minimum additional Credits in the range of 18-20 and get a degree with a minor from another Department.

c. **AICTE approval is not required for offering Minor Degree/Hons. in any such area**, however the criteria is “Minor Degree or Hons. will cumulatively require additional 18 to 20 credits in the specified area in addition to the credits essential for obtaining the Undergraduate Degree in Major Discipline (i.e. 160 credits)”.

Concept of Micro Credits / Micro Specialization

Micro Credits can be applied across various disciplines, including technical skills, soft skills, interdisciplinary topics, and emerging fields such as AI, data science, sustainability, and entrepreneurship.

Micro Credits are small, modular units of learning that allow students to gain specific skills or knowledge in a short time. These credits can be accumulated and used to meet the requirements for a diploma, undergraduate, or postgraduate degree.

Besides the core courses, programs normally have professional elective courses. Each HEI decides the electives it can or wishes to offer. In some areas may be desirable to organize a set of electives as micro specializations. A micro-specialization is to provide a limited specialization in some sub-area of various disciplines, by offering suitable electives. The goal of the micro specialization is to provide deeper understanding and skill development in that area, and can provide multiple pathways to students, as different students can graduate with different specializations (or not). The areas in which micro specialization are offered should be aligned to industry careers or higher studies. A micro specialization for various disciplines may be defined as follows:

- It has a core course as the head (starting) course for the micro specialization
- It has a clearly defined goal, and learning outcomes for the goal
- It can have 2 +/- 0.5 additional courses (besides the head course) in the sub-area aligned to the goal.

These courses can be full course (4-credits) or half-course (2 credit), and can be taken as electives by students (or extra credits.)
Institutions can replace or add a course aligned to the micro specialization goal and also define a set of courses for a micro specialization and require that a subset be taken, with perhaps one being compulsory. It should be added that HEIs are completely free to decide whether to offer micro specializations or not, and if they decide to offer, which areas to provide the specialization in. How the micro specialization is to be reflected in a student's records/certificates is also to be decided entirely by HEIs based on their policies and practices.
Multiple pathways: For supporting multiple pathways within the academic program, we propose to provide for micro specializations through thematic course streams. These can be further enhanced by HEIs with programs like honors for advanced students with more credits or advanced learning outcomes, etc.

Benefits of Integrating Micro Credits:

- Enhanced Learning Flexibility: Students can choose from a wide array of micro-courses, allowing them to tailor their education to their career goals and interests.
- Skill Development: Micro Credits focus on specific, practical skills that are immediately applicable in the workplace, enhancing employability.
- Lifelong Learning: Micro Credits support continuous learning, making it easier for students and professionals to upskill or reskill in response to industry changes.
- Global Recognition: Micro Credits can often be recognized across institutions and countries, allowing students to study globally and transfer credits easily.

INDUCTION PROGRAM

The Essence and Details of Induction program can also be understood from the 'Detailed Guide on Student Induction program', as available on AICTE Portal,

(Link:https://www.aicteindia.org/sites/default/files/Detailed%20Guide%20on%20Student%2 0Induction%20program.pdf).

For more, Refer **Appendix III.**

Induction program (mandatory)	Three-week duration
Induction program for students to be offered right at the start of the first year.	• Physical activity • Creative Arts • Universal Human Values • Literary • Proficiency Modules • Lectures by Eminent People • Visits to local Areas • Familiarisation to Dept./Branch & Innovations

A.Mandatory Visits/ Workshop/Expert Lectures:

a. It is mandatory to arrange one industrial visit every semester for the students of each branch.

b. It is mandatory to conduct a One-week workshop during the winter break after fifth semester on professional/ industry/ entrepreneurial orientation.

c. It is mandatory to organise at least one expert lecture per semester for each branch by inviting resource persons from domain specific industry.

B. Evaluation Scheme (Suggestive only):

a. For Theory Courses:

(The weightage of internal assessment and end semester exam should be 30-40% and 60-70% respectively)

The student has to obtain at least 40% marks individually both in internal assessment and end semester exams to pass.

b. For Practical Courses:

(The weightage of the internal assessment and end-semester exam should be 50-60% and 40-50% respectively)

The student has to obtain at least 40% marks individually both in internal assessment and end-semester exams to pass.

C. For Summer Internship / Projects / Seminar etc.

Evaluation is based on work done, quality of report, performance in viva voce, presentation etc.

Note: The internal assessment is based on the student's performance in mid-semester tests (two best out of three), quizzes, assignments, class performance, attendance, viva- voce in practical, lab record etc.

D. Mapping of Marks to Grades

Each course (Theory/Practical) is to be assigned 100 marks, irrespective of the number of credits, and the mapping of marks to grades may be done as per the following table:

Range of Marks	**Assigned Grade**
91-100	AA/A^+
81-90	AB/A
71-80	BB/B^+
61-70	BC/B
51-60	CC/C^+
46-50	CD/C
40-45	DD/D
< 40	FF/F (Fail due to less marks)
-	F^R (Fail due to shortage of attendance and therefore, to repeat the course)

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1. Preamble

Admissions to Chemistry and Chemical Engineering programs in premier institutes like IITs and NITs have seen a significant decline in 2024. This is part of a broader trend of decreasing interest in core engineering disciplines, especially those perceived as having fewer immediate job opportunities compared to fields like computer science, artificial intelligence, and data science.

The Chemical and Allied Industry is an indispensable pillar of all manufacturing processes and the global economy. It is not an optional sector but a foundational one, driving innovation and productivity across energy, materials processing, and waste minimization. Chemical engineering plays a vital role in transforming raw materials into essential products, optimizing energy use, and reducing pollution at every stage of manufacturing. From producing fuels, chemicals, and polymers to ensuring sustainable processes in sectors like food, pharmaceuticals, semiconductors, and agriculture, chemical engineering is at the core of modern industry. It enhances productivity while prioritizing environmental protection through pollution prevention and resource-efficient processes. Therefore, all stakeholders must recognize and bolster the critical role of chemical engineering, fostering advancements in technology, sustainability, and economic growth for a better future.

Several factors have contributed to the decline in interest in Chemical Engineering, as reported in the media. All higher educational institutions, whether under the AICTE or other premier organizations, must make concerted efforts to rekindle interest in this critical engineering discipline. In the 1960s, 70s, and 80s, Chemical Engineering was among the most preferred branches. This document will discuss the challenges facing the field and its relevance in today's world, particularly regarding climate change, energy, and material needs. Computer Science and Engineering (CSE) has displaced many reputable institutes offering Chemical Engineering, relegating them to the fifth or sixth positions and resulting in numerous vacancies.

1.1 Career Opportunities and Placements: There is a growing concern over the job prospects in Chemical Engineering. For example, in 2024, placement rates for Chemical Engineering dropped in several IITs and NITs. IIT Jammu, which had placed 85% of its Chemical Engineering students in 2023, saw only 44% placement by mid-2024. Similarly, placement rates fell at IIT Kharagpur and IIT Hyderabad. While the highest placement salary packages in some NITs and IITs remained high, the overall demand for Chemical Engineering graduates appears to be diminishing, contributing to lower student interest.

1.2 Shift in Student Preferences: Many students are increasingly gravitating towards disciplines with clearer pathways to high-paying tech jobs. Programs like computer science, data science, and IT are seeing a surge in demand, while traditional engineering branches, including Chemistry and Chemical Engineering, struggle to maintain the same level of attractiveness.

1.3 Economic Factors: Global economic uncertainties and sector-specific challenges, especially in manufacturing and core industries, are affecting recruitment trends. The manufacturing sector, which is one of the key employers for Chemical Engineering graduates, has been slower in recovering from post-pandemic challenges, influencing students' perception of the field's viability.

This declining interest is reflected in the lowered cutoff ranks for admissions into these programs in the Joint Entrance Examination (JEE), with a noticeable shift towards non-core branches. Combination of reduced placements, evolving job market demands, and students' shifting preferences are contributing to the decline in admissions to Chemistry and Chemical Engineering programs in 2024.

Therefore, the syllabus for Chemical Engineering should be newly designed. This document is thus prepared.

2. National Education Policy (NEP) 2020

In view of the National Education Policy (NEP) 2020, engineering programs require several key changes:

2.1 Multidisciplinary Approach: Integrating humanities, arts, and social sciences with engineering education to develop well-rounded graduates with broader problem-solving skills.

2.2 Flexibility in Curricula: Introducing multiple entry and exit points with certification/diploma options, allowing students to pursue different paths and re-enter the program at various stages.

2.3 Focus on Innovation & Research: Encouraging research, entrepreneurship, startup ecosystem, and hands-on learning through internships and industry partnerships, fostering creativity and critical thinking.

2.4 Use of Technology: Adopting digital tools and online learning platforms to enhance accessibility and personalized learning.

2.5 Outcome-Based Education: Emphasizing learning outcomes and competencies over rote learning, with a focus on skills relevant to the evolving job market.

These changes align with NEP 2020's goals of making engineering education more flexible, inclusive, and future-ready. Thus, in view of both NEP 2020 and the current scenario, this document is prepared.

3. Definition and Scope of Chemical Engineering

Chemical Engineering is a multidisciplinary field that deals with rate processes be they physical, chemical, biological and nuclear, and it combines the principles of **Chemistry, Physics, Mathematics, Biology, and Engineering** (*some basics of civil, mechanical, electrical, electronics, environmental and materials*) to design, develop, optimize, and operate processes that convert raw materials into valuable products. It primarily focuses on the efficient and safe production of chemicals, materials, and energy while addressing environmental, economic, and sustainability concerns. Chemical Engineering is thus the most versatile discipline and highly science based, distinct and accommodative having systems engineering approach at scales ranging from nano, micro, meso, macro and mega scales, i.e. from atom to atmosphere.

At its core, Chemical Engineering deals with rate processes—the study of how quickly reactions and physical changes occur, including material and energy balance, heat transfer, mass transfer, fluid dynamics, separation processes, and reaction kinetics and rector design. Reaction kinetics and multiphase reactors distinguished Chemical Engineering from rest of the branches of engineering. The fundamental aspect of Chemical Engineering is increasing rates, reducing processing time, minimizing contactor volumes, which refer to optimizing processes to reduce waste, energy consumption, and resource usage while maximizing production efficiency and sustainability. It deals with batch, semi-batch and continuous processes, having different designs of contactors (separators, reactors) including recycle of unreacted reactants or feed while enhancing process safety. This approach ensures that processes have a minimal environmental impact, aligning with the goals of sustainability and the circular economy.

The Chemical Engineering discipline is highly relevant to India's goal of accelerating manufacturing growth. By driving innovations in energy, sustainability, materials, and process optimization, chemical engineers will contribute significantly to making India a global leader in manufacturing. Their expertise will be crucial in aligning industrial growth with national priorities of sustainability, resilience, and global competitiveness.

In Chemical Engineering, apart from the foregoing core subjects, the following subjects are interconnected and extremely important:

- **Risk management and process safety** reduce potential operational hazards, safeguarding workers and the environment, which prevents costly incidents.
- **Process control** ensures that operations remain within optimal conditions, enabling both **process optimization** and safety.
- **Optimization** efforts lead to lower costs and higher efficiency, but must be balanced with safety requirements.
- **Process economics** provides the financial lens to ensure that safety, control, and optimization strategies result in a viable, profitable operation.

Balancing these elements is crucial to achieving long-term success in chemical industries, ensuring not only operational excellence but also sustainable profitability. These areas are related to high degree of mathematics, simulations and the modern tools of AI and ML.

4. Integration of AI and ML with Modern Chemical Engineering

AI and Machine Learning (ML) are revolutionizing Chemical Engineering by offering new ways to optimize processes, predict system behaviour, and innovate product development. Incorporating AI/ML into Chemical Engineering programs through **minor degrees** (or can brought into the main course in process optimization) will provide students with interdisciplinary skills to tackle future challenges. Key integration points include:

4.1 Process Optimization and Control: AI/ML can improve the efficiency of chemical processes by analysing vast datasets, predicting system behaviour, and implementing advanced control strategies (such as **predictive control**). This reduces the need for manual intervention and enhances process reliability.

4.2 Predictive Maintenance: AI can predict equipment failures before they occur, minimizing downtime and maintenance costs in chemical plants. This is particularly important in energy-intensive and hazardous environments.

4.3 Material Discovery: Machine learning algorithms can significantly accelerate the discovery of new materials by predicting the properties of compounds and suggesting novel chemical formulations, particularly in areas like catalysis, battery materials, and polymers.

4.4 Energy Efficiency: AI can help optimize energy usage in chemical plants by identifying patterns in energy consumption and suggesting improvements that reduce energy waste. This is aligned with sustainability goals and net-zero targets.

4.5 Sustainability Assessments: AI and ML tools can analyse life-cycle data to provide insights into how processes or materials impact the environment, helping in decision-making for sustainable practices.

4.6 Circular Economy: AI models can assist in waste stream management, helping chemical engineers design processes that maximize the reuse and recycling of materials. It can optimize logistics for material recovery and identify new opportunities for resource efficiency.

4.7 Environmental Monitoring and Control: AI models can monitor emissions, water quality, and pollutant levels in real time, providing immediate feedback for regulatory compliance and corrective action.

5. AICTE's Model Syllabus for Chemical Engineering

Based on the foregoing background the new syllabus is designed. It has enough flexibility to bring in innovation at the institute level, and the individual instructor level, and also to derive courses from MOOCs or NPTEL as per the AICTE Policy.

5.1 India's Manufacturing Growth and the Role of Chemical Engineering in Achieving Vikasit Bharat@2047: A Path to Becoming the World's 2nd or 3rd Largest Economy

India's manufacturing sector is a critical driver of economic growth, employment, and industrial development. To meet the ambitious goals set by the government, such as making India a global manufacturing hub and increasing the sector's contribution to 25% of GDP by 2050 and 70% in the service sector, several strategic shifts are required. Chemical Engineering plays a vital role in this transformation, as it underpins a wide range of industries crucial to India's growth, including, refining, biorefining, coal, minerals, pharmaceuticals, chemicals, biotech, petrochemicals, energy, materials, and sustainable manufacturing.

5.2 Manufacturing Sector and the Chemical & Allied Industries: Driving Energy, Environment, Materials, and the Circular Economy

India must expand its manufacturing capabilities to boost exports, reduce dependence on imports, and strengthen the Make in India initiative. This will require investment in advanced manufacturing technologies, infrastructure, and skilled labour in these areas and hence the model syllabus consider the following.

5.2.1 *Sustainable Industrial Development*

With growing concerns about environmental impact, India's manufacturing growth must align with global sustainability goals. This involves reducing carbon emissions, improving resource efficiency, and adopting green chemical manufacturing practices.

5.2.2 Focus on Innovation and Technology

To remain competitive globally, India must focus on technological innovation in areas like automation, digitalization, and industry 4.0, which includes AI, machine learning, IoT, and data-driven manufacturing processes. These should be used to attain process intensification in chemical manufacture and also to reduce energy requirement and Undergraduate research will an important part for achieving these goals and keeping students interest in Chemical Engineering.

5.2.3 *Employment Generation*

As manufacturing grows, it will create jobs at all skill levels. However, this requires aligning Chemical Engineering education and training programs to produce a workforce capable of handling the demands of modern manufacturing technologies and sustainable practices.

5.2.4 *Building a Resilient Supply Chain*

The COVID-19 pandemic vulnerabilities in global supply chains, and India's manufacturing sector must strengthen its domestic supply chain networks to reduce dependency on imports and ensure resilience. The pharmaceutical industry depends on 80% of API imports from China. And Indian manufacturing sector not only should focus on import substitute but also on export in niche areas.

6. Relevance of Chemical Engineering to India's Manufacturing Growth

As discussed before, Chemical Engineering is essential to many sectors that are foundational to India's manufacturing growth. Its relevance spans energy production, sustainable manufacturing, and material development, directly addressing key national priorities. Hence apart from the traditional industries, new industries based on the Chemical Engineering principles will emerge leading to a bright future for the discipline.

6.1 Refineries, Petrochemical and Chemical Industries

India is one of the largest producers of chemicals and petrochemicals. Chemical engineers are critical in designing efficient, large-scale refineries, chemical processes that maximize yield while minimizing energy consumption and waste. Innovations in process optimization and catalysis help enhance productivity while reducing environmental impact.

6.2 Pharmaceuticals and Biotechnology

India is a global leader in the pharmaceutical industry, often referred to as the "pharmacy of the world." Chemical engineers contribute to drug manufacturing by developing efficient, scalable processes for active pharmaceutical ingredients (APIs), drug formulation, and vaccine production. Biotechnology, driven by chemical engineers, is also vital in sectors like healthcare, agriculture, and food processing. This industry will be USD 500 Billion by 2047

6.3 Polymers and Materials Industries

Chemical engineering plays a crucial role in the polymer and materials industry by driving innovation and optimizing processes for the production of a wide range of materials, including plastics, composites, and advanced polymers. Chemical engineers are integral to the design and development of new materials with enhanced properties, such as increased strength, durability, and flexibility, which are essential for applications in industries like automotive, aerospace, packaging, and healthcare. They also focus on improving manufacturing processes, making them more efficient, sustainable, and cost-effective by minimizing waste, reducing energy consumption, and incorporating green chemistry principles. Furthermore, chemical engineers are key in developing recycling and upcycling processes for polymers, addressing environmental concerns and fostering the circular economy. Their expertise ensures that materials used in everyday life meet performance, environmental, and economic standards.

6.4 .Energy and Renewable Resources

As India transitions to renewable energy and works toward its net-zero emissions target, chemical engineers will play a pivotal role in biofuel production, solar energy technologies, hydrogen economy, nuclear energy, clean coal technologies and energy storage systems. They will also lead efforts in carbon capture and storage (CCS), essential for decarbonizing industrial processes.

6.5 Food Processing Industry

Chemical engineering is vital in the food processing and storage industry, where it ensures the efficient production, preservation, and quality of food products. Chemical engineers design and optimize processes for pasteurization, sterilization, drying, freezing, and packaging, enabling longer shelf lives and maintaining nutritional value. They also develop innovative food preservation techniques, such as modified atmosphere packaging and food irradiation, to reduce spoilage and enhance food safety. By applying principles of mass and heat transfer, fluid dynamics, and reaction engineering, chemical engineers help scale up food production sustainably, ensuring consistent quality while minimizing waste and energy consumption. Additionally, they play a key role in enhancing food storage systems to reduce losses and ensure food security.

6.6 Agrochemicals Industry

India’s agricultural sector heavily relies on fertilizers and pesticides. Chemical engineers contribute to the development of sustainable agrochemicals, helping increase crop yields while reducing the negative environmental impacts of traditional farming inputs. Chemical engineering is crucial to the agrochemical industry, where it enables the efficient production of fertilizers, pesticides, herbicides, and other crop-protection products that are essential for modern agriculture. Chemical engineers design and optimize processes to manufacture agrochemicals at scale, ensuring high product quality, environmental compliance, and cost-effectiveness. They apply their expertise in reaction engineering, catalysis, and separation processes to develop more sustainable methods that reduce environmental impact, such as minimizing hazardous by-products and improving resource utilization. Additionally, chemical engineers are at the forefront of developing controlled-release formulations and bio-based agrochemicals, which enhance crop yields while reducing the negative impact on ecosystems, ultimately supporting global food security.

6.7 Speciality Chemicals Industry

Chemical engineering plays a pivotal role in the specialty chemicals industry, which includes the production of dyes, pigments, electronic chemicals, and other high-value materials tailored for specific applications. Chemical engineers design and optimize complex synthesis processes to ensure consistent quality, purity, and performance of these chemicals, which are critical in industries like textiles, electronics, and pharmaceuticals. Their expertise in reaction engineering, process control, and material science enables the efficient and scalable production of specialty chemicals, often requiring precise formulation and customization. Additionally, chemical engineers focus on developing greener production methods, reducing waste, and improving energy efficiency, aligning the specialty chemicals industry with sustainability goals while meeting the ever-growing demand for advanced materials in high-tech applications

6.8 Inorganic Chemicals and Semi-conductor Industry

Chemical engineering is essential to the inorganic industry right from major bulk chemicals like sulfuric acid, ammonia, nitric acid, phosphoric acid and particularly in the semiconductor sector, where precision and material purity are paramount. Chemical engineers develop and refine processes for the production of high-purity silicon, metals, and other inorganic compounds that are crucial for semiconductor manufacturing. They design efficient methods for crystal growth, thin-film deposition, etching, and doping, all of which are critical to creating semiconductor devices used in electronics, solar panels, and telecommunications. In addition, chemical engineers contribute to advancements in nanotechnology and material synthesis, driving innovation in the semiconductor industry. By optimizing these processes for scalability, cost-effectiveness, and sustainability, chemical engineers help meet the increasing demand for semiconductors in a wide range of high-tech applications, while minimizing environmental impact.

6.9 Sustainable Process Design

The future of manufacturing is closely tied to sustainability. Chemical engineers design processes that minimize waste, use renewable resources, and integrate circular economy principles by turning waste streams into valuable products. Techniques such as process intensification and green chemistry are employed to reduce resource use and environmental harm.

6.10 Materials and Advanced Manufacturing

Modern manufacturing demands the development of advanced materials for use in industries such as electronics, automobiles, construction, and aerospace. Chemical engineers are at the forefront of developing new materials, including nanomaterials, biocompatible materials, sensors, composites, and smart materials, that are stronger, lighter, and more environmentally friendly.

6.11 Water and Resource Management

Efficient use of resources, especially water, is crucial for India’s manufacturing sector. Chemical engineers develop advanced technologies for water treatment, recycling, and resource recovery, ensuring that industries reduce their water footprint and contribute to sustainable resource management.

6.12 Digitalization in Manufacturing

The integration of Artificial Intelligence (AI), Machine Learning (ML), and Process Automation in Chemical Engineering will enable real-time optimization of manufacturing processes. The combination of physical processes with cyber world, IoT, block chain and the like will improve efficiency, reduce downtime, and allow for predictive maintenance of equipment, which is key to increasing production capacity and reducing operational costs.

