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

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

Offered by

INSTITUTE OF CHEMICAL TECHNOLOGY MUMBAI
MARATHWADA CAMPUS, JALNA

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

Elite Status and Center for Excellence

Government of Maharashtra

BT-5/6, Biotechnology Park, Additional MIDC Area,
Chhatrapati Sambhajinagar (Aurangabad) Road, Jalna: 431 203 (INDIA)

www.ictmumbai.edu.in, www.marj.ictmumbai.edu.in
Tel: (91-22) 3361 1111, Fax: 2414 5614

A. Preamble

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

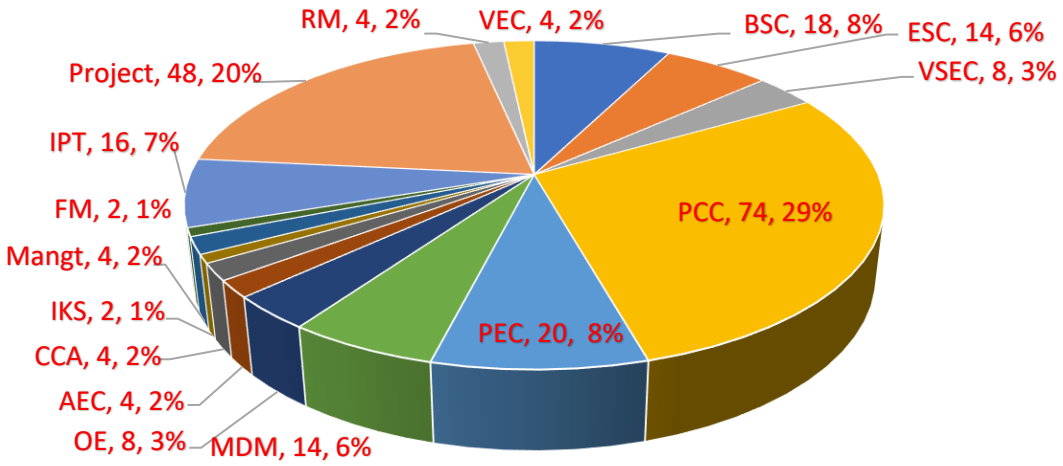


Figure 1. Distribution of various course types (in percentage) for the programme as per the guidelines of NEP 2020. This distribution does not include Honours courses having 18 credits in total.

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

B. Programme Education Objectives (PEOs)

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

C. Programme Outcome (POs)

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

D. Programme Specific Outcome (PSOs)

The graduates will be able to:

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

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

E. Graduate Attributes (GAs)

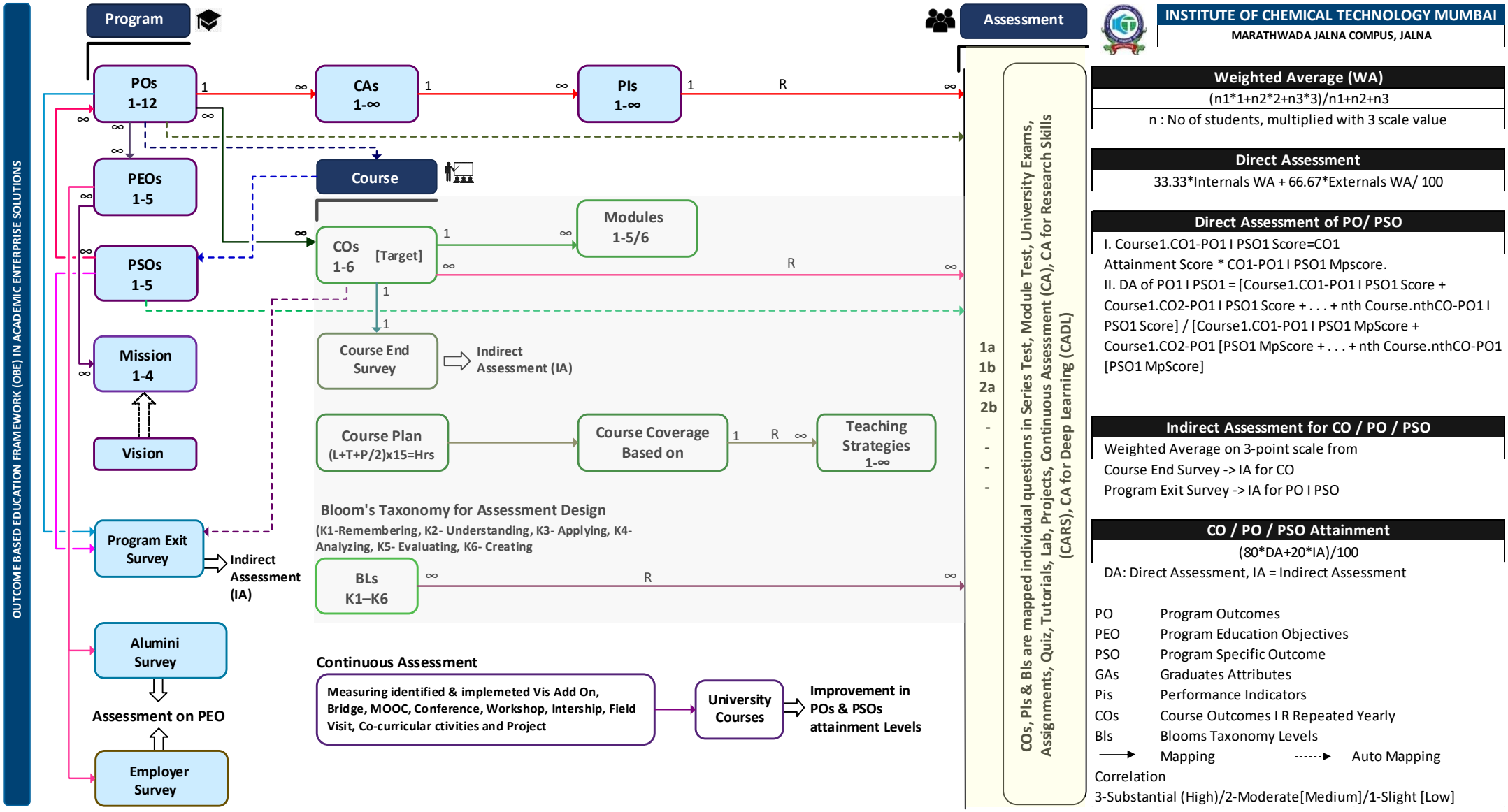
1. Problem analysis and solving skills.
2. Familiar with usage of modern tools, techniques
3. Communication Skills
4. Capacity to analyze new concepts.
5. Capacity to analyze and interpret experimental data Capacity to analyze business trends.
6. Capacity to design, optimize and operate equipment and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