6.13 Atomic Energy and Nuclear Fuel Processing

Chemical engineering plays a vital role in atomic energy and nuclear fuel processing, contributing to the safe, efficient, and sustainable generation of nuclear power. Chemical engineers are involved in the extraction, refinement, and enrichment of uranium and other nuclear fuels, ensuring the high purity required for reactor efficiency. They develop advanced separation processes for isolating isotopes and removing impurities, as well as managing the chemical reactions involved in fuel fabrication. Additionally, chemical engineers design methods for reprocessing spent nuclear fuel, recycling valuable materials, and safely managing radioactive waste to minimize environmental impact. Their expertise in heat transfer, fluid dynamics, and process safety ensures that nuclear reactors operate optimally while maintaining rigorous safety standards, making nuclear energy a key player in the global transition to cleaner, low-carbon energy.

6.14 Circular Economy, Recycle Engineering, Biorefineries and Waste to Wealth

To transition towards a circular economy, Chemical Engineers focus on technologies that turn industrial waste into valuable products, such as converting plastic waste into fuels, carbon capture utilization, and biomass conversion. These efforts align with the sustainability goals of reducing environmental impact and fostering resource efficiency. By 2050 the crude oil supply will practically come to a nought and hence bio-refineries will be the order of the day.

7. Key Initiatives in India Aligned with Chemical Engineering

The following will demonstrate the Governments efforts that are directly relevant to Chemical Engineering.

7.1 Production Linked Incentive (PLI) Scheme

The PLI scheme in sectors such as pharmaceuticals, chemicals, electronics, and energy storage provides incentives for manufacturing companies to scale up production. Chemical engineers will be key players in enhancing production efficiency and ensuring that products meet high environmental and quality standards.

7.2 Atmanirbhar Bharat (Self-Reliant India)

The drive toward self-reliance emphasizes domestic manufacturing of critical goods, especially in chemicals and pharmaceuticals. Chemical engineers will be central to developing indigenous processes and technologies, reducing reliance on imports. Startup ecosystem is being encouraged through special incentives.

7.3 National Green Hydrogen Mission and Decarbonisation

India’s ambitious plans for a green hydrogen economy will rely heavily on Chemical Engineering expertise in developing electrolysis processes, thermochemical and biomass, hydrogen storage, and transportation solutions.

8. Future of Chemical Engineering and Evolving Curriculum

The future of Chemical Engineering is highly promising, especially as the field plays a crucial role in solving some of the most pressing global challenges related to energy, the environment, and sustainability. Key trends that will shape the future of Chemical Engineering include:

8.1 Sustainability and Green Engineering

Chemical Engineering will lead the way in developing sustainable processes that reduce waste and environmental impact. There will be a focus on renewable energy, green chemistry, and eco-friendly manufacturing. Chemical Engineers will design processes with a life cycle approach to minimize the environmental footprint from production to disposal.

8.2 Energy Transition and Renewable Resources

Energy is at the core of chemical engineering, where traditional fields like petrochemical processing are being transformed to support renewable energy systems (e.g., biofuels, hydrogen energy, and solar fuels). Chemical Engineers are also involved in the design of energy storage systems such as batteries and thermal energy storage using molten salts. In energy production and optimization, chemical engineers apply thermodynamics, reaction engineering, and process optimization to improve energy efficiency and reduce emissions. Emerging areas like carbon capture and utilization, and storage (CCUS) and power-to-X technologies are crucial to achieving net-zero targets.

8.3 Circular Economy and Material Recyclability

The transition towards a circular economy will require chemical engineers to design processes that emphasize material recyclability and waste to wealth products. Future innovations will focus on converting waste into valuable resources through chemical and biochemical processes. New recycling methods for plastics, metals, and other materials will be a key area of focus.

8.4 Digitalization, AI, and Machine Learning

The integration of AI and machine learning (ML) in Chemical Engineering will revolutionize how processes are designed, controlled, and optimized. Predictive models, smart manufacturing, and real-time optimization using data-driven approaches will lead to more efficient and safer processes. These technologies will enhance predictive maintenance, process simulation, and the discovery of new materials and catalysts.

8.5 Biotechnology and Bioengineering

Chemical engineers will continue to drive advancements in biotechnology, particularly in areas like bio-based materials, biopharmaceuticals, and bioreactor design. As the demand for bio-based and sustainable products grows, chemical engineers will develop bioprocesses that leverage biological systems to produce chemicals and materials in environmentally friendly ways.

8.6 Net Zero and Decarbonization

Achieving net-zero carbon emissions by mid-century will require innovations from chemical engineers in areas such as carbon capture, utilization and storage (CCUS), low-carbon fuels, and carbon dioxide valorisation to chemicals, fuels and materials and decarbonizing industrial processes. New processes will be designed to reduce greenhouse gas emissions while maintaining economic viability.

8.7 Advanced Materials and Nanotechnology

Chemical Engineers will be at the forefront of developing new materials for applications in energy storage, water purification, drug delivery, and electronics. The field of nanotechnology will continue to grow, with chemical engineers developing nanomaterials with unique properties for specific applications. 3D Printing or Advanced Manufacturing will need new types of materials, biocompatible and corrosion resistant, refractory materials that will be the domain of Chemical Engineering. The discovery of sustainable materials will be a critical focus to reduce dependence on non-renewable resources.

8.8 Process Intensification

Future innovations will emphasize process intensification, where chemical engineers design processes that produce more product with fewer resources, smaller equipment, and reduced energy input. This aligns with the goals of reducing the environmental footprint and improving efficiency.

8.9 Water and Resource Management

With water scarcity becoming a global challenge, chemical engineers will develop technologies for water treatment, desalination, and resource recovery from wastewater. The focus will be on designing closed-loop systems where water and resources are continually recycled.

9. Outlook and Paradigm Shift for Chemical Engineering Syllabus

The future of Chemical Engineering is closely tied to the drive for sustainability, energy efficiency, and resource conservation. With its foundation in rate processes and optimization, Chemical Engineering will continue to evolve as a field that minimizes resource usage and maximizes environmental responsibility. Future chemical engineers will be innovators at the intersection of technology, energy, and sustainability, working to meet the demands of a rapidly changing world.

9.1 Chemical Technology Programmes

Basically the Chemical Technology degree programmes that have evolved in the UK, Germany, India, and South East Asia are based on fundamentals of Chemical Engineering with technologies of manufacture in specific areas such as the following but not restrictive to these area but are continuously evolving:

1. Pharmaceutical Engineering & Technology
2. Food Engineering and Technology
3. Polymer Engineering
4. Textile Chemistry and Engineering
5. Surface Coating Engineering
6. Oils Technology
7. Pulp and Paper Technology
8. Green Technology
9. Biochemical Engineering
10. Chemical Process Engineering
11. Speciality Chemicals Technology
12. Perfumery and Flavours Technology
13. Bioprocess Technology
14. Materials Technology
15. Environmental Technology
16. Semi-conductor Technology

The above can be standalone branches of Chemical Technology as major degree programmes in India which can be combined with minor programmes in one or two more disciplines.

9.2 Proposed Curriculum for Minor Degrees in AI/ML in Chemical Engineering and Chemical Technology

Chemical Engineering degree programs must evolve to incorporate emerging technologies like AI and ML, which can transform traditional sectors and foster innovation in energy, environment, and sustainability. By offering minor degrees in AI/ML, Chemical Engineering and Chemical Technology students will be equipped with cutting-edge tools to contribute to the global push for a sustainable, circular economy and achieve net-zero goals. The following components as part of some of the core subjects and or Minor degrees without losing the focus of Chemical Engineering or Chemical Technology programmes.

9.2.1 ***Fundamentals of AI/ML***: Introduction to algorithms, data science, and predictive analytics.

9.2.2 ***Process Control and Optimization***: AI applications in process engineering for real-time optimization and control.

9.2.3 ***Big Data in Chemical Engineering***: Data analytics applied to large datasets generated from industrial processes.

9.2.4 ***Smart Manufacturing***: Implementation of AI/ML in industrial automation and process monitoring.

9.2.5 ***Material Informatics***: Machine learning models applied to the discovery and design of materials for sustainable applications.

9.2.6 ***AI for Environmental Monitoring***: Application of AI/ML tools in pollution control and environmental sustainability assessments.

9. 3 Why a Standalone First Year for Chemical Engineering Makes Sense

There is a general trend in India in many colleges to have first year common for all engineering programmes. Based on the foregoing arguments, and due to the distinctive nature of Chemical Engineering and in tune with NEP 2020, the First Year of Chemical Engineering and Chemical Technology programmes should be stand alone. The reasons are as follows:

9.3.1 Requirement of Specialized Knowledge Early On

Chemical Engineering is inherently multidisciplinary, Chemical process industries, thermodynamics, fluid mechanics, mass transfer, and reaction kinetics, all of which are fundamental to the discipline and distinct from the foundational courses common to other engineering branches. Introducing these concepts early in the programme would allow students to build a deeper understanding of chemical processes, which is crucial for success in later years.

9..3.2 Focus on Core Chemical Engineering Principles

A standalone first-year program would enable students to focus on key Chemical Engineering concepts such as material and energy balance (stoichiometry), chemical process calculations, and basic process design. Early exposure to these topics would provide a solid foundation for advanced coursework and better prepare students for industry or research.

9.3.3 Tailored Curriculum for Industry Relevance

The chemical industry has specific needs, and a customized first-year curriculum would allow programs to better align with industry expectations. Skills such as material and energy balance, safety protocols, and environmental considerations could be integrated from the beginning, making graduates more ready for real-world challenges.

9.3.4 Building Domain-Specific Expertise

Starting with a common first year in general engineering may delay students from gaining expertise in key Chemical Engineering areas. Further for the early exit as envisage in NEP with a certificate or diploma in Chemical Engineering needs a standalone first year which cannot be common. A standalone first-year program would help students become chemically literate engineers early on, enabling them to contribute more effectively to areas like energy transition, sustainable process design, and green chemistry.

10. Common First Year with Chemical Technology programmes

10.1 Shared Foundations

Both **Chemical Engineering** and **Chemical Technology** programs are closely related, focusing on the design, optimization, and operation of chemical processes. A common first year for both could focus on foundational subjects, like **basic chemistry**, **material science**, and **chemical processes**, which are relevant to both streams.

10.2 Broader Skill Development

Since chemical technology is more applied, focusing on **industrial processes** and **product development**, a common first year could give students exposure to both the theoretical and practical aspects of the field. This would allow students to later choose their preferred specialization (either engineering or technology) with a broader understanding of the field.

10.3 Flexibility in Career Path

A shared curriculum with chemical technology would provide flexibility for students who may want to switch between the two streams, depending on their interests. Chemical engineers may decide to pursue careers in product development or process technology, and vice versa.

11. Why the Common First-Year Model for All Engineering Programs Isn't Ideal for Chemical Engineering

11.1 Lack of Specialized Knowledge

The common first-year structure delays the introduction of Chemical Engineering-specific subjects, which are essential for grasping advanced topics later. This can make it difficult for students to adapt in the second year, when Chemical Engineering courses are introduced abruptly.

11.2 Unique Requirements of the Discipline

Chemical Engineering requires a strong grasp of both engineering principles and chemical sciences, which is distinct from other engineering disciplines such as mechanical, electrical, or civil. The common first-year model, which focuses on general engineering topics, does not cater to these specific needs.

11.3 Missed Opportunities for Early Skill Development

Early introduction to industry-relevant skills like process modelling, simulation tools, and lab-based chemical processes could give students a head start in understanding Chemical Engineering processes in a real-world context.

A standalone first-year program for Chemical Engineering or a common first-year program with chemical technology would offer several advantages over the current common curriculum for all engineering disciplines. This would allow for early specialization, industry-aligned skill development, and a more robust foundation in the unique aspects of chemical engineering. By tailoring the curriculum to the specific needs of chemical engineers, educational institutions can better prepare students for the demands of the chemical industry, sustainability challenges, and technological advancements.

12. Course Delivery and Examination Pattern

Over the years, the annual examination system based on the British model, which was highly stressful and promoted rote learning, has been replaced by the semester pattern, typically divided into two terms of about five months each, followed by a two-month summer break. However, this system has its drawbacks, particularly as it leaves students idle during their prime years, which can have negative societal impacts. In the light of the NEP 2020, which emphasizes hands-on experience in sectors where students will find employment, the trimester system emerges as a more effective approach. This model, widely practiced in the US and Canada, has consistently produced successful entrepreneurs and promotes a "learn and earn" mindset by keeping students engaged year-round while allowing them to balance work and study. The trimester system aligns well with the NEP's focus on experiential learning and better prepares students for the demands of the workforce.

12.1 Semester or Trimester

Institutions can adopt either the semester or trimester pattern depending on their infrastructure, industry connections, and faculty resources. Importantly, the total number of credits required for obtaining a degree or exiting the program at various levels remains the same, regardless of whether a semester or trimester system is in place. With AICTE's initiatives, such as the Professor of Practice and Industrial Sabbaticals for faculty, the trimester system may be particularly advantageous for leading institutions with strong entrepreneurial legacies. This system allows for more frequent engagement with industry, better aligning academic schedules with internships, industrial training, and hands-on projects. Moreover, the introduction of faculty-owned startups and the emphasis on innovation will benefit from the trimester model, as it provides faculty and students with the flexibility to balance academic work with entrepreneurial and practical endeavours. By maintaining the same credit requirements across both systems, institutions can offer the benefits of a more dynamic and flexible education model without compromising academic rigor or program outcomes.

12.2 Trimester System

The trimester system of university education offers several advantages over the semester system, particularly in the context of India's National Education Policy (NEP) 2020, which emphasizes flexibility, skill development, and experiential learning. Here are the key advantages of the trimester system compared to the semester system, with reference to the goals of NEP 2020 and the example of the University of Waterloo's co-op model in Canada is one of the most successful models having direct connect with industry leading to many startups during the course of study.

Several universities in the U.S. and Canada have strong co-op programs, integrating academic studies with practical work experience. These programs provide students with opportunities to alternate between academic terms and paid work placements, gaining hands-on experience in their chosen fields. For instance, in the US, the following Universities run successful co-op programmes: Northeastern University – Known for its extensive co-op program, offering placements across various disciplines, particularly in business, health, and engineering; Drexel University – Offers a flexible co-op program where students can complete one to three six-month co-op experiences; Rochester Institute of Technology (RIT) – RIT is well-regarded for its co-op placements, particularly in technology, engineering, and design; Georgia Institute of

Technology – Provides a robust co-op program, especially in engineering and computer science, where students gain up to a year of work experience, and Purdue University.

In Canada, several top universities offer robust co-op programs, allowing students to gain practical, hands-on work experience as part of their academic journey: University of Waterloo – Hosts the largest co-op program in the world, offering over 120 programs across diverse fields, including engineering, business, and health; University of Toronto – Features various co-op opportunities, with its Professional Experience Year (PEY) program allowing students to take a 12-16 month work term; McGill University – Offers a strong international focus in its co-op programs, allowing students to gain work experience globally; University of British Columbia (UBC) – Provides co-op options in engineering, business, science, and arts, emphasizing industry-academic connections; University of Alberta – Particularly well-known for its engineering and business co-op programs, backed by a wide network of industry partners.

These co-op programs are integrated into the academic curriculum, enabling students to graduate with both a degree and significant professional experience. NEP precisely aims at such a model.

The advantages of trimester system are as follows:

1. Enhanced Flexibility and Choice

- **Trimester System:** Under the trimester system, students have the opportunity to complete three terms in an academic year (rather than two in a semester system). This allows them to either accelerate their studies, spread their workload, or explore a broader range of electives.
- **NEP 2020 Alignment:** NEP 2020 advocates for a more flexible curriculum that caters to students' interests and career goals. The trimester system gives students more flexibility to structure their education based on their personal learning pace and professional aspirations.

2. Integration of Work Experience (Alternate Classroom and Work Term)

- **Trimester System with Co-op Model:** A key benefit of a trimester system, as exemplified by the **University of Waterloo's** co-op model, is the integration of alternate classroom terms and work terms. This allows students to gain practical experience while they study. Every alternate term could be dedicated to internships, projects, or industry-based learning.
- **NEP 2020 Alignment:** NEP 2020 places a significant focus on vocational education, internships, and skill-based learning. The trimester system supports this by offering flexibility in scheduling work terms, allowing students to engage in meaningful work experiences without disrupting their academic progress.

3. Shorter, Focused Terms

- **Trimester System:** Each trimester term typically lasts about 10–12 weeks, allowing for more focused, intensive learning periods. In contrast, semester systems run longer (typically 15–18 weeks), which can lead to a more spread-out curriculum.

- **NEP 2020 Alignment:** The trimester system's shorter, concentrated terms align with NEP's vision for an engaging, multidisciplinary curriculum that doesn't overload students but encourages continuous learning. This setup encourages deeper engagement with fewer courses per term, promoting better retention and understanding of subjects.

4. Faster Completion of Degrees

- **Trimester System:** Students can potentially complete their degrees faster in a trimester system, as there is an additional academic term each year. This allows them to take more courses within the same timeframe or use the third term for catching up on credits.
- **NEP 2020 Alignment:** NEP 2020 promotes multiple entry and exit points, which means students may leave with certificates, diplomas, or degrees at different stages. The trimester system, with its faster pace, fits well into this structure, allowing students to complete various stages of education more quickly and efficiently.

5. Continuous Learning Opportunities

- **Trimester System:** With three terms in a year, there is less academic downtime, which leads to continuous learning and engagement. Students remain engaged in academic activities throughout the year, which improves their academic continuity.
- **NEP 2020 Alignment:** NEP 2020 encourages lifelong learning and continuous skill upgrading. A trimester system ensures that there is no significant gap between academic terms, facilitating an ongoing learning process, especially for courses that require sustained focus and development over time.

6. Opportunities for International Collaboration, Learning and Research

- **University of Waterloo Example:** The University of Waterloo is known for its alternating classroom and work terms, which have proven effective in bridging academia and industry. This model could serve as a reference for Indian universities looking to implement the trimester system. In addition to the co-op program, Waterloo's flexibility in term scheduling also enables students to engage in international exchange programs, thereby broadening their exposure.
- **NEP 2020 Alignment:** NEP emphasizes global collaboration and the internationalization of higher education. The trimester system allows Indian universities to better align their academic calendars with international universities, thereby facilitating student exchanges, internships abroad, and collaborative projects.
- **Recruiting International Faculty for a Term:** This system makes it possible to recruit some of the best faculty from abroad to teach cutting edge courses and do collaborative research which has been encouraged by some of the DST international programmes.

7. Improved Industry Connections

- **Trimester with Work Terms:** The trimester system, particularly when paired with work terms like in the Waterloo model, strengthens university-industry relationships. Students gain real-world experience, and companies benefit from access to a regular pool of skilled interns or trainees.
- **NEP 2020 Alignment:** NEP encourages industry-academia linkages to promote innovation and entrepreneurship. The trimester system supports this through frequent

work terms, where students can apply their academic knowledge in real-world settings, enhancing both employability and practical skills.

8. Mitigation of Student Burnout

- **Trimester System:** The trimester system provides regular, shorter breaks between terms, which helps students rest and recharge, mitigating burnout compared to the longer, more intense periods of a semester system.
- **NEP 2020 Alignment:** NEP emphasizes the importance of student well-being and creating a more engaging and less stressful learning environment. The trimester system's balanced approach with regular breaks aligns with this philosophy.

The foregoing analysis vis-à-vis NEP demonstrates how the trimester system, especially when integrated with work terms, offers significant advantages for Indian universities aiming to implement the principles of NEP 2020. The combination of flexibility, experiential learning, and continuous academic engagement makes the trimester system an attractive option for enhancing the quality of higher education in India. It aligns well with NEP's goals of promoting multidisciplinary education, industry collaboration, and student-centered learning pathways.

9. Opportunities for Faculty for Practical Experience

The trimester system offers several key benefits to faculty members, allowing them to balance teaching, research, and industry engagement. Faculty can dedicate two trimesters to teaching and use the third to conduct research or collaborate with industry. This flexibility enables faculty to address real-world challenges, refine their course content, and develop industry-sponsored projects. Additionally, it opens opportunities for consultation activities, enhancing the academic experience for students while bringing industry knowledge into the classroom. A well-structured revenue-sharing model between faculty and the institute ensures faculty members can supplement their income, benefiting both their professional development and the institution's industry ties.

13. Examination Pattern

13.1 Semester System

The proposed assessment system emphasizes continuous evaluation to ensure student engagement and fairness. A 30% weightage is allocated to continuous assessments, consisting of five tests, with the best three scores accounting for 10% each. This system accommodates absences due to unforeseen circumstances, ensuring students are not unduly penalized for health or personal issues. Mid-semester exams would account for 20%, providing a checkpoint for progress, while the final examination contributes 50%. To further support students and reduce backlogs, a repeat end-semester exam should be conducted within one month, allowing students who may have failed or missed the exam to promptly retake it and avoid delays in their academic progress. This balanced approach promotes consistent learning, reduces pressure on final exams, and encourages a proactive response to challenges throughout the semester.

13.2 Trimester System

The trimester system should ensure course content or credits are completed within 13-14 weeks, followed by an end-trimester examination. Since students will alternate between academic terms and work terms, 70% of the assessment should be allocated to continuous evaluation. This can be structured around 10 tests, with the best 7 being considered for grading. This approach removes the need for a mid-term exam, helping to reduce burnout and unnecessary stress, making learning more engaging and enjoyable. The end-term examination will carry 30% weightage, ensuring that a final comprehensive evaluation is still in place.

For students who do not achieve passing marks in the continuous assessment, a repeat end-term exam should be offered to provide a second chance to improve their scores. The overall passing criteria would be set at 50% of the total marks. This system is designed to accommodate varying learning paces while maintaining academic rigor, providing a fair opportunity for students to succeed without the overwhelming pressure of traditional assessment models.

A hybrid approach to attendance, combining online and physical participation, can enhance flexibility in the learning environment. However, it is crucial to limit online attendance to a maximum of 25% for lectures. This ensures that students benefit from the essential face-to-face interactions that foster engagement, collaboration, and deeper understanding of course material.

Limiting online attendance encourages students to participate actively in the classroom, where they can benefit from immediate feedback, discussions, and networking opportunities with peers and faculty. The remaining 75% of attendance should be in-person, which facilitates richer learning experiences and reinforces community-building among students.

Moreover, integrating online attendance for certain components—such as guest lectures or supplementary sessions—can enhance accessibility without compromising the primary learning experience. This approach not only accommodates diverse learning preferences but also prepares students for a future where flexibility in the workplace is increasingly valued.

By implementing a clear attendance policy that balances both online and physical presence, educational institutions can create a more effective and engaging learning atmosphere that supports student success.

14. Proposed Syllabus for Bachelor's Degree and Integrated Master's in Chemical Engineering

Based on the preceding considerations, the syllabus can be crafted to align with the principles of the National Education Policy (NEP), which emphasizes flexible pathways for both entry and exit into academic programs. This syllabus will be designed to cater to diverse learning needs and facilitate smooth transitions for students.

Institutions have the autonomy to develop individual course content, including selecting appropriate textbooks, designing practical laboratory experiences, and incorporating demonstration laboratories and simulations. This approach allows field while ensuring that students gain both theoretical knowledge and practical skills.

Moreover, incorporating feedback from industry stakeholders and academic experts during the syllabus development process will ensure that the curriculum remains relevant and aligned with current industry standards and practices. This collaborative effort will not only enhance the quality of education but also better prepare students for real-world challenges, fostering a workforce that is adaptable, innovative, and equipped with the skills necessary for success in a rapidly changing environment.

By creating a syllabus that embraces these principles, educational institutions can contribute to a more inclusive and dynamic learning ecosystem that supports lifelong learning and professional growth.

14.1 Exist Policy

The syllabus for Chemical Engineering programs must be distinctly tailored to reflect the unique demands and complexities of the profession. Unlike other engineering disciplines, the focus should be on a blend of fundamental and applied courses that foster innovation, enabling the creation of new industries and startups while supplying the skilled workforce needed by processing industries across the globe.

In alignment with the National Education Policy (NEP), which emphasizes flexible exit routes throughout the educational journey, this syllabus will encompass various credentials: certificates (1.5 years), diplomas (2 years), undergraduate degrees (3 years), and full four-year degrees with honors, integrating undergraduate research components and internships. This comprehensive approach ensures that students have multiple pathways to succeed in their careers, catering to varying levels of commitment and professional aspirations.

Sr. No.	Exit Year	Activity	Credits	Duration (No of Weeks)
1	1st Year (After Semester II)	8 credit course workshop/chemistry lab (after semester 2)	8	8 weeks
2	2nd Year (After Semester IV)	Certificate Course in Practice of Chemical Technology (CCPCT)	8	8 weeks
3	3rd Year (After Semester VI)	In-plant training	8	8 weeks

By emphasizing both theoretical foundations and practical applications, the syllabus aims to equip students with the skills necessary to drive advancements in chemical engineering, ultimately contributing to economic growth and technological progress in the sector.

- **Chemical Engineering (ChE) as an Applied Science**: Chemical Engineering is fundamentally a science-based but applied discipline that encompasses various rate processes, including physical, chemical, biological, and nuclear phenomena. Its core objectives include increasing reaction rates, reducing volumes, enhancing process efficiency, intensifying operations, minimizing waste, and promoting sustainability. The principles of ChE are applied across a vast scale, from atomic interactions to atmospheric phenomena. The discipline inherently adopts a Systems Engineering approach, which integrates the miniaturization industry, such as micro-reactors and micro-separators, and larger-scale processes, facilitating innovations in recycle engineering, waste-to-wealth concepts, and circular economy practices.
- **Core Expertise and Evolving Skillsets**: Traditional core areas of ChE, including applied chemistry, physics, engineering mathematics, transport processes, process design, safety analysis, and business communication, are increasingly complemented by expertise in molecular and nanoscience, biosystems, sustainability, and cyber tools. Contrary to the misconception that Chemical Engineering focuses solely on chemistry and basic physics, it demands a strong mathematical foundation akin to other engineering branches. The emergence of new technologies, including artificial intelligence (AI), machine learning (ML), and deep learning, will play a crucial role in advancing Chemical Engineering (ChE 4.0+).
- **Adaptation to Future Changes**: The upcoming changes in the field over the next 25 years necessitate the development of a flexible and relevant syllabus model that equips chemical engineers with the necessary skills to secure employment across various industries or to launch startups.
- **Sustainability and Climate Considerations**: There is an urgent need to cultivate an environmentally, economically, and socially sustainable global circular economy. Countries are increasingly motivated to reduce their dependence on fossil fuel imports by diversifying energy sources, with the Net Zero Economy now a global consensus. Addressing climate change and reducing greenhouse gas (GHG) emissions are paramount concerns that should be integrated into Chemical Engineering practices.
- **Innovative Production Techniques**: In the future, Chemical Engineering will harness advancements in computational modeling, data analytics, optimization tools, and bio-based catalysts to manufacture fuels and chemicals at scale with significantly lower emissions.

- **Integration of Traditional and Advanced Methods**: The future energy landscape will combine traditional Chemical Engineering areas such as transport phenomena and process design with cutting-edge computational capabilities, bio-catalysts, and advanced sensors.
- **Renewable Energy Applications**: Renewable energy sources, including solar, wind, hydrogen, hydro, geothermal, and nuclear systems, all rely on Chemical Engineering principles. The declining costs of solar electricity generation illustrate the potential for innovative chemical plants powered by renewable energy, emphasizing the need for improved energy storage solutions beyond lithium-based technologies, while also highlighting the importance of material processing and recycling within the ChE curriculum.
- **Safety and Design Principles**: It is essential that processes and products are designed with safety in mind, ensuring that chemicals and materials are cost-, material-, and energy-efficient to promote recycling.
- **Lifecycle Analysis and End-of-Life Solutions**: The solutions for product end-of-life and lifecycle analysis must meet or exceed the performance of existing products, with biorefineries utilizing waste biomass for chemical, fuel, and material production taking centre stage.
- **Influence on Food and Healthcare**: Chemical Engineering governs critical sectors such as food processing and healthcare. Notable advancements since 2008 include CRISPR gene editing tools, accessible gene analyses, and the integration of data science and informatics into these fields.
- **Impact on Society**: Chemical engineers significantly impact billions of lives, in part due to their ability to leverage emerging technologies from various fields. As AI technology matures, its integration into Chemical Engineering will further enhance capabilities across diverse applications.
- **Deep Learning in Chemical Engineering**: Deep learning, a key facet of AI, offers transformative solutions across all domains, making it an invaluable asset in the toolbox of chemical engineers.
- **Innovative Processes for Sustainability**: Research into alternative production methods and chemical reactions will focus on reducing waste, conserving water, minimizing hazardous materials, and improving energy efficiency and product yield.
- **Interdisciplinary Nature of Chemical Engineering**: Chemical Engineering serves as a "multilingual" discipline, facilitating effective communication and collaboration with various branches of science, engineering, technology, mathematics, and medicine.
- **Expanding Educational Pathways**: Pursuing minors in AI, ML, and data analytics alongside a major in Chemical Engineering can enhance skill sets and empower future chemical engineers.
- **Flexible Degree Structures**: The structure of major and minor degrees will depend on institutional expertise in engineering, basic sciences, and humanities, with the option to supplement studies through online courses. This flexibility may allow for the creation of designer degrees encompassing one major and two to three minors, fostering a multidisciplinary approach to education.

These enhancements clarify the critical role of Chemical Engineering and its evolution, ensuring that students are well-prepared for future challenges and opportunities.

14.2 Pattern of Education

The National Education Policy (NEP) emphasizes hands-on experience in education, allowing institutions to adopt either a **semester** or **trimester** system based on their unique contexts. This choice will depend on factors such as faculty expertise, research programs, and industry connections. While the total number of credits will remain constant, institutions may opt for the trimester system if it aligns with their location and culture of research and innovation. The primary objective is to develop industry-trained, industry-ready graduates and cultivate a new generation of entrepreneurs.

Institutions will have the flexibility to choose between a semester or trimester format. Regardless of the chosen system, the curriculum must incorporate provisions for industrial internships and undergraduate research, especially for a four-year degree program or a five-year integrated program that awards both bachelor's and master's degrees upon completion of the fifth year. The fifth year will focus on research, allowing students to explore startup ideas.

Importance of Industrial Internships: Industrial internships or work terms are crucial for student development. To facilitate this, the Ministry of Education should establish a **Student Internship Responsibility (SIR)** in consultation with the Ministry of Skill Development, ensuring that stipends are provided by industries and organizations. In the trimester system, even certificate holders should gain practical experience through industrial training. While this initiative falls outside the purview of our committee, we can recommend it for consideration.

Subject Distribution and Exit Routes: The curriculum should include a distribution of subjects with clear exit provisions: students can exit after completing the first year with a certificate, the second year with a diploma, and the third year with a degree in Chemical Engineering.

14.3 Curriculum Structure for Chemical Engineering Programme

1. **First Year**
    - **Core Subjects:**
        - General Chemistry
        - Mathematics
        - Physics
        - Biology
    - **Foundational Courses:**
        - Introduction to Chemical Engineering and the Chemical Industry
        - Material and Energy Balances
        - Computer Programming
        - Introduction to Artificial Intelligence (AI) and Machine Learning (ML)
        - Instrumental Methods of Analysis
2. **Second Year**
    - **Core Subjects:**
        - Transport Phenomena
        - Thermodynamics
        - Introduction to Separation Processes
        - Materials Science
3. **Third Year**

- **Core Subjects:**
    - Process Control
    - Chemical Process Economics
    - Multiphase Reactor Design
    - Advanced Transport Phenomena
    - Advanced Separation Processes

14.4 Semester pattern with 8 semesters plus internships

Pattern of Examination	**Semester**	**To be decided**
	No. of Credits	
Semester 1		**24**
Semester 2		**22**
Internship	**(Two months)**	**2**
Semester 3		**24**
Semester 4	**UG research is part**	**2**
Internship		**2**
Semester 5	**UG research is part**	**24**
Semester 6	**UG research is part**	**22**
Internship		**2**
Semester 7		**24**
Semester 8		**24**

14.5 Trimester pattern for B Tech (Four years with 12 trimesters)

The class is initially divided into two batches upon admission, following this structured approach to optimize infrastructure utilization. This method not only enhances efficiency but also allows for potentially doubling the intake capacity or improving management thereof.

Year	**Trimester**	**Class room learning**	**Industry placement**	**Comments**
First	1	Batch A + Batch B		Both together to learn basics
	2	Batch B	Batch A	
	3	Batch A	Batch B	
Second	4	Batch B	Batch A	
	5	Batch A	Batch B	
	6	Batch B	Batch A	
Third	7	Batch A	Batch B	

	8	Batch B	Batch A	
	9	Batch A	Batch B	
4	10	Batch B	Batch A	
	11	Batch A	Batch B	
	12	Both batches together		

15. Integrated M. Tech. (Five Years trimester with 15 trimesters; 2 terms for research) With Major and Minor Degree Programmes

Year	Trimester	Class room learning	Industry placement	Comments
First	1	Batch A + Batch B		Both together to learn basics
	2	Batch B	Batch A	
	3	Batch A	Batch B	
Second	4	Batch B	Batch A	
	5	Batch A	Batch B	
	6	Batch B	Batch A	
Third	7	Batch A	Batch B	
	8	Batch B	Batch A	
	9	Batch A	Batch B	
Fourth	10	Batch B	Batch A	
	11	Batch A	Batch B	
	12	Batch B	Batch A	
Fifth	13	Batch A	Batch B	
	14	Batch A + Batch B		8-month industrial design project
	15	Batch A + Batch B		Both together to graduate

Students studying during the classroom term should have UG research component. It can start from Trimester 5. Additional 20 credits of research should be required for Honours degree.

15.1 Major in Chemical Engineering

15.2. Minor Degree (minimum 1; maximum 2)

1. Refineries, Petrochemical and Chemical Industries
2. Pharmaceuticals and Biotechnology
3. Polymers and Materials Industries
4. Energy and Renewable Resources
5. Processing Industry
6. Agrochemicals Industry
7. Speciality Chemicals Industry
8. Inorganic Chemicals and Semi-conductor Industry
9. Sustainable Process Design
10. Materials and Advanced Manufacturing
11. Water and Resource Management
12. Digitalization in Manufacturing
13. Atomic Energy and Nuclear Fuel Processing
14. Circular Economy, Recycle Engineering, Biorefineries
15. Waste to Wealth
16. Sustainability and Green Engineering
17. Energy Transition and Renewable Resources
18. Circular Economy and Material Recyclability
19. Digitalization, AI, and Machine Learning
20. Biotechnology and Bioengineering
21. Net Zero and Decarbonization
22. Advanced Materials and Nanotechnology
23. Process Intensification
24. Water and Natural Resource Management
25. Fundamentals of AI/ML, Deep Learning
26. AI and Process Control and Optimization
27. Big Data Analytics in Chemical Engineering
28. AI and Smart Manufacturing
29. Material Informatics
30. AI for Environmental Monitoring
31. Green Chemistry and Engineering
32. Sustainability Engineering
33. Agrochemical Engineering
34. Dyestuff and Colorants Technology
35. Fibres and Textile Processing Technology
36. Food Biotechnology
37. Food Engineering and Technology
38. Pharmaceutical Technology
39. Perfumery and Flavour Technology

40. Green Technology
41. Petrochemical Engineering
42. Polymer Engineering
43. Materials Engineering
44. Surface Coating Technology
45. Nanotechnology
46. Civil Engineering
47. Electrical Engineering
48. Electronics Engineering
49. Mechanical Engineering
50. Data Analytics
51. Chemical Technology Management
52. Process Safety and Risk Management
53. Supply Chain Management
54. Genetic Engineering

15.3 Programme Education Objectives

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

15.4 Programme Outcome

1. Chemical Engineers having sound knowledge of mathematics, sciences, engineering fundamentals
2. Chemical Engineers with knowledge of fundamentals and innovation to solve the problems related to energy, food, environment, healthcare, etc.
3. Chemical Engineers with ability to keep abreast with the scientific literature, new technologies and new developments
4. Chemical Engineers who can work on complex problems in team and multidisciplinary situations
5. Chemical Engineers who can help government, society and industry in managerial activities related to chemical and allied industries
6. Chemical Engineers who can help government, society and industry to do technology development related activities for chemical and allied industries

7. Chemical Engineers who can cater to the needs of chemical industry, research organizations and academic institutes
8. Chemical Engineers who can set-up their own ventures and generate employment
9. Chemical Engineers who can promote awareness in society about Chemical Engineering profession

15.5 Graduate Attributes

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

16.Syllabus Structure for Bachelor's Course

In India, specific nomenclature has been traditionally used for chemical engineering degree programs. For instance, the first two programs at Jadavpur and ICT Mumbai are titled B. Chem. Eng., B.E. (Chem. Eng.), and B. Tech. (Chem. Eng.). These titles should be preserved due to the strong brand value these institutes have built over several decades.

SEMESTER – I											
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs/Week**			**Marks for various Exams**				
				L	**T**	**P**	**C. A.**	**M.S.**	**E. S.**	**Total**	
CHT1251	Applied Chemistry	BSC	2	2	0	0	20	30	50	100	
CHP1252	Applied Chemistry Laboratory	BSC	2	0	0	4	50	0	50	100	
MAT1101	Applied Mathematics - I	BSC	4	3	1	0	20	30	50	100	
GET1123	Structural Mechanics	ESC	3	2	1	0	20	30	50	100	
GEP1124	Structural Mechanics Laboratory	ESC	1	0	0	2					
GET1125	Electrical Engineering and Electronics	ESC	2	1	1	0	20	30	50	100	
GEP1126	Electrical Engineering and Electronics Laboratory	ESC	2	0	0	4	50	0	50	100	
GEP1127	Engineering Graphics and Computer Aided Drafting (CAD)	VSEC	2	0	0	4	50	0	50	100	
HUP1110A	Communication Skills - English	AEC	2	0	0	4	50	0	50	100	
HUPXXXXA	OPEN Activity - Sports/ Fine arts/Yoga/ Music/NSS**	CCA	2	0	0	4					
	Total		**22**	**8**	**3**	**22**					

SEMESTER – II										
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs/week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
PYT1251	Applied Physics	BSC	2	2	0	0	20	30	50	100
PYP1252	Applied Physics Laboratory	BSC	2	0	0	4	50	0	50	100
MAT1102	Applied Mathematics - II	BSC	4	3	1	0	20	30	50	100
GET1128	Elements of Mechanical Engineering	ESC	4	3	1	0	20	30	50	100
CET1151	Introduction to Chemical Engineering	ESC	2	2	0	0	20	30	50	100
CEP1152	Material Balance and Energy Balance Calculations	PCC	2	0	0	4	50	0	50	100
CEP1153	Engineering Applications of Digital Computers	VSEC	2	0	0	4	50	0	50	100
HUTXXXZA	MOOC- Indian Knowledge System (NPTEL/SWAYAM - Introduction to Ancient Indian Technology)	IKS	2	2	0	0				
HUTXXXYA	OPEN Activity- Sports/ Fine Arts/Yoga/ Music/NSS**	CCA	2	0	0	4				
	Total		22	12	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.

SEMESTER – III										
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs /week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CET1154	Fluid Flow	PCC	2	1	1	0	20	30	50	100
CET1155	Heat Transfer	PCC	2	1	1	0	20	30	50	100
CET1156	Engineering Thermodynamics	PCC	2	1	1	0	20	30	50	100
CET1157	Process Safety	PCC	2	1	1	0	20	30	50	100
CEP1158	Chemical Engineering Laboratory - I	PCC	2	0	0	4	50	0	50	100
	MDM-I: From Sciences and/or any other Engineering / Humanities Discipline	MDM	2	2	0	0	20	30	50	100
	From Basic Sciences (Chemistry/ Physics/Biology / Maths / Humanities)	OE	4	2	1	2	20	30	50	100
HUP	Communication Skills – (Marathi / Hindi or Any other language will be chosen using MOOCS)	AEC	2	0	0	4	50	0	50	100
HUT1252	Basic Principles of Finance & Economics	Management	2	2	0	0	20	30	50	100
CET1159	Environmental Sciences	VEC	2	2	0	0	20	30	50	100
	Total		22	12	5	10				

SEMESTER – IV										
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs/week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CET1160	Chemical Engineering Operations	PCC	4	2	2	0	20	30	50	100
CET1161	Industrial Chemistry and Reaction Engineering	PCC	4	2	2	0	20	30	50	100
CET1162	Instrumentation and Process Dynamics	PCC	2	1	1	0	20	30	50	100
	MDM II: From Sciences and/or any other Engineering /Humanities Discipline	MDM	2	2	0	0	20	30	50	100
	From Basic Sciences (Chemistry/ Physics/ Biology / Maths) or Humanities	OE	2	2	0	0	20	30	50	100
CEP1163	Chemical Engineering Laboratory - II	VSEC	2	0	0	4				
HUT1253	Production Management	Management	2	2	0	0	20	30	50	100
	Digital Computation in Emerging Areas **(NPTEL course: Introduction To Industry 4.0 And Industrial Internet Of Things)**	VEC	2	0	0	4	50	0	50	100
	Community Projects#	Field Project	2	0	0	4				
	Total		22	11	5	12				

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.

SEMESTER – V											
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs /week**			**Marks for various Exams**				
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CET1165	Chemical Reaction Engineering	PCC	2	1	1	0	20	30	50	100
CET1166	Momentum Transfer	PCC	2	1	1	0	20	30	50	100
CET1167	Chemical Engineering Thermodynamics	PCC	4	3	1	0	20	30	50	100
CEP1168	Chemical Engineering Laboratory - III	PCC	2	0	0	4	50	0	50	100
CEP1169	Process Simulation Laboratory - I	PCC	2	0	0	4	50	0	50	100
	Chemical Engineering Elective - I Offered by Dept / NPTEL / MOOCS	PEC	4	3	1	0	20	30	50	100
	MDM III: From Sciences and/or any other Engineering / Humanities Discipline	MDM	4	3	1	0	20	30	50	100
	MOOCs- From Other Science Disciplines and Humanities	OE	2	2	0	0				
CET1170	Honors Course – I (Biochemical Engineering)	PCC	4	3	1	0	20	30	50	100
	Total		26	16	6	8				

SEMESTER – VI										
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs/week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CET1171	Multiphase Reaction Engineering	PCC	3	2	1	0	20	30	50	100
CET1172	Chemical Process Control	PCC	2	1	1	0	20	30	50	100
CET1173	Material Technology	PCC	2	2	0	0	20	30	50	100
CET1174	Separation Processes	PCC	3	2	1	0	20	30	50	100
CET1175	Heat Transfer Equipment Design	PCC	2	1	1	0	20	30	50	100
	Chemical Engineering Elective – II Offered by Dept / MOOCS	PEC	4	3	1	0	20	30	50	100
CET1176	Honours Course - II (Mathematical Methods and Optimization in Chemical Engineering)	PCC	4	2	0	4	20	30	50	100
	MDM IV: From Sciences and/or any other Engineering / Humanities Discipline	MDM	2	2	0	0	20	30	50	100
CEP1177	Process Simulation Laboratory - II	VSEC	2	0	0	4	50	0	50	100
CEP1178	Chemical Engineering Laboratory - IV	VSEC	2	0	0	4	50	0	50	100
	Total		26	15	5	12				

PECs;

Note: (1) Semester VI-PEC reduced from 8 to 4, VSEC and PCC increased by 2 each

SEMESTER – VII											
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs/week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CET1179	Chemical Process Development and Engineering	PCC	3	2	1	0	20	30	50	100
CET1180	Chemical Project Economics	PCC	2	2	0	0	20	30	50	100
	Chemical Engineering Elective – III (offered by Dept / MOOCS) (One of the elective can be CET1181 - Environmental Engineering and Chemical Process Safety)	PEC	3	2	1	0	20	30	50	100
GEP1138	Chemical Process Equipment Design and drawing	PCC	2	0	0	4	50	0	50	100
	Chemical Engineering Elective - IV Offered by Dept / MOOCS	PEC	2	2	0	0	20	30	50	100
CET1182	Honours Course – III (Refinery Science and Engineering)	PCC	3	2	1	0	20	30	50	100
	MDM V: From Sciences and/or any other Engineering /Humanities Discipline	MDM	2	2	0	0	20	30	50	100
CEP1183	Literature Review (Research Methodology - I)	RM-I	2	1	0	2	50	0	50	100
CET1184	Design and Analysis of Experiments (Research Methodology - II)	RM-II	2	1	0	2	20	30	50	100
CEP1185	Design Project – I	Project	4	0	0	8				
	Total		25	14	3	16				
SEMESTER – VIII (10 Weeks)										
Course Code	**Subjects**	**Course Type**	**Credits**	**Hrs /week**			**Marks for various Exams**			
				L	**T**	**P**	**C. A.**	**M. S.**	**E. S.**	**Total**
CEP1186	Design Project – II	PCC	4	0	0	12				
HUT1254	Industrial and Organizational Psychology	PCC	2	3	0	0	20	30	50	100
	Chemical Engineering Elective - V Offered by Dept / MOOCS	PEC	2	3	0	0	20	30	50	100
	MDM VI: From Sciences and/or any other Engineering /Humanities Discipline	MDM	2	3	0	0	20	30	50	100
CET1187	Honours Course – IV (Catalytic Science and Engineering)	PCC	4	4	2	0	20	30	50	100
CET1188	Honours Course – V (Statistical Thermodynamics)	PCC	3	3	2	0	20	30	50	100
	SEMESTER – VIII (12-16 Weeks)									
CEP1189		Internship/ On Job Training Project	12	0	0	0				
	Total		29	16	4	12				

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
VEC: Value Education Course: e.g. Understanding India, Environmental Science / Education / Digital and Tech solutions
RM: Research Methodology
CCA: Co-curricular activities: Health and wellness / Yoga / Sports / Cultural activities / NSS/NCC/Applied visual performing arts

16.2 Bachelor's Chemical Engineering or Chemical Technology Honour's Degree Programmes

The Bachelor's Chemical Engineering or Chemical Technology Honours Degree in chosen Major Engg./ Tech. Discipline with Multidisciplinary Minor (180-194 credits) enables students to take up five-six additional courses in the same Engg./ Tech. discipline of 18 to 20 credits distributed over semesters III to VIII. The decision regarding the mechanism of distribution of these 18-20 credits over semesters III to VIII, which are over and above the min.160-max.176 Credits prescribed for Four Year Multidisciplinary Bachelor's Degree in Engg./ Tech., will be taken by Academic Authorities of University/ Autonomous Engineering Colleges.

16.3 Bachelor' Chemical Engineering or Chemical Technology with Research Degree in chosen Major Engineering or Technology Programmes

Under Bachelor's Engg./ Tech. Honours with Research Degree in chosen Major Engg./ Tech. Discipline with Multidisciplinary Minor (180-194 credits), the students will work on a research project or dissertation for 18 credits in the fourth year in the respective Major Engg./ Tech. Discipline. 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/ Autonomous Engineering Colleges. These 18 Credits will be over and above the min.160-max.176 Credits prescribed for Four Year Multidisciplinary Bachelor's Degree in Engg./ Tech. Program.

16.4 Eligibility for taking Honors and/or Research

Eligibility for admission to the UG Bachelor's Degree with Double Minor/ Honors /Research as per UGC guidelines: Minimum CGPA/CPI of 7.5 or minimum 75% after Fourth semester for UG Bachelor's Degree with Honors and Minimum CGPA/CPI of 7.5 or minimum 75% after sixth semester for UG Bachelor's Degree with Research.

First Year (Semester ONE)

	Course Code: CHT1251	**Course Title: Applied Chemistry**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**0**	**0**
Course Outcomes (students will be able to…..)					
1	Understand reactions and chemistry of various aromatic compounds.				
2	Write simple mechanisms of aromatic reactions				
3	Describe the fundamental concepts related to spectroscopic, electrochemical and chromatographic analysis				
4	Differentiate the analytical methods based on advantages and limitations				
5					
List of Prerequisite Courses					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	**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**		
2	**Aromatic electrophilic substitution**: Activating and deactivating functional groups on aromatic compounds, resonating structures, reactions such as Halogenation, Nitration, Friedel Crafts alkylation and acylation, sulfonation, Diazotization and important reacts of arene diazonium salts. Dyes – Chromophore and auxochrome concept, Azo dyes		**12**		
3	**Aromatic compounds:** Problems associated with S_NAr reactions and how to overcome them. Mechanism for aromatic nucleophilic substitutions.		**4**		
4	**Spectroscopic methods:** general principles, UV-visible spectroscopy, fluorescence spectroscopy		**4**		
5	**Chromatographic methods:** general principles, Basic instrumentation, and typical applications of GC, HPLC		**6**		
6					
7					
List of Text Books					
1	Organic Chemistry, L.G. Wade Jr, Pearson Education				
2	Organic Chemistry, Paula Y. Bruice, Pearson Education				
3	Fundamentals of Analytical Chemistry by D. A. Skoog, D. M. West, F. James Holler and S. R. Crouch, Cengage Learning, 2014.				
4	Principles of Instrumental Analysis by D. A. Skoog, F. James Holler and S. R. Crouch, Cengage Learning, 2007				
List of Additional Reading Material / Reference Books					

	Course Code: CHP1252	Course Title: Applied Chemistry Laboratory	Credits = 2		
			L	T	P
	Semester: I	Total contact hours: 60	0	0	4

	Course Outcomes (students will be able to…..)	
1	Students will be able to list steps for identifying simple organic compounds.	
2	Students will be able to list some methods of separation of organic compounds	
3	List simple methods of chemical analysis	
4	Determination of physic chemical parameters using simple laboratory tools	
	List of Prerequisite Courses	
	Standard XII Chemistry	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	ORGANIC CHEMISTRY: a) Identification of an organic compound through elemental analysis, group detection, physical constants (m.p and b.p) and derivatisation. b) Separation and purification of binary mixtures of the type (1): water soluble-water insoluble, both water soluble, c) Separation and purification of binary mixtures of the type (2): liquid-liquid by distillation, dissociation –extraction, crystallization, etc	20
2	PHYSICAL CHEMISTRY: a) Determination of the dissociation constant of the weak electrolyte using conductometry b) Determination of the redox potential of $Fe(aq)3+Fe(aq)2+/$ system by potentiometric method c) Determination of energy of activation of the reaction	20
3	INORGANIC / ANALYTICAL CHEMSITRY: a) Determination of Fe(III) with EDTA by photometric titration b) Determination of the dissociation constant of the given weak polybasic acid by pH-metry c) Detection / quantitative determination of cations / anions in salts.	20
	List of Text Books	
1	Practical Organic Chemistry, by I.L. Finar	
2	Practical physical Chemistry – B.Viswanthan and P.S. Raghavan	
3	Practical physical Chemistry- Alexander Findlay	
4		
	List of Additional Reading Material / Reference Books	

	Course Code: MAT1101	Course Title: Applied Mathematics - I	Credits = 4		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
HSC Standard Mathematics					
List of Courses where this course will be prerequisite					
Applied Mathematics – II (MAT XXXX)					
Description of relevance of this course in the B. Chem. Engg. Program					
This is a basic Mathematics course. This knowledge will be required in almost all subjects later on. 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)			**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		
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	K1, K3, K4
CO2	Understand different techniques for evaluating single and multiple integrals and apply them compute surface and volume integrals.	K2, K3, 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.	K1, K2, K3
CO4	Understand the computational and geometrical concepts related to eigenvalues and eigenvectors and apply them to solve computational problems arising from chemical engineering	K1, K2, K3
CO5	Build mathematical models governed by differential equations to formulate Chemical Engineering problems and solve the equation using appropriate analytical techniques	K3, K4, K5, 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	K3, K4, K5
K1 – Remembering, K2 – Understanding, K3 – Applying, K4 – Analyzing, K5 – Evaluating, K6 – Creating		

	Course Code: GET1123	Course Title: Structural Mechanics	Credits = 3		
			L	**T**	**P**
	Semester: III	**Total contact hours: 32 Hrs**	**2**	**1**	**0**
List of Prerequisite Courses					
Maximum Marks : 100					
	Engineering Mathematics Fundamentals				
	Materials in Engineering				
List of Courses where this course will be prerequisite					
	Equipment Design and Drawing I				
	Equipment Design & Drawing II				
	Chemical Process Equipment				
	Material Technology				
Description of relevance of this course in the B. Chem. Engg. 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		
List of Text Books/ Reference Books					
	Engineering Mechanics Vol I Statics by B. N. Thadani, Publisher Wenall Book Corporation				
	Introduction to Mechanics of Solids by Egor Popov, Prentice Hall of India Pvt. Ltd				

	Mechanics of Materials by Ferdinand Beer and E. Russel Johnston, Tata McGraw Hill Publishing Co. Ltd.	
	Fundamentals of applied Mechanics by Dadhe, Jamdar and Walavalkar, Sarita Prakashan Pune	
	Engineering Mechanics by S. Timoshenko and D. H. Young, McGraw Hill Publications	
	Strength of Materials by Ferdinand Singer and Andrew Pytel, Harper Colins Publishers	
Course Outcomes (students will be able to…..)		
1	Understand the use of basic concepts of Resolution and composition of forces.	CO 1
2	Analysis of the beams, truss or any engineering component by applying conditions of equilibrium.	CO 2
3	Understand the advantages and disadvantages of various geometric sections used in engineering design.	CO 3
4	Understand the different stresses and strains occurring in components of structure various standard loadings and in case of any complicated loading.	CO 4
5	Determination of shear stress, bending stresses in the beams with simple and complex loading.	CO 5
6	Understand how to calculate the deformations such as axial, normal deflections under different loading conditions.	CO 6

	Course Code: GEP1124	Course Title: Structural Mechanics Laboratory	Credits = 1		
			L	**T**	**P**
	Semester: I	**Total contact hours:30**	**0**	**0**	**2**

List of Prerequisite Courses		
	XIIth Standard Physics, Mathematics, Applied Mathematics I and II, Structural Mechanics	
List of Courses where this course will be prerequisite		
	Equipment design and Drawing I and II, Home Paper I and II	
Description of relevance of this course in the B. Chem. Engg. Program		
This subject will help students to understand use of basics of Applied Mechanics and Strength of Materials. In engineering equipment which different types of forces are to be considered and how to quantify them. What are different conditions of equilibrium and how to apply them analyse the problems. Importance of centre 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**
	Suitable number of experiments from the above list will be performed (Minimum 5): 1. To study simple lifting machine and determine Law of Machine for (Screw Jack and Differential wheel and axle). 2. To study graphical methods of analysis. 3. To study the Universal testing machine and tests. (Demonstration) 4. To study Non-destructive testing methods in Engineering 5. Demonstration of Smith Hammer test, Ultrasonic pulse velocity test 6. To study corrosion of reinforcement. (Demonstration) 7. To study properties of cement composites and its applications. 8. To study effect of performance enhancing admixtures and additives for cement composites. 9. To study methods of manufacturing for Fibre Reinforced Polymer Composites 10. To study various materials used for flooring. 11. To study various materials used for Pipes for different engineering applications.	
List of Textbooks/ Reference Books		
	Engineering Mechanics Vol I Statics by B. N. Thadani, Publisher Wenall Book Corporation	
	Introduction to Mechanics of Solids by Egor Popov, Prentice Hall of India Pvt. Ltd	
	Mechanics of Materials by Ferdinand Beer and E. Russel Johnston, Tata McGraw Hill	
	Fundamentals of applied Mechanics by Dadhe, Jamdar and Walavalkar, Sarita Prakashan Pune	
	Engineering Mechanics by S. Timoshenko and D. H. Young, McGraw Hill Publications	
	Strength of Materials by Ferdinand Singer and Andrew Pytel, Harper Colins Publishers	
Course Outcomes (students will be able to…..)		
	Further understanding of the concepts in the Theory course of Structural Mechanics	

	Course Code: GEP1126	**Course Title: Electrical Engineering and Electronics Laboratory**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	XIIth Standard Mathematics and Physics courses, Applied Physics I, Electrical Engg and Elctronics				
List of Courses where this course will be prerequisite					
	Chemical Process Control				
Description of relevance of this course in the B. Chem. Engg. Program					
Students will get an insight to the importance of Electrical Energy in Chemical Plants. The students will understand the basics of electricity, selection of different 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**		
	Suitable no. of experiments related the following concepts will be conducted: **Introduction to various Instruments and components in Electrical Engineering and Electronics** **Electrical Engineering**: Verification of Network Theorems Study of RLC circuits Load test on transformer Load test on induction motor (demo) Study of 3 phase circuits **Electronics:** Study of half wave, full wave rectifier circuits Study of input and output characteristics of a transistor. Study of operational amplifier circuits Study of sensors and transducers				
List of Textbooks/ Reference Books					
	Electrical Engineering Fundamentals by Vincent Deltoro				
	Electronic devices and circuits by Boylstead, Nashelsky				
	Electrical Machines by Nagrath, Kothari				
	Electrical Machines by P.S. Bhimbra				
	Electrical Technology by B.L.Theraja, A.K.Theraja vol I,II,IV				
Course Outcomes (students will be able to…..)					
1	Understand the basic concepts of D.C., single phase and three phase AC supply and circuits Solve basic electrical circuit problems				
2	Understand the basic concepts of transformers and motors used as various industrial drives.				
3	Understand the basic concepts of electronic devices and their applications in power supplies, amplification and instrumentation				
4	Understand the basic concepts of Data acquisition, signal conditioning				

	Course Code: GET1125	**Course Title: Electrical Engineering and Electronics**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics courses, Applied Physics - II				
List of Courses where this course will be prerequisite					
	Chemical Process Control, Energy Engineering,				
Description of relevance of this course in the B. Chem. Engg. Program					
Students will get an insight to the importance of Electrical Energy in Chemical Plants . The students will understand the basics of electricity, selection of different 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	**Fundamentals of DC Circuits** Voltage and Current Sources, Basic Laws, Network Theorems, Superposition Theorem and Thevenin's Theorem,		4		
2	**AC Fundamentals:** A.C. through resistance, inductance and capacitance, simple RL, RC and RLC circuits. Power, power factor		4		
3	**Three Phase Systems**: Three phase system of emfs and currents, Star and Delta connections, Three phase power		3		
4	**Single phase transformers**: Principle of working, Efficiency, regulation.		3		
5	**Electrical drives**: Basic concepts of different types of Electrical motors as drives, Their suitability for various applications.		2		
6	**Regulated power supplies**, Diodes as rectifiers, Half wave and Full wave rectifier, Filters and Regulators		3		
7	**Bipolar junction transistors**: Different configurations, Characteristics, Concept of basic amplifier circuits, Amplifier gain, Transistor as switch		3		
8	**Introduction to Integrated circuits:** Basic concepts of ICs		2		
9	**Introduction to data acquisition and signal conditioning,** Basic concept and Block diagram, Concept of conversion of physical quantity to electrical signal, signal conditioning, Introduction to A/D and D/A converters		3		
10	**Introduction to instrumentation amplifiers and their applications** Operational Amplifier – Notation, Pin diagram, Differential and common mode gain, CMRR, Applications as non-inverting, inverting, summing, differential amplifiers, integrator, differentiator,		3		
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 Technology by B.L.Theraja, A.K.Theraja vol I,II,IV				
Course Outcomes (students will be able to….)					
1	Understand the basic concepts of D.C., single phase and three phase AC supply and circuits Solve basic electrical circuit problems				
2	Understand the basic concepts of transformers and motors used as various industrial drives.				
3	Understand the basic concepts of electronic devices and their applications in power supplies, amplification and instrumentation				
4	Understand the basic concepts of Data acquisition, signal conditioning				

Course Code: GEP1127	**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, Equipment Design and Drawing, Home Paper – II, Structural Mechanics	
	Description of relevance of this course in the B. Chem. Engg. 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 very common to all engineers and technologists. These and many other processes require machines and equipment. One should be familiar with the design, manufacturing, working, maintenance of such machines and equipment. The subject of "drawing" is a medium through which, one can learn all such matter, because the "drawings" are used to represent objects and processes on the 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 on in the professional career.	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Orthographic projections:** 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:** Need for the drawing sectional views, concept of sectioning and section lines, sectional drawings of different solids and machine components, auxiliary planes and views. 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:** 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, Concept of surface development of respective solids, Development of surfaces of cylinders, prisms, pyramids, cones etc. Interpenetration of two or more solids and their respective drawings	12
4	**Introduction to Computer Aided Drafting (CAD):** Basic introduction to CAD softwares, 2D and 3D drawings, drawing modification and dimensioning, different components of an engineering drawing in the industry.	08
5	**Isometric projections using CAD:** Concept of isometric views, isometric projections and isometric scale, Iso metric projections of different solids and machine components using CAD softwares.	08
6	**Assembly drawing using CAD:** Basics of Assembly drawing, preparation of 3d components and assembling on CAD softwares, labelling and table creation for bill of materials	12
	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…..)	
1	Read Drawing	
2	Can understand different views.	

3	Can draw 3d drawing on a CAD software	

	Course Code: HUT1110A	**Course Title:** **COMMUNICATION SKILLS - ENGLISH**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours:30**	**0**	**0**	**4**
Course Outcomes (students will be able to…..)					
1	Student would be able to illustrate the 5 step communication process				
2	Student would be able to explain the end goal of communication				
3	Student would be able to explain barriers to clear communication				
4	Student would be able to articulate the role of visual communication within society, and implement the creative process to express himself/herself.				
5	Student would be able to identify the most relevant textbooks, reviews, papers and journals				
List of Prerequisite Courses					
	BASIC ENGLISH LANGUAGE OF THE XII GRADE LEVEL				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Communication as a way of life Process of communication and its elements Functions of communication and importance in future careers Essentials of good communication		6		
2	The communication cycle The 5 step communication cycle: Idea formation Message encoding Message transmission Decoding Feedback		4		
3	Factors affecting effective communication Planning for effective communication Modes of communication		3		
4	Non verbal communication Gestures Facial expressions Posture and movement Paralinguistics Eye contact Image management		4		
5	Presentation skills What makes good presentation Prsenting the message Presenting oneself Visual Communication		8		
6	Introduction to research study Introduction to databases Introduction to citation and referencing styles How to conduct literature review Preparation of a report based on literature review		5		
List of Text Books					
	THE SCIENCE OF EFFECTIVE COMMUNICATION: Improve Your Social Skills and Small Talk, Develop Charisma and Learn How to Talk to Anyone- Ian Tuhovsky				

	The Quick and Easy Way to Effective Speaking- Dale Carnegie	
List of Additional Reading Material / Reference Books		
	The Hindu Businessline	
	National Newspapers' editorials	

First Year (Second Semester)

	Course Code: PYT1251	**Course Title: Applied Physics**	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**0**	**0**
Course Outcomes (students will be able to…)					
1	Assign Miller indices to various crystallographic planes and directions in a crystal lattice, thereby understand periodicity in the crystal lattice.				
2	Analyze a given x-ray diffraction pattern to deduce the crystal structure of the material and calculate the values of the basic structural parameters.				
3	Classify solids, and in turn semiconductors, based on electron occupancy and calculate basic quantities related to charge transport in them.				
4	Use basic vector calculus to describe the laws of electrostatics and magnetostatics.				
5	Apply the laws of electrostatics to dielectric materials.				
6	Understand the microscopic origins of magnetism in materials through semi-classical theories.				
List of Prerequisite Courses					
1	Standard XI and XII Physics course				
2	Standard XII Chemistry course				
List of Courses where this course will be prerequisite					
1	Applied Physics Laboratory (Sem-II)				
2	Materials Technology (Sem-VI)				
3	Materials Science Minor program courses (Sem-III, IV, V, VI, VII, VIII)				
4	Open Elective courses from Physics Department (Sem-II, IV, V)				
Description of relevance of this course in the B. Chem.Engg. 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					
	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		
	Crystallographic planes and directions: concept of Miller indices and its determination, examples; calculation of inter-planar spacing in terms of Miller indices.		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		
	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					
	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		
	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		

	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

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 Code: PYP1252	**Course Title: Applied Physics Laboratory**	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**-**	**-**	**4**
Course Outcomes (students will be able to…)					
1	Independently set up, handle, and use basic setups to measure and obtain various physical quantities.				
2	Use basic instruments like vernier-caliper, screw-gauge, travelling microscope, thermometer, etc. to make accurate measurements.				
3	Correlate and use directly measured quantities to obtain the relevant parameters through appropriate formulae, calculations, and/or graphical plotting, thereby understand the measurement principle involved in the experimental setups.				
4	Preliminarily treat the obtained datasets statistically to obtain errors in the experiments.				
List of Prerequisite Courses					
1	Standard XI and XII Physics course				
2	Applied Physics (theory) in tandem				
Description of relevance of this course in the B. Chem.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)				
	Determination of Co-efficient of Viscosity by Poiseuille's method				
	Thermistor characteristics: Determination of Bandgap of a semiconductor				
	Determination of compressibility of liquids using an Ultrasonic Interferometer				
	Measurement of thermal conductivity of a solid: Lee's disc method				
	Photoelectric effect: Determination of h/e				
	Hall effect-I (sample current variation) Determination of carrier type and concentration in a semiconductor				
	Hall effect-II (magnetic field variation) Determination of carrier type and concentration in a semiconductor				
	Newton's rings: Determination of wavelength of light				
	Laser Diffraction: Determination of particle size				
	Studying variation of compressiblity of liquid as function of temperature				
	Estimating resisitivity of semiconductor using four probe method				
	Determination of magnetic susceptibility of paramagnetic liquid using Quincke's method				
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 Code:	**Course Title: Applied Mathematics – II**	**Credits = 4**

			L	T	P
	MAT1102		**L**	**T**	**P**
	Semester: II	**Total contact hours: 60**	**3**	**1**	**0**

List of Prerequisite Courses	
HSC Standard Mathematics, Applied Mathematics – I (MAT XXXX)	
List of Courses where this course will be prerequisite	
Description of relevance of this course in the B. Chem. Engg. Program	
This is a basic Mathematics course. This knowledge will be required in almost all subjects later on. 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)	**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

	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-Wiely, 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 analyze various engineering problems and make inference about the system	K2, K3, 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	K2, K3, K4,
CO3	classify higher of partial differential equation and solve parabolic equation using separation of variables.	K1, K2, K3
CO4	Understand the principles of various numerical approximation techniques and apply them to solve system of linear equations and nonlinear algebraic equations	K3, K4
CO5	Approximate appropriate mathematical functions from equal an unequally spaced data and perform integration using various numerical methods	K2, K3, 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	K3, K4, K5
K1 – Remembering, K2 – Understanding, K3 – Applying, K4 – Analyzing, K5 – Evaluating, K6 – Creating		

	Course Code: GET1128	Course Title: Elements of Mechanical Engineering	Credits = 4		
			L	T	P
	Semester: II	Total contact hours: 60	3	1	0
List of Prerequisite Courses					
	Chemical Engineering Thermodynamics-I, Material and Energy Balance Calculations, Applied Physics I and II, Applied Mathematics – I and II				
List of Courses where this course will be prerequisite					
	Process Dev. and Engg., Home Paper I and II, Env. Eng. And Proc. Safety, Chem. Project Engg and Eco.,				
Description of relevance of this course in the B. Chem. Engg. 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, Different types of Steam Nozzles, Variation of area, velocity, and specific volume		2		
7	Elements of Steam condenser, various 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. Vapour compression refrigeration cycle. Methods of increasing COP of VCRS. Vapour 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		
List of Textbooks/ Reference Books					
	1. Thermodynamics by P.K. Nag 2. Power plant by Morse 3. Heat Engines by P.L. Balani 4. Hydraulic Machines by Jagdish Lal 5. Refrigeration and air conditioning by C.P. Arora 6. Theory of Machines by Rattan. S.S 7. Gas turbine theory by HiH Saravanamutoo.				
Course Outcomes (students will be able to….)					

1	Understand first law and second law of thermodynamics with its implications. (K2)	
2	Describe the properties of steam and working of various steam boilers (K2)	
3	Explain the working principles of power developing systems such as steam turbines, gas turbines and internal combustion engines. (K2)	
4	Describe the working principle of vapour compression and vapour absorption refrigeration systems. (K2)	
5	Discuss different types of power transmission systems and their typical applications. (K2)	
6	Explain the working principles of power absorbing devices such as pumps and compressors. (K2)	

	Course Code: CET1151	**Course Title: Introduction to Chemical Engineering**	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**0**	**0**
Course Outcomes (students will be able to…..)					
1	Student would be able to understand the chemical sector and role of chemical engineers				
2	Student would be able to understand and predict the growth of various chemical sectors				
3	Student would be able to understand the sequence of processing steps in chemical industry				
List of Prerequisite Courses					
	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) Speciality 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		
List of Text Books					
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) Publisher: PHI LEARNING PVT. LTD-NEW DELHI				
3	Chemical Engineering: An Introduction (Cambri…(Paperback) by Morton Denn (Cambridge University Press)				
List of Additional Reading Material / Reference Books					

	Course Code: CEP1152	**Course Title: Material Balance and Energy Balance Calculations**	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60 hrs**	**0**	**0**	**4**
Course Outcomes (students will be able to…..)					
1	Students will be able to convert units of simple quantities from one set of units to another set of units				
2	Students will be able to calculate quantities and /or compositions, energy usages, etc. in various processes and process equipment such as reactors, filters, dryers, etc.				
List of Prerequisite Courses					
	XIIth Standard Mathematics, Chemistry, Physics, Applied Mathematics – I, Organic Chemistry – I, Applied Physics – I, Analytical Chemistry,				
	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, Behaviour 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		
List of Text 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.				
List of Additional Reading Material / Reference Books					

	Course Code: CEP1153	**Course Title: Engineering Applications of Digital Computers**	**Credits = 2**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**0**	**0**	**4**

	Course Outcomes (students will be able to…..)	
1	Students would be able to carry out Spreadsheet calculations for Chemical Engineering problems	
2	Students would be able to develop programming logic and code it in software	
	List of Prerequisite Courses	
	XIIth Standard Mathematics and Physics Courses, Applied Mathematics – I and II	
	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
	List of Text Books	
	Microsoft Office help	
	Python: The Complete Reference, Martin Brown	
	Unit Operations of Chemical Engineering, McCabe, Smith and Harriott (for case studies)	
	List of Additional Reading Material / Reference Books	

Second Year (Semester THREE)

	Course Code: CET1154	**Course Title: Fluid Flow**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**
	Course Outcomes (students will be able to…..)				
1	Calculate pressure drop in pipelines and equipment for different situations such as single and two phase flow, fixed and fluidized beds				
2	Calculate forces on particles and terminal velocities of particles				
3	Design pumps and piping systems for simple situations				
	List of Prerequisite Courses				
	XIIth Standard Physics and Mathematics, Applied Physics – I and II, Applied Mathematics – I and II				
	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	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 Fluidised Beds, Flow through porous media		6		
	List of Text Books				
	Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N.				
	Fluid Mechanics, Kundu Pijush K.				
	Fluid Mechanics, F. W. White				
	Unit Operations of Chemical Engineering, McCabe, Smith and Harriott				
	List of Additional Reading Material / Reference Books				

	Course Code: CET1155	**Course Title: Heat Transfer**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Momentum and Mass transfer, Applied Mathematics I and II, Material and Energy Balance Calculations				
List of Courses where this course will be prerequisite					
	Chemical Reaction engineering, Multiphase Reactor Engineering, Process Development and Engineering, Home Paper I and II, Env. Engg. and Process Safety, etc.				
Description of relevance of this course in the B. Chem. Engg. 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 fluidised 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		
List of Text Books/ Reference Books					
	Process Heat Transfer, Kern D.Q.				
	Heat Exchangers, Kakac S., Bergles A.E., Mayinger F				
	Process Heat Transfer, G. Hewitt				
Course Outcomes (students will be able to…..)					
1	Calculate temperature profiles in a slab at steady state				
2	Calculate heat transfer coefficients for free and forced convection in different heat transfer equipment				
3	Rate performance of heat exchanger using NTU-epsilon method				
4	Design agitated vessel for heat transfer controlled process				

	Course Code: CET1156	**Course Title: Engineering Thermodynamics**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Mechanical Engineering Course (ESC) from first year syllabus				
Description of relevance of this course in the B. Chem. Engg. 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 and 1st Law of Thermodynamics to open processes Concept of Equilibrium: Entropy and Gibbs-Free Energy		2		
2	Need for Entropy and Gibbs Energy, Exergy, Industrial Applications of Second Law of Thermodynamics using Ideal Gas Law and Thermodynamic Property Charts and Tables		4		
3	Equations for Property Changes, Maxwell Relations and the need for Equations of State. Residual Properties, Industrial Applications using Equations of State		4		
4	Phase Equilibria for Pure Fluids, Fugacity and Fugacity Coefficient		4		
5	Thermodynamic Properties of Mixtures, Gibbs Duhem Equation		4		
6	Phase Equilibrium in Mixtures, Fugacity and Fugacity Coefficient in Mixtures		4		
7	Vapor – Liquid Equilibria in Ideal Mixtures, T-x-y and P-x-y diagrams, Bubble point and Dew point calculations for Ideal mixtures		4		
8	Non-Ideal Mixtures, Excess Properties and activity coefficients		4		
List of Text Books/ Reference Books					
	Introduction to Chemical Engineering Thermodynamics: Smith, van Ness, Abbott				
	Chemical, Biochemical and Engineering Thermodynamics: S. I. Sandler				
	Reference Books				
	Properties of Gases and Liquids: Reid, Prausnitz, Pauling				
Course Outcomes (students will be able to…..)					
1	Calculate Enthalpy, Entropy and Gibbs energy changes in fluids with changes in temperature and pressure (K3)				
2	Analyse process efficiencies using entropy or exergy concepts (K4)				
3	Calculate saturation temperature and pressure relationship for pure fluids from equations of state (K3)				
4	Analyze vapor – liquid equilibria in ideal mixtures (K4)				

	Course Code: CET1157	**Course Title: Process Safety**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**

Course Outcomes (students will be able to…..)		
1	identify hazards in a given process and assess the same and provide solutions for operating safely.	
2	specify safety requirements for storage and handling of a given chemical.	
List of Prerequisite Courses		
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Safety management in chemical industry (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 (a) Flammable and combustible liquids (b) Storage and handling of hazardous chemicals (c) Norms for safe handling of chemicals at workplace (d) Safety during transportation of hazardous substances	10
3	Basics of laboratory safety (a) MSDS and personal protective equipment (b) Electrical safety (c) Fire safety (d) Machine safety (e) Cylinder safety (f) Bio safety	10
List of Text Books		
	Chemical Process Safety: Fundamentals with Applications – Daniel A. CROWL and Joseph F. LOUVAR	
	Guidelines for Process Safety Management, Environment, Safety, Health, and Quality – Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)	
	Chemical Process Safety Learning from Case Histories – Roy E. SANDERS	
	Guidelines for Process Safety Documentation – Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)	
List of Additional Reading Material / Reference Books		

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code:
CEP1158</td><td rowspan="2">Course Title: Chemical Engineering Laboratory - I</td><td colspan="3">Credits = 2</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: III</td><td>Total contact hours: 60</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>1</td><td colspan="2">Student would be able to Learn to experimentally verify various theoretical principles</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="2">Student would be able to Visualize practical implementation of basic Chemical Engineering principles</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Student would be able to Develop experimental skills</td><td colspan="3"></td></tr>
<tr><td>4</td><td colspan="2">Student would be able to Connect classroom teaching with the laboratory practicals</td><td colspan="3"></td></tr>
<tr><td>5</td><td colspan="2">Student would be able to Improve understanding about safety in the laboratory</td><td colspan="3"></td></tr>
<tr><td colspan="6">List of Prerequisite Courses</td></tr>
<tr><td></td><td colspan="2">Introduction to Chemical Engineering, Material Balance and Energy Balance Calculations, Fluid Flow, Heat Transfer, Engineering Thermodynamics, Mathematics I, Mathematics II, Applied Physics, Applied Chemistry</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td>1</td><td colspan="2">8-10 Experiments on Fluid Flow</td><td colspan="3">40</td></tr>
<tr><td>2</td><td colspan="2">2-3 Experiments on Heat Transfer</td><td colspan="3">10</td></tr>
<tr><td>3</td><td colspan="2">2-3 Experiments on Thermodynamics</td><td colspan="3">10</td></tr>
<tr><td colspan="6">List of Text Books</td></tr>
<tr><td>1</td><td colspan="2">McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="2">Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical Engineering design, 1996.</td><td colspan="3"></td></tr>
<tr><td>4</td><td colspan="2">Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007.</td><td colspan="3"></td></tr>
<tr><td colspan="6">List of Additional Reading Material / Reference Books</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
</table>

	Course Code: **HUT1252**	**Course Title:** **Basic Principles of Finance and Economics**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**2**	**0**	**0**

Course Outcomes (students will be able to…..)		
1	Students will be able to know and apply accounting and finance theory.	
2	Students will be able to understand the mechanics of preparation of financial statements, their analysis and interpretation	
3	Students will be able to explain basic economic terms, concepts, and theories	
4	Students will be able to identify key macroeconomic indicators	
List of Prerequisite Courses		
	MATHS-1 AND MATHS -2 OF FIRST YEAR COURSEWORK	
List of Courses where this course will be prerequisite		
	PROJECT ECONOMICS **FUNDAMENTALS OF MARKETING MANAGEMENT AND MARKET RESEARCH**	
Description of relevance of this course in the BACHELOR'S Program		
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	INTRODUCTION Explaining the Economy The Supply and Demand Model Using the Supply and Demand Model	3
2	THE COMPETITIVE EQUILIBRIUM MODEL Deriving Demand Deriving Supply Market Equilibrium and Efficiency	5
3	DEVIATIONS FROM COMPETITION Monopoly and Market Power Between Monopoly and Competition Antitrust Policy and Regulation	5
4	MACRO FACTS AND MEASURES Getting Started with Macroeconomic Ideas Measuring Production, Income and Spending of Nations	5
5	ACCOUNTING TRANSACTIONS Journal entries Debit credit rules Compound journal entry Journal and ledger Rules of posting entries Trial balance	5
6	CAPITAL AND REVENUE	5

	Income and expenditure Expired costs and income Final accounts Manufacturing accounts Trading accounts Profit and Loss account Suspense account Balance sheet	
7	CONCEPT OF DEPRECIATION	2
List of Textbooks		
	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		
	Basic Finance for Nonfinancial Managers: A Guide to Finance and Accounting Principles for Nonfinancial Managers- Kendrick Fernandez Microeconomic Theory: Basic Principles and Extensions- Walter Nicholson and Christopher Snyder Macroeconomics(10e) Part of: Pearson Series in Economics (23 books) - by Froyen	

	Course Code: CET1159	**Course Title: Environmental Sciences**	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**2**	**0**	**0**
Course Outcomes (students will be able to…..)					
1	Describe the methods of industrial effluent treatment				
2	apply the learning for selection and implementation of appropriate waste management technique for sustainable development				
List of Prerequisite Courses					
	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		
List of Text 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				
List of Additional Reading Material / Reference Books					

Second Year (Semester FOUR)

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: CET1160</td><td rowspan="2">Course Title: Chemical Engineering Operations</td><td colspan="3">Credits = 4</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: IV</td><td>Total contact hours:60</td><td>2</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">List of Prerequisite Courses</td></tr>
<tr><td colspan="2"></td><td colspan="1">Material & Energy Balance Calculations, Physical Cheiistry, Organic Chemistry-I and II, Chem. Eng. Thermodynamics-I, Momentum and Mass Transfer</td><td colspan="3"></td></tr>
<tr><td colspan="6">List of Courses where this course will be prerequisite</td></tr>
<tr><td colspan="2"></td><td>This is a basic Chem Engg. course. It is required in almost all the courses, such as, Separation Processes, Chemical Engineering Laboratory I, II and III, Process Simulation Lab – I and II, Home Paper I and II, etc.</td><td colspan="3"></td></tr>
<tr><td colspan="6">Description of relevance of this course in the B. Chem. Engg. Program</td></tr>
<tr><td colspan="6">This is a basic Chem Engg. course. The principles learnt in this course are required in almost all the courses and throughout the professional career of Chemical Engineer</td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td>1</td><td colspan="2">Introduction to Unit Operations and Chemical Engineering Processes, Introduction to mass transfer: Concepts of Convective and diffusive transport</td><td colspan="3">4</td></tr>
<tr><td>2</td><td colspan="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</td><td colspan="3">12</td></tr>
<tr><td>3</td><td colspan="2">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</td><td colspan="3">12</td></tr>
<tr><td>4</td><td colspan="2">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</td><td colspan="3">10</td></tr>
<tr><td>5</td><td colspan="2">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</td><td colspan="3">8</td></tr>
<tr><td>6</td><td colspan="2">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</td><td colspan="3">10</td></tr>
<tr><td>7</td><td colspan="2">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</td><td colspan="3">4</td></tr>
<tr><td colspan="6">List of Text Books/ Reference Books</td></tr>
<tr><td>1</td><td colspan="2">Richardson, J.F., Coulson, J.M., Harker, J.H., Backhurst, J.R., 2002. Chemical engineering: Particle technology and separation processes. Butterworth-Heinemann, Woburn, MA.</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="2">Seader, J.D., Henley, E.J., 2005. Separation Process Principles, 2 ed. Wiley, Hoboken, N.J.</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Svarovsky, L., 2000. Solid-Liquid Separation. Butterworth-Heinemann, Woburn, MA.</td><td colspan="3"></td></tr>
<tr><td>4</td><td colspan="2">McCabe, W., Smith, J., Harriott, P., 2004. Unit Operations of Chemical Engineering, 7 ed. McGraw-Hill Science/Engineering/Math, Boston.</td><td colspan="3"></td></tr>
</table>

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…..)	
1	Know the significance and usage of different particulate characterization parameters, and equipment to estimate them	
2	Describe Size reduction energy requirements, estimate performance of equipment, selection and sizing of equipment	
3	Analyze filtration data and select systems based on requirements, estimate filtration area for given requirements, understand filter aids and their usage	
4	Draw T-y-x diagrams, and y-x diagrams, operating lines, feed line, bubble point, dew point calculations, ternary phase diagrams, partition coefficient	
5	Describe two common modes of drying, industrial drying equipment	
6	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	

	Course Code: CET1161	**Course Title:** Industrial Chemistry and Reaction Engineering	**Credits = 4**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**2**	**2**	**0**

	Course Outcomes (students will be able to…..)	
1	Design chemical reactors optimally, using minimum amount of data	
2	design experiments in a judicious way to get the required data, if not available	
3	Increase capacity and/or selectivity and/or safety by improving/changing the reactor type/sequence and/or operating conditions	
4	Draw process flow diagrams/process block diagrams for the manufacture of various chemicals from process description	
5	List out various alternatives for carrying out a particular process and provide recommendations for the best choice	
6	List Principles of combustion systems for solid, liquid and gaseous fuel	
	List of Prerequisite Courses	
	Physical Chemistry, Material & Energy Balance Calculations, Applied Mathematics I and II, Momentum and Mass Transfer, Chem Engg Thermodynamics I and II	
	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
	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	
5	Heterogeneous Reactions, Vol. I and II – L. K. Doraiswamy, M. M. Sharma	
6	Encyclopedia of Chemical Technology, Kirk-Othmer	
7	Ulmann's Encyclopedia of Industrial Chemistry	
8	Industrial Organic Chemistry, Weissermel & Arpe	
9	Chemical Process Industries, Shreve B. Austin	
10	Chemical Process Technology, Moulijn, M. and van Dippen	
11	Dryden's Outlines of Chemical Technology	
12	Elements of Fuels, Furnaces and Refractories, O.P. Gupta	
13	Fuels handbook, Johnson	
	List of Additional Reading Material / Reference Books	

	Course Code: CET1162	**Course Title: Instrumentation and Process Dynamics**	**Credits = 2**		
			L	**T**	**P**
	Semester:	**Total contact hours: 30**	**1**	**1**	

Course Outcomes (students will be able to…..)		
1	To identify appropriate instrument for measurement of process variables	
2	To estimate time variant nature of process	
3	To classify nature of the system as first order, second order, etc,	
4	To estimate response of the system when subjected to change	
5	To understand behavior of combined systems	
List of Prerequisite Courses		
	Maths-I: Laplace Transform to solve differential equations, Linear Algebra	
	Physics-I	
	Fluid Flow & Heat Transfer	
	General Chemistry	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Instrumentation for measurement of temperature, flow, pressure, level, concentration. Basic underlying principles and physical construction of instruments,	6
2	Precision, Sensitivity, accuracy and error analysis of measurements, Transduces, Transmission of signals, Drift	2
3	Unsteady mass and energy balances of system, dynamic equations	2
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	6
5	Combination of systems and their response to input changes, Open Loop response	2
6	Overview of dynamic model equations of typical Chemical Engineering operations, such as level in a tank, temperature in a heated tank, CSTR, distillation column, Distributed parameter systems, packed column, Heat exchanger	6
7	To design a simple control system of first order and second order nature, e.g. P, PI and PID	4
8	Electronics for control systems: Distributed control system, Programmable Logic Controllers, SCADA, HMI	2
List of Text Books		
	Instrumentation, Eckman	
	Chemical Process Control- George Stepheanopoulous	
List of Additional Reading Material / Reference Books		

	Course Code: CEP1163	**Course Title: Chemical Engineering Laboratory - II**	**Credits = 2**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**0**	**0**	**4**

Course Outcomes (students will be able to…..)		
1	Student would be able to Learn to experimentally implement various theoretical principles	
2	Student would be able to Utilize the Chemical Engineering equipment to generate experimental data	
3	Student would be able to Calculate experimental results	
4	Student would be able to Improve ability to write laboratory reports	
5	Student would be able to Improve ability for oral communication	
List of Prerequisite Courses		
	Material Balance and Energy Balance Calculations, Fluid Flow, Heat Transfer, Engineering Thermodynamics, Mathematics I and II, Chemical Engineering Operations, Industrial Chemistry and Reaction Engineering, Instrumentation and Process Dynamics	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	1-2 Experiments on Fluid Dynamics	6
2	4-6 Experiments on Heat Transfer	18
3	1-2 Experiments on Reaction Engineering	6
4	6-8 Experiments on Chemical Engineering Operations	24
5	1-2 Experiments on Instrumentation	6
List of Text 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.	
List of Additional Reading Material / Reference Books		

	Course Code: HUT1253	**Course Title: Production Management**	**Credits = 2**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 30**	**2**	**0**	**0**

	Course Outcomes (students will be able to…..)	
1	Student would be able to gain knowledge about managing production processes.	
2	Student would be able to explain the importance, functions and productivity of the conversion process	
3	Student would be able to gain knowledge about various productivity techniques	
	List of Prerequisite Courses	
	NONE	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	The production function Operation concept of production Production as the conversion process Productivity of conversion process Components of production function-Planning, organising and controlling	6
2	Manufacturing systems Factors influencing choice of manufacturing system Classification of manufacturing systems Jobbing production Batch production Mass or flow production	8
3	Facilities location Factors governing plant location Economic survey of site selection Urban, sub-urban, rural site location	6
4	Productivity techniques Kaizen Kanban JIT 5S Poka yoke Six sigma	5
5	Gantt chart for production planning and control	5
	List of Text Books	
	Modern Production / Operations Management, (8e)- Buffa and Sarin Operations Management,12e-Jay Heizer, Barry Render, et al.	
	List of Additional Reading Material / Reference Books	
	OPERATIONS MANAGEMENT 13TH EDITION by William J. Stevenson Operations and Supply Chain Management (SIE) | 15th Edition by Richard B. Chase, Ravi Shankar, et al.	

Third Year (Semester FIVE)

	Course Code: CET1165	**Course Title:** Chemical Reaction Engineering	**Credits = 2**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 30**	**1**	**1**	**0**
Course Outcomes (students will be able to…..)					
1	design chemical reactors optimally, using minimum amount of data				
2	design experiments in a judicious way to get the required data, if not available				
3	fix some problems related to operability and productivity				
4	Select appropriate single and multiphase reactor configuration for given application				
List of Prerequisite Courses					
	Physical Chemistry, Material & Energy Balance Calculations, Applied Mathematics I and II, Momentum and Mass Transfer, Chem Engg Thermodynamics I and II				
	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		
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				
5	Heterogeneous Reactions, Vol. I and II – L. K. Doraiswamy, M. M. Sharma				
List of Additional Reading Material / Reference Books					

	Course Code:CET1166	**Course Title: Momentum Transfer**	**Credits = 2**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 30**	**1**	**1**	**0**
Course Outcomes (students will be able to…..)					
1	Calculate velocity profiles, forces, pressure drops for simple 1 –D laminar flow situations				
2	Calculate forces on particles and terminal velocities of particles				
3	Apply Momentum, Heat and mass transfer concepts to simple situations				
4	Select appropriate measurement technique for detailed characterization in chemical process equipment				
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics, Applied Physics – I and II, Applied Mathematics – I and II				
	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 modeling, multiphase system modeling etc		4		
List of Text Books					
	Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N.				
	Fluid Mechanics, Kundu Pijush K.				
	Fluid Mechanics, F. W. White				
	Unit Operations of Chemical Engineering, McCabe, Smith				
List of Additional Reading Material / Reference Books					

	Course Code: CET1167	**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 course in Second Year				
Description of relevance of this course in the B. Chem. Engg. 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, azeotropy, non-zero heats of mixing, sparingly soluble gases and solids, electrolytes etc. Student who have taken this course may be expected to intelligently analyze practically the full spectrum of industrial chemical processes.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Revision of Concepts of Ideal and non-ideal mixtures		4		
2	Models of the Liquid Phase: Activity Coefficient Models (Redlich-Kister, Wilson et al, UNIQUAC and NRTL)		8		
3	Vapor – liquid equilibria in non-ideal mixtures including azeotropes and high pressure vapor – liquid equilibria using gamma-phi and phi-phi approaches		8		
4	Use of VLE data in design and analysis of distillation processes		4		
5	Solubility of Gases in Liquids, concept of infinite dilution activity coefficient and Unsymmetric convention, Henry's law, Shair Prausnitz correlation		8		
6	Liquid – Liquid Equilibria and Phase splitting, applications to extraction		8		
7	Solubility of Solids in Liquids		4		
8	Debye Huckel Theory, activity coefficients of electrolytes		4		
9	Chemical Equilibrium in Ideal and non-ideal Mixtures in single phase reacting mixtures		6		
10	Chemical Equilibrium in Ideal and non-ideal mixtures in Heterogenous reacting mixtures		6		
List of Text Books/ Reference Books					
	Chemical, Biochemical and Engineering Thermodynamics: S. I. Sandler				
	Introduction to Chemical Engineering Thermodynamics: Smith, van Ness, Abbott				
	Reference Books				
	Properties of Gases and Liquids: Reid, Prausnitz, Pauling				
Course Outcomes (students will be able to…..)					
1	Calculate Vapor – liquid equilibria in binary non-ideal mixtures using activity coefficient models (K2)				
2	Calculate solubility of solutes (gases and solids) in liquids (K2)				
3	Calculate liquid – liquid equilibria using activity coefficient models (K2)				
4	Analyze equilibria in reacting mixtures (K3)				

	Course Code: CEP1168	**Course Title: Chemical Engineering Lab-III**	**Credits = 2**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 60**	**0**	**0**	**4**
Course Outcomes (students will be able to…..)					
1	Student would be able to Design and implement the experimental procedure with minimal assistance				
2	Student would be able to Connect various Chemical Engineering subjects for common output				
3	Student would be able to Analyze large experimental data and results				
4	Student would be able to Improve ability to write scientific reports				
5	Student would be able to Improve ability draw conclusions				
List of Prerequisite Courses					
	Material Balance and Energy Balance Calculations, Fluid Flow, Heat Transfer, Engineering Thermodynamics, Mathematics I and II, Industrial Chemistry and Reaction Engineering, Instrumentation and Process Dynamics, Chemical Reaction Engineering, Momentum Transfer, Chemical Engineering Thermodynamics				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	4-6 Experiments on Momentum Transfer		18		
2	2-3 Experiments on Chemical Engineering Thermodynamics		10		
3	4-6 Experiments on Reaction Engineering		16		
4	2-4 Experiments on Chemical Engineering Operations		10		
5	1-2 Experiments on Instrumentation		6		
List of Text 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.				
List of Additional Reading Material / Reference Books					

	Course Code: CEP1169	Course Title: Process Simulation Laboratory - I	Credits = 2		
			L	T	P
	Semester: V	Total contact hours: 60	0	0	4

	Course Outcomes (students will be able to…..)	
1	Use advanced programming software with built in functions	
2	Write own functions/macros	
3	Solve Chemical Engineering problems using computers	
4	Design a distillation column using short-cut and rigorous method	
	List of Prerequisite Courses	
	XIIth Standard Physics and Mathematics, Applied Physics – I and II, Applied Mathematics – I and II	
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Introduction to object-oriented programming in python	8
2	Mathematical methods in Chemical Engineering such as simultaneous linear and nonlinear equations, interpolation, optimization	8
3	Design of chemical reactors: CSTR, PFR, multiple reactions, adiabatic, non-isothermal systems etc	8
4	Flash vessel calculations	4
5	Design of Chemical Engineering equipment	12
6	Process flow sheeting	4
7	Chemical process simulators such as Aspen, Coco simulators etc (mixing blocks, reactors, short cut and detailed design of separation equipment such as distillation, sizing of heat exchangers)	16
	List of Text 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	
4	ASPEN manual	
	List of Additional Reading Material / Reference Books	

Third Year (Semester SIX)

	Course Code:CET1171	**Course Title: Multiphase Reaction Engineering**	**Credits = 3**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 45**	**2**	**1**	**0**
	Course Outcomes (students will be able to…..)				
1	calculate operating regime for a given reaction.				
2	calculate intrinsic kinetics from the data on model contactors.				
3	calculate conversion / selectivity / size / temperature / pressure / power required for conducting a given multiphase reaction equipment.				
	List of Prerequisite Courses				
	Chemical Reaction Engineering , Momentum Transfer, Mass Transfer, Heat Transfer, Chemical Reaction Engineering, Chemical Engineering Operations, Separation Processes, Chem Engg Thermodynamics				
	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, sectionalised bubble columns,		8		
2c	Internal loop and external loop air-lift reactors, jet loop reactors,		6		
2d	Fluid-fluid reactors such as spray columns, packed columns, plate columns, static mixers, rotating disc contactors		5		
2e	Fixed bed reactors, trickle bed reactors,		4		
2f	Solid-liquid and gas-solid fluidised bed reactors, solid-gas transport reactors		4		
	List of Text 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				
	List of Additional Reading Material / Reference Books				

	Course Code:CET1172	**Course Title: Chemical Process Control**	**Credits = 2**		
			L	**T**	**P**
	Semester:	**Total contact hours:30**	**1**	**1**	**0**
Course Outcomes (students will be able to…..)					
1	To design a controller and understand behavior of a close loop controlled system				
2	To evaluate performance of a close loop control system, stability and controllability, Robustness				
3	To select and Design control strategy				
4	To evaluate a multivariable system, design multivariable controllers				
5	To evaluate plant-wide control systems				
List of Prerequisite Courses					
	Maths-I and Maths-II				
	Instrumentation and Process dynamics				
	Chemical Reaction Engineering				
	Transport Phenomena				
	Chemical Process safety				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Design of controllers using frequency response technique, Nyquist and Bode Stability criteria,		4		
2	Control Strategies- Cascade control, Ratio Control, Feedforward control, Dead time compensation		4		
3	Multivariable Systems, Identification of Interaction and selection of pairings, Design of controllers for multivariable systems, Decouplers,		4		
4	Modern control strategies, Internal model control, Dynamic Matrix control		4		
5	Design of control systems for CSTR, Distillation column, heat exchangers		6		
6	Process Instrumentation diagrams, Safety alarms and interlocks		2		
7	Control of batch processes, programmable logical controllers, Distributed control systems, supervisory Control systems		2		
7	Digital control systems, Introduction to z-transforms		2		
8	Flow-sheet modelling and Simulation of plant-wide control systems		2		
List of Text Books					
	Chemical Process Control- George Stephenopoulus				
	Process control- Shinskey				
List of Additional Reading Material / Reference Books					

	Course Code: CET1173	**Course Title: Material Technology**	**Credits = 2**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 30**	**2**	**0**	**0**
Course Outcomes (students will be able to…..)					
1	Students will be able to read and interpret the Phase Diagrams				
2	Student would be able to select a proper MOC				
3	Student would be able to describe causes of mechanical failure and failure analysis				
4	Student would be able to analyse the corrosion problems in process industry and control the corrosion				
5	Student would be able to learn from incidences				
List of Prerequisite Courses					
	Structural Mechanics, Applied Physics I and II, physical chemistry				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Engineering Materials: Classification, study of ferrous and nonferrous materials		2		
2	Phase diagrams of steel and the applications of phase diagrams		2		
3	Effect of structure on properties: subatomic to macroscopic level		4		
4	Modification and control of material properties		3		
5	Polymeric materials , Ceramic materials, Composite materials and Smart materials		3		
6	Corrosion Engineering: Electrochemical principles, different types of corrosion, Polarisation, mechanisms of corrosion control and prevention, preventive coatings. Corrosion behavior of important alloys such as stainless steels, brass etc.		8		
7	Theory of failure: Crystal defects, plastic deformation. Types of mechanical failure, fracture , fatigue and creep		6		
8	Criteria for selection of materials in chemical process industry		2		
9					
	TOTAL		**30**		
List of Text Books					
	The Essence of Materials for Engineers, Robert W. Messler, Jr.				
	Materials Science and Engineering, Raghavan V.				
	Materials Science and Engineering, Van Vlack L.H.				
List of Additional Reading Material / Reference Books					
	Metals handbook				
	Engineering Materials and Applications, Flin R.A., Trojan P.K.				

	Course Code: CET1174	Course Title: Separation Processes	Credits = 3		
			L	**T**	**P**
	Semester: V	**Total contact hours:45**	**2**	**1**	**0**

List of Prerequisite Courses		
	Material & Energy Balance Calculations, Chemical Engineering Operations – I, Chem. Eng. Thermodynamics-I and II, Momentum Transfer, Applied Mathematics I and II	
List of Courses where this course will be prerequisite		
	Chemical Engineering Laboratory, Process Simulation Lab – I and II, Home Paper I and II, Proc Dev and Engg.,	

Description of relevance of this course in the B. Chem. Engg. Program
This is a course further built up on and in continuation with Chem. Engg. operations. It forms the basis oc 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	10
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	10
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	10

List of Text Books/ 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…..)		
1	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	
2	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	
3	Explain how crystals grow, Explain the importance of supersaturation in crystallization. Describe effects of mixing on supersaturation, mass transfer, growth, and scale-up of crystallization	
4	Explain membrane processes in terms of the membrane, feed, sweep, retentate, permeate, and solute-membrane interactions. 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.	

	Course Code: CET1175	**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 and Mass transfer, Applied Mathematics I and II, Material and Energy Balance Calculations	
	List of Courses where this course will be prerequisite	
	Chemical Reaction engineering, Multiphase Reactor Engineering, Process Development and Engineering, Home Paper I and II, Env. Engg. and Process Safety, etc.	
	Description of relevance of this course in the B. Chem. Engg. 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, multipass 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 vapours: 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 vapours in presence of non-condensables.	8
5	Heat transfer to boiling liquids: Process design aspects of evaporators, natural and forced circulation reboilers	8
	List of Text Books/ Reference Books	
	Process Heat Transfer, Kern D.Q.	
	Heat Exchangers, Kakac S., Bergles A.E., Mayinger F	
	Process Heat Transfer, G. Hewitt	
	Course Outcomes (students will be able to…..)	
1	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.	
2	Identify and select type of shell and tube exchanger based on TEMA classification.	
3	Design a reboiler system for distillation	

	Course Code: CEP1177	**Course Title: Process Simulation Laboratory - II**	**Credits = 2**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 60**	**0**	**0**	**4**
Course Outcomes (students will be able to…..)					
1	Solve Chemical Engineering design problems involving iterative calculations				
2	Solve Chemical Engineering problems involving non-linear equations coupled with ODEs/PDEs				
3	Develop and optimize a process flow sheet for chemical production				
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics, Applied Physics – I and II, Applied Mathematics – I and II				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Detailed design of multicomponent distillation		8		
2	Detailed design of shell and tube heat exchanger		8		
3	Detailed design of multiphase reactor system such as hydrogenation etc		8		
4	Detailed design of continuous crystallizer (MSMPR)		4		
5	Modeling and simulation of transient systems (solution of partial differential equations)		8		
6	Detailed design of batch crystallizer		4		
7	Advanced process flow sheeting: mechanical vapor compression refrigeration, absorption refrigeration		8		
8	Data analytics: feature importance, bagging and boosting, hyper parameter optimization		6		
9	Uncertainty analysis		6		
List of Text 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				
4	ASPEN manual				
List of Additional Reading Material / Reference Books					

	Course Code: CEP1178	**Course Title: Chemical Engineering Laboratory - IV**	**Credits = 2**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 60**	**0**	**0**	**4**
Course Outcomes (students will be able to…..)					
1	Student would be able to Completely design and implement the experimental procedure				
2	Student would be able to Process complex information to solve Chemical Engineering problems				
3	Student would be able to Evaluate a large experimental data and results for recommendation				
4	Student would be able to Improve ability to write cohesive technical document				
List of Prerequisite Courses					
	Material Balance and Energy Balance Calculations, Fluid Flow, Heat Transfer, Engineering Thermodynamics, Mathematics I and II, Industrial Chemistry and Reaction Engineering, Instrumentation and Process Dynamics, Chemical Reaction Engineering, Momentum Transfer, Chemical Engineering Thermodynamics, Multiphase Reactors, Chemical Process Control, Separation Processes, Heat Transfer Equipment design				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	6-8 Experiments on Multiphase Reactors		22		
2	2-3 Experiments on Heat transfer		8		
3	4-6 Experiments on Chemical Process Control and Dynamics		18		
4	2-4 Experiments on Mass Transfer and Separation Processes		12		
List of Text 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.				
List of Additional Reading Material / Reference Books					

Fourth Year (Seventh Semester)

	Course Code: CET1179	**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					
	All Chemical Engineering subjects, Material Science and Engineering, Env Engg and Proc Safety				
List of Courses where this course will be prerequisite					
	Home Paper I and II				
Description of relevance of this course in the B. Chem. Engg. 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		3		
5	Process Engineering aspects of low and medium volume chemicals including process development.		3		
6	Concept of dedicated and multiproduct plant facilities, pilot plant, mini plants		3		
7	Development and evaluation of alternative flow sheets		3		
8	Scale up aspects; identification of controlling steps of process,		3		
9	Green Engineering principles		6		
10	Utilisation of energy; cost of utilities, heat exchange networks		3		
11	Process intensification		3		
12	Preparation of Conceptual process and instrumentation diagrams. .		3		
13	Preparation of process specifications for typical equipment.		3		
14	Safety and Risk of chemical processes		3		
15	Learn from mistakes		3		
List of Text Books/ Reference Books					
	Industrial Chemical Process Design, D. L. Erwine				
	Laboratory Chemical Process Development, Anderson N.				
	Organic Unit Processes, Groggins				
	Chemical Process Engineering: Design and Economics, Silla H.				
	Handbook of Chemical Process Development, Chandalia S. B.				
	Conceptual Chemical Plant Design, Douglas J. M.				
Course Outcomes (students will be able to…..)					
1	to select a strategy for a process from amongst the alternatives				
2	Determine strategy for carrying out a particular process				
3	Prepare specifications for a particular equipment				
4	Calculate utility requirements				

	Course Code: CET1180	**Course Title: Chemical Project Economics**	**Credits = 2**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Material and Energy Balance Calculations, Equip Des and Dwg I, Energy Engineering, Ind Eng Chem.				
List of Courses where this course will be prerequisite					
	Home Paper I and II				
Description of relevance of this course in the B. Chem. Engg. 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 andConcepts of "Quality by Design" including typical design deliverables andunderstanding 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 contract. 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		
List of Text Books/ Reference Books					
	Chemical Project Economics, Mahajani V. V. and Mokashi S M.				
	Plant Design and Economics for Chemical Engineers, Peters M.S., Timmerhaus K.D.				
	Process Plant and Equipment Cost Estimation, Kharbanda O.P.				
Course Outcomes (students will be able to…..)					
1	Calculate working capital requirement for a given project				

2	Calculate cost of equipment used in a plant total project cost	
3	Calculate cash flow from a given project	
4	Select a site for the project from given alternatives	
5	List out various milestones related to project concept to commissioning	

<table>
<tr><td rowspan="2"></td><td rowspan="2">Course Code:
CET1181</td><td rowspan="2">Course Title: Environmental Engineering and Chemical Process Safety</td><td colspan="3">Credits = 3</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td></td><td>Semester: III</td><td>Total contact hours: 45</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6" align="center">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>1</td><td colspan="2">Select appropriate pollution abatement technique for a given pollutant</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="2">Carry out quantitative environmental impact assessment of a process</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Analyze the case scenarios of major industrial disasters</td><td colspan="3"></td></tr>
<tr><td>4</td><td colspan="2">Carry out HAZOP/LOPA analysis of various unit operations and process equipment</td><td colspan="3"></td></tr>
<tr><td>5</td><td colspan="2">Design pressure relief valve, flare and stacks based on the available process data</td><td colspan="3"></td></tr>
<tr><td colspan="6" align="center">List of Prerequisite Courses</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2" align="center">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td>1</td><td colspan="2">Industrial wastewater treatment: characterization of effluents (COD and BOD), treatment levels (primary, secondary and tertiary) and strategies (physical, chemical and biological), sludge treatment and valorization</td><td colspan="3">8</td></tr>
<tr><td>2</td><td colspan="2">Details of the effluent treatment plant and machines, chemical pipelines and storage condition, segregation of waste streams (high COD and low COD)</td><td colspan="3">4</td></tr>
<tr><td>3</td><td colspan="2">Current practices in wastewater treatment: examples and case studies</td><td colspan="3">4</td></tr>
<tr><td>4</td><td colspan="2">Management of municipal solid waste, waste-to-energy strategies, refuse-derived fuel, hazardous waste, E-waste, battery waste, plastic waste</td><td colspan="3">3</td></tr>
<tr><td>5</td><td colspan="2">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</td><td colspan="3">6</td></tr>
<tr><td>6</td><td colspan="2">Prevention and control of accidental release of contaminants, plume behavior, dispersion modeling</td><td colspan="3">4</td></tr>
<tr><td>7</td><td colspan="2">Lessons learned from major industrial disasters and recent process safety incidents</td><td colspan="3">2</td></tr>
<tr><td>8</td><td colspan="2">Process safety management, Risk assessment and identification, HAZOP, LOPA and FMEA</td><td colspan="3">4</td></tr>
<tr><td>9</td><td colspan="2">Process hazards, design and control: safe design of process vessels, safety systems, color coding, earthing, safety-related equipment</td><td colspan="3">7</td></tr>
<tr><td>10</td><td colspan="2">Risk-based process safety, Inherently safer design</td><td colspan="3">3</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="6" align="center">List of Text Books</td></tr>
<tr><td></td><td colspan="2">Chemical Process Safety: Fundamentals with Applications – Daniel A. CROWL and Joseph F. LOUVAR</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="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)</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Chemical Process Safety Learning from Case Histories – Roy E. SANDERS</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Guidelines for Process Safety Documentation – Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)</td><td colspan="3"></td></tr>
<tr><td colspan="6" align="center">List of Additional Reading Material / Reference Books</td></tr>
</table>

	Course Code: GEP1138	**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, Materials Science and Engineering, Engineering Graphics I and IIm				
List of Courses where this course will be prerequisite					
	Home Paper I and II, Equipment Design & Drawing II, Chemical Project Engineering and Economics, Process Dev and Engineering				
Description of relevance of this course in the B. Chem. Engg. 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. 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. a) Design of shells subjected to internal and external pressures. b) Types of Jackets /Coils used for heating and cooling in reaction vessels and their design. c) Type of agitators and their design. Design of agitator system components such as shafts,stuffing box etc.		14		
7	Mechanical Design of Heat Exchangers a) Components of shell and tube type heat exchangers. b) Design of various components of heat exchangers such as Fixed tube sheet type,U tube, Floating head etc. Various codes for heat exchangers.		12		
8	Mechanical design of distillation columns a) Various components of columns such as trays, packings, downcomers,bubble cap etc b) Design of shell for various stress conditions. Tray supports and their design		12		
List of Text Books/ Reference Books					

	Process equipment Design By V V Mahajani, S. B. Umarji	
	Equipment Design by Dawande	
	Process equipment Design by Young	
	Welding Technology by O.P. Khanna, Welding Technoloy by Little	
Course Outcomes (students will be able to…..)		
1	Understand general design procedure for chemical process equipment. (K2)	
2	Design and draw pressure vessels and its parts subjected to internal pressure. (K6)	
3	Design and draw reactors and its parts subjected to internal and external pressure. (K6)	
4	Design and draw shell and tube type of heat exchangers. (K6)	
5	Design and draw tray columns and its parts. (K6)	
6	Understand different types of supports for chemical process equipment.(K2)	

	Course Code: CEP1183	Course Title: Literature Review (Research Methodology – I)	Credits = 2		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 45**	**1**	**0**	**2**

	Course Outcomes (students will be able to…..)	
1	Understand the basic concepts of research and the components therein, formally	K2
2	Understand and appreciate the significance of statistics in Chemical Technology, Pharmacy and Chemical Engineering	K2
3	Understand and apply importance of literature survey in research design	K3
4	Understand an in-depth knowledge on the documentation in research	K2
5	Evaluate importance of various parts of a research report/paper/thesis in presentation of research results	K4
6	Prepare and Deliver a model research presentation	K5
7	Understand the significance of various types of IPRs in research	K1
8	Create a model research project	K6
	List of Prerequisite Courses	
1	NA	
	List of Courses where this course will be prerequisite	
1	NA	

Description of relevance of this course in the B. Chem. Engg. 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 Academic Honesty Practices General philosophy of science & Arguing About Knowledge Case studies in science history	3
2	Motivation and Background 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 What is Research, How to start?, Approaches to find research problems and psychological experiments Literature survey, Textbooks, Review and research papers How to ask Questions What is worthwhile research problem, Analytical and synthetic research approach	4
5	Finding and Solving Research Problems What is Research, How to start?, Approaches to find research problems and psychological experiments 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	4

	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	
7	Experimental Research Inventory Management, Material Management Learning required skills for research, Documentation and lab notebook guidelines, 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 Skeleton of research paper, author guidelines, good writing skills, importance of discussion, Macro-level discussion. Structure of the documents. General issues of presentability. Micro-level discussion. Stylistic issues. Examples of bad and good writings.	6
10	Publishing and Reviewing Publication process, How to publish papers, where to submit, Review process and reacting to a review report Reviewing scientific papers	4
11	Scientific Norms and Conventions Authorship. Plagiarism. Simultaneous submissions. Reviewing norms. Referring to other papers. Use of data. Collaborative Research Work	3
List of Textbooks		
	Menzel, D.; Writing a Technical Paper; McGraw-Hill, United States (1961).	
	Best, J. W., Kahn, J. V., Jha, A. K.; Research in Education; 10th ed.; Pearson, New Delhi, India (2005)	
List of Additional Reading Material / Reference Books		

	Course Code: CET1184	Course Title: Design and Analysis of Experiments (Research Methodology – II)	Credits =2		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 45**	**1**	**-**	**2**

List of Prerequisite Courses		
	Applied Mathematics I	
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 B. Chem. Engg. Program		
Modern day manufacturing activities and R&D activites need decisions taken with a scientific rigour 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 organisations, or academic research should have a reasonably 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 Strategy of Experimentation, Typical applications of Experimental design, Basic Principles, Guidelines for Designing Experiments.	4
2	Review of Probability and basic statistical inference: 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 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: 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
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 GebhardtOptimal 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…..)		
1	Students should be able to understand basic principles of design of experiments.	
2	Students should be able to perform statistical analysis of single experiments and do post hoc analysis.	
3	Students should be able to conduct experiment and analyse the data using statistical methods.	
4	Students should be able to choose an appropriate design given the research problem.	
5	Students should be able to perform statistical analysis of different designs using R and interpret the results.	

	Course Code: CEP1185	**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 B. Chem. Engg. 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 on design, which will set by one or more of the teachers in the institution. The design will have to be submitted in the form of a standard typed 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. Additional details may be given to the students from time to time by the coordinator.		120		
List of Text Books/ Reference Books					
Course Outcomes (students will be able to…..)					
1	Identify market requirement related to a particular chemical				
2	Draw a process block diagram from a given process description.				
3	Select a site for the project				
4	Develop a PFD based on block diagram				
5	Do material and energy for all the equipment in PFD.				

Fourth Year (Semester EIGHT)

<table>
<tr><td rowspan="2"></td><td>**Course Code: CEP1186**</td><td>**Course Title: Design Project – II**</td><td colspan="3">**Credits = 4**
L / **T** / **P**</td></tr>
<tr><td>**Semester: VIII**</td><td>**Total contact hours: 120**</td><td>**0**</td><td>**0**</td><td>**12**</td></tr>
<tr><td colspan="6">**List of Prerequisite Courses**</td></tr>
<tr><td></td><td colspan="2">All</td><td colspan="3"></td></tr>
<tr><td colspan="6">**List of Courses where this course will be prerequisite**</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="6">**Description of relevance of this course in the B. Chem. Engg. Program**</td></tr>
<tr><td colspan="6">This course enables students to integrate all the subjects that they have learnt and design plants / processes from Chemical Engineering Principles.</td></tr>
<tr><td></td><td colspan="2">**Course Contents (Topics and subtopics)**</td><td colspan="3">**Reqd. hours**</td></tr>
<tr><td>1</td><td colspan="2">There would be two submissions: (iii) Process Design, (iv) P&ID, Mechanical design, Costing, feasibility. The submissions will be presented to a panel of faculty members / examiners. The submissions would be given a weightage of 50 marks. There will be a weightage of 60% for the submissions and 40% for the presentation. Final report of the home paper would be given a weightage of 50 marks. There will be a viva-voce after the submission of the report. The weightage for the viva-voce would be 50 marks. Additional details may be given to the students from time to time by the Coordinator</td><td colspan="3">120</td></tr>
<tr><td colspan="6">**List of Text Books/ Reference Books**</td></tr>
<tr><td colspan="6">**Course Outcomes (students will be able to…..)**</td></tr>
<tr><td>1</td><td colspan="2">Students should be able to design, calculate size/power/internals, etc required for all the process equipment in the PFD together with necessary instrumentation, safety aspects.</td><td colspan="3"></td></tr>
<tr><td>2</td><td colspan="2">Students should be able to calculate costs of equipment</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Students should be able to perform a techno economic feasibility of the selected process.</td><td colspan="3"></td></tr>
</table>

	Course Code: **HUT1254**	**Course Title:** **Industrial and Organizational Psychology**	**Credits = 2**		
			L	**T**	**P**
	Semester: VIII	**Total contact hours:30**	**3**	**0**	**0**
		Course Outcomes (students will be able to…..)			
1	Student would be able to understand the process of corporate recruitment.				
2	Student would be able to use the information while applying for jobs				
3	Student would be able to gain knowledge on how to perform well in an interview process				
4	Student would be able to gain knowledge on how goals are set in any organization and performance is measured.				
		List of Prerequisite Courses			
	NONE				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Basics of management The eras of management Mission and vision of organizations		3		
2	Micro organizational behaviour Psychoanalytical framework Common personality traits Hofstede cultural dimensions		5		
3	Employee Recruitment and Selection Concept of Role Job description and man specifications Some methods of recruitment Selection methods		6		
4	Employee performance MBO Appraisal methods Review meetings		5		
5	Employee motivation Employee pre disposition to motivation Goal setting Recent motivation theories How to motivate trouble spots		5		
6	Group dynamics Theories of group formation Pitfalls of a group Conflicts		6		
		List of Text Books			

	Human Resource Management (15e) - Gary Dessler, Biju Varrkey Management(15e)-Robbins	
List of Additional Reading Material / Reference Books		
	Select HBR articles	
	Industrial/Organizational Psychology: An Applied Approach- Michael Aamodt	

HONOURS Syllabus

	Course Code: CET1170	**Course Title: Biochemical Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Chemical Reaction Engineering, Introduction to Biological Sciences and Bioengineering, Physical Chemistry, Material and Energy Balance Calculations, Chem Engg Thermodynamics I and II, Chem Engg Operations				
List of Courses where this course will be prerequisite					
	Multiphase Reactor Engineering, Env. Engg and Proc Safety, Proc Dev and Engg., Home Paper I and II				
Description of relevance of this course in the B. Chem. Engg. 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, thermostabilization, immobilization of enzymes		3		
7	Enzymes as industrial catalysts- Examples		2		
8	Plant and animal cell cultures for the production of 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		
List of Text Books/ Reference Books					
	BioChemical Engineering Fundamentals, Bailey and Olis, Wiley				
	Biotransformations and Bioprocesses, Doble,Anilkumar and Gaikar, Marcel Dekker				
Course Outcomes (students will be able to…..)					
1	Calculate microbial/enzymatic kinetics parameters				
2	Design enzyme reactors and scale up fermenters				
3	Calculate biomass production/substrate requirements				
4	Decide process parameters				
5	Estimate energy equipment/oxygen requirements				
6	Estimate bio-reactor size/time for a given microbial/enzymatic process.				

	Course Code: CET1176	**Course Title: Mathematical Methods and Optimization in Chemical Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 60**	**2**	**0**	**4**

	List of Prerequisite Courses	
1	Applied Mathematics – I and II, Momentum Transfer, Chem. Eng. Operations, Chem Engg Thermodynamics I and II	
	List of Courses where this course will be prerequisite	
1	Transport Phenomena	
2	Heat transfer, Chemical Reaction Engineering , Chemical Process Control, Optimization of Chemical Engineering Systems, Home Paper I and II, Seminar, etc.	
	Description of relevance of this course in the B. Chem. Engg. 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
	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…..)	
1	Formulate a Chemical Engineering problem into a mathematical problem	
2	Solve (analytically or numerically) ODE and PDE equations encountered in Chemical Engineering Applications	
3	Assess stability of Chemical Engineering systems	
4	Formulate a Chemical Engineering problem into an optimization problem	

5	Solve (analytically or numerically) optimization problems encountered in Chemical Engineering Applications	

	Course Code: CET1182	**Course Title: Refinery Science and Engineering**	**Credits = 3**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 45**	**2**	**1**	**0**
List of Prerequisite Courses					
1	Material and Energy Balance Computation, Chemical Reaction Engineering, Heat Transfer				
List of Courses where this course will be prerequisite					
1					
Description of relevance of this course in the B. Chem. Engg. Program					
	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		4		
4	Refinery processes - thermal cracking, fluid catalytic cracking, hydrotreating, catalytic reforming, refinery alkylation, isomerization		9		
5	Integration of petrochemical processes with refinery		4		
6	Material selection in refinery technology		4		
7	Treatment processes, gas cleaning		3		
8	Safety, health and environment issues		4		
9	Renewable and alternative fuels		4		
10	Biorefineries		5		
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…..)					
1	To understand refining trends, challenges and key issues				
2	To analyze the role of refining processes in the world energy challenge				
3	To propose feasible solutions for energy security in India				

	Course Code: CET1187	**Course Title: Catalytic Science and Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester: VIII	**Total contact hours: 60**	**4**	**2**	**0**
List of Prerequisite Courses					
1	Applied Chemistry, Chemical Reaction Engineering				
List of Courses where this course will be prerequisite					
Description of relevance of this course in the Bachelor's Program					
	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		10		
6	Poisoning, promotion, deactivation and selectivity , Catalytic process engineering , Measurement of catalytic rates and kinetic parameters, Types of reactors		10		
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…..)					
1	Understand synthesis, characterization, activity and deactivation of heterogeneous catalyst				
2	Understand the mechanisms of homogeneous catalysis				
3	Understand the role of catalysis in industrial processes				
4	To plan, develop and test catalyst for given application				
5	Suggest strategies for catalyst development				
6	Select and design multiphase catalytic reactors				

	Course Code: CET1188	**Course Title: Statistical Thermodynamics**	**Credits = 3**		
			L	**T**	**P**
	Semester: VIII	**Total contact hours: 45**	**3**	**2**	**0**
Course Outcomes (students will be able to…..)					
1	Student would be able to understand and use the concept of microcanonical, canonical, grand-canonical and PVT ensembles and the partition functions thereof				
2	Student would be able to relate macroscopic thermodynamic quantities like entropy and free energy to the partition functions				
3	Student would be able to understand the algorithms behind Monte Carlo simulations and write a simple Monte Carlo Simulation				
4	Student would be able to understand the algorithms behind Molecular Dynamics Simulations and write a simple MD simulation				
5	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.				
List of Prerequisite Courses					
	Mathematics especially probability, vectors and linear algebra, Computer Programming especially working with arrays and vectors.				
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction to statistical mechanics – a first look at the Canonical Ensemble. Introduction to the Boltzmann Distribution		3		
2	Introduction to the microcanonical, PVT and Grand Canonical Ensembles		3		
3	Macroscopic Thermodynamic Quantities as Functions of Ensembles with particular emphasis on the microscopic level difference between Heat Transfer and Work Transfer.		3		
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 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.		5		
6	Introduction to Importance Sampling, detailed balance and the Metropolis Monte Carlo Algorithm		3		
7	Writing a code for Monte Carlo simulations in 1D using periodic boundary conditions		3		
8	Phase Space, the Liouville Theorem and Molecular Dynamics Simulations		3		
9	Symplectic integrators and writing a code for molecular dynamics simulations in 1D using periodic boundary conditions		3		
10	Fluctuation Dissipation theorem and the Green Kubo relations to determine transport properties from MD simulations 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		3		

List of Text 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)	
List of Additional Reading Material / Reference Books		

CEP1189: Internship / On Job Training

CEP 1710 Internship
• In the Eighth semester, every student will have to undergo an internship and/or On Job Training. The Internship would be of 12 credits. • The internship would be assigned to the student by the Departmental Internship Coordinator, with the approval of Head, Chemical Engineering Department. • The total duration of the internship would be for a period equivalent to 12 Calendar weeks. The internship may be completed in one or more organizations as described below. • The internship could be of the following forms: Industrial internship in a company (within India or Abroad) involved in R&D / design / manufacturing (QA/QC/Plant Engineering/Stores and Purchase) / marketing / finance / consultancy / Technical services / Engineering / Projects, etc. • At the end of the internship, each student will submit a written report based on the work carried out during the Internship. The report will be countersigned by the Supervisor from Industry / Institute as the case may be. • Performance of the student will be assessed based on the written report and a presentation to a committee consisting of two faculty members from the Chemical Engineering Department. • Students will be assigned a grade based on the written report and a presentation; evaluated by a committee of faculty members. • Feedback will be taken from Industry mentors and this will used while assigning the grades.

LIST OF ELECTIVES

ELECTIVE SUBJECTS

The elective subjects may be added from time to time with prior approval from UGPC/Senate.

1.	**PYT 1104E – Molecular Quantum Mechanics (Applied Physics Department)** **Revision of Basic Concepts** Schrodinger equation for the hydrogen atom, solution in terms of radial and angular wavefunctions, significance of quantum numbers, atomic spectra. The quantum harmonic oscillator, eigenvalues and eigenfunctions (no detailed derivation), significance of 'zero-point' energy. **Origin of Molecular Spectra** Analysis of diatomic molecule as a rigid rotator, rotational and vibrational energy levels of a simple diatomic molecule. **Approximation methods in Quantum Mechanics** Brief introduction to perturbation theory with simple examples, variational theorem, analysis of helium atom as an example. **Molecular Quantum Mechanics** Molecular orbital and valence bond theories for diatomic molecules, Born-Oppenheimer approximation, LCAO method in H_2^+ ion and H_2 molecule, valence bond method
2.	**PYT 1105E – Statistical Mechanics (Applied Physics Department)** **Basic Statistical Approach to a System** 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. **Ensemble approach to Thermodynamics of Physical Systems** 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. **Generalised Interactions** Grand canonical ensemble, systems with variable number of particles, chemical potential, partition function for a grand canonical ensemble, relation to thermodynamic variables. **Applications to Multi-phase Systems** 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.
3.	**CHT 1403E – Advanced Spectroscopy (Applied Chemistry Department)** **UV-VIS spectroscopy -** Woodward rules, aromatic and heterocyclic compounds **IR spectroscopy:** FT technique, group frequencies, vibrational coupling. NIR spectroscopy. New applications **Raman spectroscopy:** Stokes, anti-Stokes and Releigh scattering, rotational and vibrational transitions. Raman vs IR. **NMR spectroscopy:** Pulse technique, FID, and FT. Relaxation and saturation phenomena, quadrupole relaxation, isotopomers. **H1 NMR:** Chemical shifts and factors affecting the same, spin-spin coupling of different systens, different spin systems, coupling constants. Simplification of complex spectra: Double resonance and decoupling, lanthanide shift reagents, INDOR technique. **C13 NMR:** Basics, doble resonance, **2D NMR:** H1-H1- COSY, H1-C13 HETCOR- APT and DEPT, C13-C13 connecticity: INADEQUATE **F19 and P31 NMR** Through space interactions: NOE and NOESY

	Solid state NMR and MAS. **Mass spectrometry:** Basics, EI and CI techniques. Isotopic abundance, fragmentation, rearrengment of ions, Maclaferty rearrangement, retrodiels-alder reaction. **Hyphenated techniques:** GC-MS, LC-MS, LC-MS-MS, GC-IR, GC-AIS, GC-NMR, LC-NMR **ESR spectroscopy:** Theory, experimental technique, Hyperfine splitting **Mossbaur spectroscopy** Structure elucidation using combined stereoscopic methods Emission: Flame photometry, ICP, Ark-Spark spectra, Phosphorescence, XRF
4.	**CHT 1205E – Organometallic Chemsitry (Applied Chemistry Department)** **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. Nomenclature and heptacity. Electron counting and 16 and 18 electron rules - applications and exceptions. Stability. Stereochemical nonrigidity in organometallic compounds. 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 **Bimetallic and cluster complexes**: Structure and applications in catalysis **Basic organometallic reactions:** Ligand substitution, oxidative reactions, migratory reactions, migratory insertion, extrusion, oxidative addition, reductive elimination, reductive elimination –mechanism and stereochemistry. **Nucleophilic regents with C-M bond:** Li, Mg, Al, Ti and Ce alkyls; Organicuprates, organic zinc reagents Alkyne complexes: Pauson Khand reaction. The use of stoichiometric transition metal complexes in the synthesis of complexes organic molecules - enantioselective synthesis via organometallic compounds. Organo silicon compounds, boranes, carboranes and, metallocarboranes, organo platinum complexes, metallocenes Importance of organometallic compounds in Biological systems
5.	**CHT 1206E – Green Chemistry & Catalysis (Applied Chemistry Department)** **Concept of Green Chemistry:** Twelve principles of green chemistry, E factor, Waste management **Types of catalysis:** Homogeneous and Heterogeneous catalysis. Catalytic cycles **Organometallic compounds used as catalysts:** Pd, Rh, and Ru in C-C bond formation. Catalytic properties of mononuclear compounds **Homogeneous catalysis:** Hydrogenation, hydroformylation, hydrocyanation, Hydrosilylation, Wilkinson catalysts, Chiral ligands and chiral induction, Ziegler-Natta catalysts **Mercuration and oxymercuration** **Organopalladium catalysts:** Suzuki coupling, Heck coupling and related cross coupling reactions. **Alkene oligomerization and metathesis.** **Catalytic oxidations and reductions:** Epoxidation, dihydroxylations. including carbonylation, decarbonylation, olefin isomerization, arylation **Important catalytic reactions:** Monsanto acetic acid process, Wacker process, Heck reaction.
6.	**CHT 1303 – Theoretical and Computational Chemistry (Applied Chemistry Department)** **Basics:** Wave character and wave functions, De Broglie equation, normalization and orthogonalization, Quantum mechanical operators, Schrodinger equation, particle in an infinite square well potential, quantum mechanical harmonic oscillator, angular momentum operator and rigid rotor, Born Oppenheimer approximation, potential energy surfaces, self consistent field wave functions, **Computauional methods:** Molecular mechanics, MO theory, semi empirical and ab initio methods, SCF theory, Hartree Fock method, DFT.
7.	**MAT 1107E – Momentum, Heat and Mass Transfer (Applied Mathematics Department)** Derivation of equation of momentum, energy, mass transfer in curvilinear coordinate system, constitutive equation (Newtonian & Non Newtonian fluids), 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). 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) . Flow stability, theory of ordinary diffusion in liquids, diffusion with homogenous chemical reaction, diffusion into a falling liquids films (forced convection mass transfer).
8.	**MAT 1108E – Turbulent Flow and CFD (Applied Mathematics Department)** 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. Turbulent boundary layer flows and similar solutions Grid generation 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)
9.	**GET 1303E – Advanced Strength of Materials (General Engineering Department)** Analysis of Trusses - Condition for perfect truss, redundancy, stable, unstable truss. Analysis of truss by method of joints, method of sections. Torsion of a circular shaft - concept, basic derivation, shear stress distribution, simple problem. Short and Long columns (Struts) - Basic concept, crippling load, end conditions. Euler's and Rankine's approach (without derivations) 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). 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. 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. 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. 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.
10.	**HUT 1105E – Industrial Economics (Humanities)** Nature and Significance of Economics Demand and supply / elasticity of demand and supply, price determination, demand forecasting theory of firm : (A) financial aspects : cost analysis, revenue structure, conditions for profit maximisation, different market structures (B) technical aspects : factors of production, role of entrepreneur, laws of return, returns to scale. Money market and capital market, evolution of money and banking, foreign exchange and currency de-valuation. Budget, taxation, public expenditure, borrowing and deficit financing Development issues and economic planning in India, Role of public sector / liberalisation / privatisation / globalization

11.	**CET 1506E – Engineering Aspects of Manufacturers of Organic Chemicals (Chemical Engineering Department)** Special features of process parameters and reactors used for typical organic processes such as hydrogenation, oxidation, alkylation, nitration, sulphonation etc. Different strategies of conducting reactions. Introduction to a few name reactions such as Friedel Crafts reactions, Sandmeyers reaction, Darzens condensation, etc. Typical reaction schemes for the synthesis of medium and low volume chemicals, with an emphasis on the alternative flow sheets of the entire process.
12.	**CET 1204E – ElectroChemical Engineering (Chemical Engineering Department)** Introduction to eletrochemical engineering. Theoretical aspects and special features of electrochemical process. Role of mass transfer in a variety of electrochemical processes. Some aspects of electrochemical reactor design. Scale-up and optimization of reactors.
13.	**CET 1712E – Mathematical Methods in Chemical Engineering (Chemical Engineering Department)** Classification of problems in Chemical Engineering. Typical problems from heat transfer, catalysis, mass transfer with chemical reaction, dynamics of process equipment, etc. Numerical evaluation of Laplace Transforms. Separation of variables, Eigen values, Collocation Techniques.
14.	**CET 1713E – Statistical Methods in Engineering (Chemical Engineering Department)** Continuous and discrete probability distributions, normal, chi-square, gamma, Poisson distributions. Applications. t-Tests, F-Test, Homogeneity tests, Quality Control. Acceptance sampling Linear regression and lack of fit Contingency tables.
15.	**CET 1103E – Heat Transfer Equipment Design (Chemical Engineering Department)** Classification of Heat Transfer Equipment, direct, indirect, boiling, fired, Fluidised, geometry, construction. Thermal design methods of heat exchangers : survey, capital NTU, LMTD concept, temperature approach, etc. Shell and Tube heat exchangers : thermal, mechanical design, hydraulic design and equations, introduction to codes and standards Extended surface heat exchanger design : plates, plate fins, effectiveness factor. Heat transfer equipment with phase change, two phase flow maps, and design of equipment for heat transfer and pressure drop. Fluidised bed and direct heat exchangers design methodology. Synthesis of optimal heat exchanger networks. Worked Examples
16.	**CET 1205E – Mixing (Chemical Engineering Department)** Examples of industrial importance Flow pattern, power consumption, classification of impellers, internals Mechanism of mixing, Blending in viscous and turbulent system, Suspension of solid particles, Heat transfer, Gas-liquid dispersion, Liquid-liquid dispersions, Three phase dispersions, Solid-solid mixing, emulsions, pastes, Mass transfer at gas-liquid, liquid-liquid, solid-solid and solid-liquid interface Process design and scale-up considerations case studies
17.	**CET 1507E – Petroleum Reservoir Engineering (Chemical Engineering Department)** Energy sources, world scenario, oil pricing, Genesis of petroleum and migration, Composition of petroleum and its classification, Petroleum reservoirs, 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, Fluid displacement and frontal displacement; Buckley-Leverett theory, Material balance, Decline curve analysis, Well patterns and displacement efficiencies, Primary recovery, Gravity drainage, Waterflooding , Mechanisms of microscopic and macroscopic flow, Transportation of oil and gas, Production rate, reservoir life, Heavy oil and tar sand technologies, Residual oil determination, Computer modelling of reservoirs, Tertiary recovery methods
18.	**CET 1508 – Enhanced Oil Recovery (Chemical Engineering Department)**

	Residual oil and tracer studies, Defining enhanced oil recovery, Basic equations for fluid flow in porous media, Petrophysics and petrochemistry, Phase behaviour and fluid properties, Efficiency of waterflooding , Pore level mechanisms, Mobility control , capillary number, bond number correlations, Heterogeneity of pore structure and reservoirs, Thermal methods , Steam stimulation, steam flooding and hot water drive, Combustion- forward and reverse, Ancillaries in thermal methods, Miscible flooding, Surfactant flooding, Microemulsion flooding, Foam flooding, Polymer flooding, Micellar-polymer flooding, Alkaline flooding, Carbon dioxide flooding, Inert gas injection, Reactive gas injection, Microbial recovery
19.	**CET 1104E – Flow Though Porous Media (Chemical Engineering Department)** Relevance of pore structure in science and technology, Examples from oil reservoirs, catalysis, soil science, membranes, aquifers, foods, polymers, biology, etc., Pore structures and their determination, Capillarity and wettability, Models of pore structure, Wettability and flow histories, Single phase flow, Multiphase flow, Percolation processes and network models, Fractal models, Simulations of macroscopic properties, Pore level mechanisms of flow, Diffusion and dispersion in porous media, Membrane transport, Analysis of trickle and packed beds, Ultrafiltration, Models of catalyst poisoning and deactivation, Geostatistics
20.	**CET 1509E – Refinery Science and Engineering (Chemical Engineering Department)** Terminology, Origin, Kerogen, Occurrence, Recovery, Classification, Composition, Evaluation, Fractionation, Identification, Asphaltic constituents, Refining chemistry, Refining distillation, Thermal cracking, Catalytic cracking, Hydroprocessing, Reforming, Treatment processes, Gas cleaning, Products, Petrochemicals
21.	**CET 1206E – Fundamentals of Catalytic Science and Engineering (Chemical Engineering Department)** Relevance and examples, Atom economy and green chemistry concepts, Homogenous and heterogeneous catalysis, 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, Determination of surface structure though modern methods , Significance of Pore structure and models, Solid and surface chemistry of catalysis, Quantum mechanical, molecular mechanical and hybrid models, Catalyst design through artificial intelligence and computer modelling, Poisoning, promotion, deactivation and selectivity , Catalytic process engineering , Measurement of catalytic rates and kinetic parameters, Types of reactors
22.	**CET 1207E – Homogeneous Catalysis (Chemical Engineering Department)** Examples, Single phase and multiphase catalytic reactions, Acid--base catalysis, Transition metal catalysis, Bio-catalysis : Microbes and enzymes, Phase transfer catalysis, Micellar catalysis, Microemulsion catalysis, Electron transfer catalysis, Heteropoly acid catalysis, Homogeneous polymer catalysis, Heterogenisation of homogeneous catalysts, Catalysis by microwaves and ultrasound, Catalyst recovery and reuse
23.	**CET 1208E – Catalytic Green Science and Technology (Chemical Engineering Department)** 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, Catalyst design, preparation and activation, Clay and modified clays, Ion exchange resins, Zeolites and zeotypes , Heteropoly acids, Inorganic-organic catalysts, Immobilised enzymes, zeozymes, complexes, Electrochemical catalysis, Photocatalysis, Microwave catalysis, Ultrasound catalysis, Synergistic catalysis, Important examples from, Refinery industry -FCC, reforming, platforming, hydroforming, polymerisation, alkylation, isomerisation; hydrodesulfurisation, hydronitrogenation, Pharmaceutical and fine chemical industry, Dyestuff and intermediate industries, Perfume and flavour industry, Polymer industry, Textile industry, Paint industry, Edible oil industry, Food industry, Waste water treatment, Catalysis for auto-exhaust pollution abatement, DeNox, DeSOx technologies
24.	**CET 1602E – Colloid and Interfacial Science (Chemical Engineering Department)** Capillarity: Definition, Existence of surface tension/surface free energy, Laplace equation, Young Equation, Capillarity rise phenomena, Measurement of surface tension, Contact angle Wetting characteristics Surface Thermodynamics : Surface thermodynamic properties, Kelvin Eqn. Gibbs eqn, Surface Excess, Monolayer phase

	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 Micelles: Classes of surfactants, synthesis of surfactants, Micelle structures, Determination of HLB, Models for micelle formation, Swollen micelles, Hydrotropy Solubilization in micelles :Location of solubilizate in micelles, Measurement of solubilization, Spectroscopic methods:NMR, Fluorescence, IR etc, Detergency, selective solubilization Emulsions :Micro and macro emulsions, Stability of emulsions (Mechanical vs. thermodynamic), Bancroft rule, deemulsification, HLB for emulsion, multiple emulsions, applications Foams: Gibbs triangle, Film elasticity, drainage of films, Foam, defoaming, applications of foams
25.	**CET 1603E – Interfacial Science and Engineering (Chemical Engineering Department)** 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 aphrons. 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. Experimental techniques of measurement of relevant properties: surface tension, solubilization, thermodynamic properties, spectroscopic techniques Rheological aspects of two phase (involving microphases) flow and transport, visco-elasticity of surfactant solutions. Solubilization and catalysis by microphases: Models, theories and data, surface potential and equations of state, double layer theory, layer DebyeHuckel theory, Thermodynamics of solubilization, Hydrotropy Emulsification and Demulsification, foam breakage, theories of coalescence, and agglomeration, Brownian motion, shear and other models. Applications: Adsorption, foam fractionation, froth floatation Enhanced oil recovery, Novel separation processes, Coagulation, Flocculation, Microelectronics, surface vapour deposition, other applications with techniques Monte Carlo simulation for molecular dynamics of structures, graphics software for structural display., Diffusion on the surface and in microphases.
	CET 1403E – Adsorptive Separations (Chemical Engineering Department) Separation Processes: overview, alternative separation techniques, Mass separating agents Adsorbents: Molecular sieves activate carbon,zeolites alumina, silica ion exchangers, Polymeric adsorbents 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 Design of adsorbers: Gaseous and liquid phase adsorption Theoretical analysis of diffusion in relation to adsorption in micropores Chromatographic separations: Bulk chemicals separations, Purification, refining operations, Biochemical applications Novel separation techniques using adsorbents, Industrial examples
	CET 1209E – Advanced BioChemical Engineering (Chemical Engineering Department) Biotechnology, Biochemistry and microbiology, Enzymatic reactions, cell culturing Enzyme engineering, enzyme modifications, stability, reactivity and selectivity considerations Genetics and Genetic engineering, DNA recombinant technology, Hybridoma technology, single cell proteins, gene manufacturing Fermentation and design of fermenters with modified organisms

	Bioprocess simulations, molecular modelling for protein synthesis and drug design, protein engineering Applications in fermentation industry, pharmaceutical industry, medical field such as gene therapy, Biomedical engineering Bioreactor design, Scale up of bioreactions/reactors, Downstream processing in biochemical industry Organic synthesis using enzymes
	CET 1404E – Downstream Processing in Biochemical Industry (Chemical Engineering Department) 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 , 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, Aqueous two phase extraction, affinity partitioning, dye ligand partitioning, Reverse micellar extraction of proteins and enzymes, 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, Protein purifications, precipitation, affinity precipitation, adsorptive and chromatographic separations of proteins, design of adsorption columns, Methods of operation., Gel permeation chromatography, metal ligand chromatography, dye ligand chromatography, affinity chromatography, expanded bed chromatography, Applications in biochemical industry.
	CET 1405E – Advanced Separation Processes Membrane Processes : Principles of various membrane processes like Reverse Osmosis, pervaporation, gas separation and electro-dialysis. Design equations and module design. Concentration polarization. Adsorption and Ion Exchange Processes : Adsorption and ion exchange equilibria. Various isotherms. Contact filtration, design of fixed bed adsorber including breakthrough cuurve. Chromatographic Separations : Principles of chromatographic separation, criteria for effective separation, supports and methodology and process design. Separation of Racemic Mixtures : Principles of racemic modification and their application in separation of racemic mixtures with specific examples. Dissocaition Extraction, Reactive Extraction
	CET 1210E – Introduction to Polymer Engineering (Chemical Engineering Department) Introduction to Polymers : Classification based on application and history, Natural and synthetic polymers and types e.g. fibres, rubbers, adhesives, resins, plastics, etc. Classification based on properties/structures : Thermoplastic, thermosetting, crystalline, amorphous, molecular weights status, transitions, glass transition temperature Polymer formation/modification : Functionality and reactions, chain, ionic, condensation, co-ordination, complex polymerisation, Kinetic schemes, Orders of reactions, Cross-linking, Co-polymerisation, Heat effects 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.
	CET 1604E – Polymer Processing (Chemical Engineering Department) Plastic Technology : Moulding, (injection, blow) extrusion, cold-not and vacuum forming multipolymer systems. Equipment design and operating conditions Fibre Technology : Textile processing, fibre spinning and after treatment. Equipment design and operating conditions Elastomer Technology : Vulcanisation, Reinforcement compounding Equipment- design & operating conditions, environmental impact Recycle of polymers : Reprocessing techniques and limitations Selection of polymers : domestic & engineering usage Rheological and mechanical measurements concept of solution viscosity
	CET 1211E – Polymer Reactor Engineering (Chemical Engineering Department)

	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 Kinetic modelling of co-polymerisation processes.
	CET 1605E – Advanced topics in Polymer Chemistry/Physics Characterisation/Analysis of Polymers (Chemical Engineering Department) Structure/property relationship : Morphology & Cristallinity Mechanical and Chemical properties Structure/Rheology relationships Rheology, elasticity, Viscoelasticity, yield and fracture chemical resistance Properties of commercial polymers. PE, PP, Acrylic, amides & peptides phenolic & Urethane resins Role of Additives : Type of additives and their role in altering the properties Polymer composites : Carbon filled, fibre filled etc. Reinforced polymers 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. Selection of polymers, domestic and engineering usage.
	CET 1510E – Fuels Engineering (Chemical Engineering Department) Classification of fuels : G/L/S Automotive Fuels Bharat Standards II III & IV **Gaseous Fuels:** Natural Gas: Processing for pipe line specs CO_2/H_2S/COS Removal Gas dehydration Gas compression for pipe line transport Coal bed methane, Bio Gas (methane) CNG : As auto fuel, Compression, CNG stations 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 **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 **Solid Fuels** : Characterization - Coal - Biomass - Residue from Refinery - Plastic waste - Municipal domestic waste **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

	Gasification of i) Coal, Indian Coal ii) Biomass iii)Refinery Heavy Residue **Power generation**, combined cycle, cogeneration
	CET 1511E – Plant Utilities (Chemical Engineering Department) Role of Process Utilities in process industries. Impact on Project economics 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. Application of steam systems in chemical process plants, design of efficient steam heating systems, condensate utilization, flash steam, steam traps. Characteristics properties, classification, selection and industrial applications Characteristics of air and air receivers, instrument air. Inert gas generation Vacuum system engineering. Electrical Power : HT/LT Area classification, Motors/drives selection accordingly. Single line diagram. Emergency Drives Identification Emergency power. Inverters, DG sets. Etc. Estimation of utilities Utilities Audit
	CET 1512E – Project Management: Case Study Approach (Chemical Engineering Department) Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution : conception to commissioning. Project execution as conglomeration of technical and non technical activities. Detailed Engineering activities. Pre project execution main clearances and documents Project team : Role of each member. Importance Project site : Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process.
	CET 1606E – Advanced Materials (Chemical Engineering Department) Nanostructured Materials: Metal nano particles, their structure and properties Carbon nano tubes: manufacture, properties and applications. Nano materials in catalysis. Composite Materials: Polymer composites, metal-metal composites, polymer-metal composites, metal- ceramic composites. Superconducting Materials: Principles of superconductivity, properties, advantages and limitations of superconductors. Applications superconductors

Smart Materials: Shape memory alloys, Auxetic materials and Biomimmicking materials. Stimulii for sensors and actuators.

CET 1513E – Process Systems Engineering (Chemical Engineering Department)

Introduction to Systems Engineering: Systems and their origin, examples of problems in Systems Engineering

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

Structural Analysis of Systems: Graphs and digraphs: Representation of systems, Partitioning and Precedence Ordering of systems, Structural analysis of modeling equations, Structural controllability and observability of systems, Applications to engineering problems

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

Optimization of Systems: Theory and Algorithms: Basic concepts and definitions, Linear programming, Unconstrained nonlinear optimization, Nonlinear Programming, Combinatorial optimization, Applications to engineering problems

Simulation of Dynamic Systems: Basic concepts: Systems described by ODEs and DAEs, Formulating dynamic simulations; consistent initialization, Numerical integration of ODEs and DAEs, Modeling-simulation of hybrid Discrete/Continuous systems, Applications to engineering systems

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

CET 1106 – CFD applications in chemical processes (Chemical Engineering Department)

Derivation of equations of momentum and energy for turbulent flows.

Finite volume technique

One dimensional heat conduction and flow

Grid generation

Space and time discretization

Pressure velocity coupling (simple, simpler & SIMPLEC)

OpenFOAM software, simulation of pipe flow, backward step, flow past cylinder

Commercial software, simulation of pipe flow, backward step, flow past cylinder, stirred vessel, bubble column, cyclone separator, spray dryer etc.

Suggested Books:

Versteeg and malalasekera, "An introduction to computational fluid dynamics. The finite volume method", (2007)

Patankar S., "Numerical heat transfer and fluid flow", (1980)

CET 1407 – Process Design of Heat and Mass Transfer Equipment

(3 Credits: 2 Lectures + 1 Tutorial – 3 hours per week, 45 hrs total)

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. The topics will include some of the following equipment (but not limited to):

(1) Equipment for heat transfer: plate heat exchangers, plate fin exchangers, finned tube exchangers, thermo-siphon reboilers, evaporators, condensers, etc.

(2) Equipment for Unit operations: plate and packed columns, spray towers, etc.

(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.

CET 1408 Advanced Membrane Separations

Introduction : classification and definitions

Membrane Processes and their applications: Microfiltration, Ultrafiltration and micelle-enhanced ultrafiltration, Nanofiltration, Reverse osmosis, Dialysis, piezodialysis, electrodialysis, Pervaporation and membrane distillation, Gas permeation,Liquid membranes, Ion exchange membranes

Transport mechanisms, and mathematical modelling

Membranes: Design of membranes, Characterization
Polarisation and fouling: Polarisation phenomena and fouling concentration polarization, Characteristic flux behaviour in pressure driven membrane operation, Membrane fouling, Methods to reduce fouling
Process design: modules and configurations: Capillary, hollow fibre, tubular, Plate and frame, Spiral wound
Membrane reactors and their applications in biotechnology
Text books:
Mulder, M.H.V. Membrane Separations, Springer.
Philip, R., Wankat, C. Rate-Based Separations, Springer.
Reference books:
Nunes, S.P., Peinemann, K.V. Membrane Technology in the Chemical Industry, Wiley.
Rautanbach and R. Albrecht, Membrane Processes, Wiley.
Crespo, J.G., Bodekes, K.W. Membrane Processes in Separation and Purification, Kluwer Academic Publications.
Geankoplis, C.J. Transport Processes and Unit Operations, Prentice-Hall.

CET 1607 Biomaterials: Biodegradable Materials for Biomedical Applications
Introduction of Biomaterials
Biomaterials Surfaces: Structure and Properties, Surface Energy
Adsorption and Reconstruction at Surfaces,
Protein-Surface Interactions
Proteins: Structure, Properties, Functions, Protein Adsorption: Complex Phenomena, Measurement
Cell-Surface Interactions: Host Response to Biomaterials: Cell adhesion mechanism, coagulation cascade, immune response
Surface Characterization: AES, XPS, AFM, Contact Angle
Quantifying Cell Behavior: Cell Culture, Cellular Assays
Biosensors and Diagnostic devices
Drug Delivery: Controlled Release, Diffusion Controlled and Membrane based devices, Mechanical Pumps
Biomaterial for Organ Replacement
Mechanical Properties, Bone Substitutes
Introduction of Tissue Engineering: Cell, Scaffold design, Artificial liver, pancreas, cartilage
Regulatory overview
Text Books:
Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine. 2nd ed. Burlington, MA: Academic Press, 2004. ISBN: 9780125824637.

MAT XXXXE: Machine Learning
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
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.
Decision Trees, Bagging and Boosting, Random Forests, Gradient Boosting, Artificial Neural Network
Classification problem: Logistic Regression, Support Vector Machines, Receiver operating characteristic (ROC) curves, Area under the curve (AUC) and other related accuracy measures
Multivariate methods: Principal Component Analysis, Factor Analysis, Principal component regression, K-means clustering, Hierarchical Clustering, Multi-dimensional scaling
Text Books:
1.Andreas C. Müller and Sarah Guido, Introduction to Machine Learning with Python: David Barber A Guide for Data Scientists, (2016), O'Reilly Media.
2.Hands on Machine Learning with R by Bradley Boehmke and Brandon Greenwell, CRC Press, 2020.

	3.Introduction to Statistical Learning with Application in R by James, G., Witten, D., Hastie, T. and Tibshirani, R, 2011. 4. All of Statistics: A concise course on Statistical Inference by Larry Wasserman, 2009. 5. The Elements of Statistical Learning by Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie (2001), Springer. 6.Ethem Alpaydin, Introduction to Machine Learning by (2004), The MIT Press, Cambridge. 7. Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques by (2011), Elsevier 8. Machine Learning: A Probabilistic Perspective (Adaptive Computation and Machine Learning series) by Kevin P. Murphy (2012)
	MAT XXXXE: Optimization Techniques Review of local maximum/minimum Method of Lagrange Multipliers and KKT methods One dimensional Optimization Techniques: Fibonacci search method, Golden section method and interpolation method. Direct Search unconstrained optimization: Powell's method, Nelder-Mead (simplex) method Gradient Search Optimization Methods: Steepest Descent Method, Newton's Method, Conjugate gradient methods Linear Programming: Simplex Method, Revised Simplex Method and other Advanced Methods, Integer Programming Modern Optimization Techniques; Genetic Algorithms, Simulated Annealing, Ant Colony Optimization Textbooks: 1.Engineering Optimization: theory and practices, S.S. Rao, New Age International Pvt. Ltd. 2.An Introduction to Optimization, Edvin K. P. Chong & Stanislab H. Zak, Wiley Publication 3.Optimization for Engineering Design, K. Deb, Prentice Hall, India
	HUT 1102E: Perspectives of Society, Science and Technology History of Science and Technology and its relevance in the respective era Recent developments in technology (chemical, biotechnology energy, telecommunications, etc.) and their influence on society Economics and Sustainable Development Value system and Ethics in the profession of Technology, Science and Engineering. Problems before the World and India. Various approaches in solving them. Integrating Issue: Society and Science Industrial disasters and their effect on science and technology and society Environmental degradation, global warming and their effect on science and technology and society IPR issues and their relevance to science and technology and society Some aspects of future of Society, Technology, Science and Engineering. Interdependence of Theology and Science Impact of climate change on the nexus of water, energy and water Technology and World Peace Role of Innovation and R&D Industry-Academia Interaction to Enhance Standard of Living Textbooks: Science, Technology and Society: An Encyclopedia by Sal Restivo, Oxford University Press 2005 Science, Technology and Society: A Sociological Approach by Wenda K. Bauchspies, Jennifer Croissant, Sal P. Restivo Vision of STS: Counterpoints in Science Technology and Society Studies by Stephan H. Cutcliffe, Carl Mitcham, Sunny Press 2012

17. Five Year Integrated M. Tech. Degree Programme

The structure of the program, with the fifth year dedicated to research and startup development, creates a unique pathway for self-employment and job creation. Students will not only work on solving real-world problems but also develop innovations that can lead to the formation of startups. These startups can serve as platforms for self-employment, allowing students to turn their research into entrepreneurial ventures.

By focusing on projects that reach Technology Readiness Level (TRL) 5, students can ensure their ideas are ready for practical implementation. Through collaborative projects, they can pool their expertise with classmates, forming joint ventures that foster teamwork and innovation. This approach also opens opportunities to employ peers from the same class, as different facets of the project—such as research, development, marketing, and management—can benefit from diverse skill sets within the batch.

Additionally, the integration of Chemical Engineering Economics and Process Viability studies ensures that projects are not only technically sound but also financially sustainable, increasing the likelihood of successful startups that can scale, thereby generating more employment. The result is a robust environment where students can create self-employment opportunities and, through their ventures, provide jobs to others, ultimately contributing to economic growth and the creation of a thriving entrepreneurial ecosystem.