F. Vision

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

G. Mission

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


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

H. Syllabus Structure for Int. M. Tech.

Semester I

Course Code	Subjects	Course Type	Credits	Hrs/Week			Marks for various Exams			
				L	T	P	C. A.	M. S.	E. S.	Total
CHT4151	Applied Chemistry	BSC	2	2	0	0	20	30	50	100
CHP4151	Applied Chemistry Lab	BSC	2	0	0	4	0	50	50	100
MAT4151	Mathematics-I	BSC	4	3	1	0	20	30	50	100
PHT4151	Applied Physics	BSC	2	2	0	0	20	30	50	100
PHP4151	Applied Physics Lab	BSC	2	0	0	4	0	50	50	100
EST4151	Structural Mechanics	ESC	2	2	0	0	20	30	50	100
ESP4151	Structural Mechanics Lab	ESC	2	0	0	4	0	50	50	100
ESP4152	Engineering Graphics with Computer Aided Modelling	VSEC	2	0	0	4	0	50	50	100
HUP4151	Communication Skills- English	AEC	2	2	0	0	0	50	50	100
HUP4152	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	2	0	0	4				
	Total		**22**	**11**	**1**	**20**				

Semester II

Course Code	Subjects	Course Type	Credits	Hrs/Week			Marks for various Exams			
				L	T	P	C. A.	M. S.	E. S.	Total
CHT4152	Applied Chemistry II	BSC	2	2	0	0	20	30	50	100
MAT4152	Mathematics: II	BSC	4	3	1		20	30	50	100
EST4153	Electrical Engineering and Basic Electronics	ESC	2	2	0	0	20	30	50	100
ESP4153	Electrical Engineering and Basic Electronics Lab	ESC	2	0	0	4	0	50	50	100
EST4152	Mechanical Engineering	ESC	4	2	1	0	20	30	50	100
EST4154	Introduction to Chemical Engineering	ESC	2	2	0	0	20	30	50	100
CEP4151	Material Balance and Energy Balance Calculations	PCC	2	0	0	4	0	50	50	100
ESP4154	Engineering Applications of Digital computers	VSEC	2	0	0	4	0	50	50	100
HUT4153	MOOC- Indian Knowledge System	IKS	2	2	0	0	20	30	50	100
HUP4154	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	2	0	0	4				
	Total		**24**	**13**	**2**	**16**				

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

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

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

Semester III

Course Code	Subjects	Course Type	Credits	Hrs/Week			Marks for various Exams			
				L	T	P	C. A.	M. S.	E. S.	Total
CET4251	Fluid Flow	PCC	2	1	1	0	20	30	50	100
CET4252	Heat Transfer	PCC	2	1	1	0	20	30	50	100
EST4155	Engineering Thermodynamics	PCC	2	1	1	0	20	30	50	100
CET4253	Industrial Chemistry and Reaction Engineering	PCC	4	3	1	0	20	30	50	100
CEP4251	Chemical Engineering Lab-I	PCC	2	0	0	4	0	50	50	100
XXT	From sciences and/or any other Engineering Discipline	MDM	2	2	0	0	20	30	50	100
CET	From Basic Sciences (Chemistry/ Physics/Biology / Maths)	OE	4	2	0	4	0	50	50	100
XXT	From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science)	OE	2	2	0	0	20	30	50	100
HUT4155	Communication Skills-Marathi (Any other language will be using MOOCS)	AEC	2	2	0	0	20	30	50	100
HUT4156	Basic Principles of Finance & Economics	Management	2	2	0	0	20	30	50	100
CET4257	Environmental Sciences	VEC	2	2	0	0	20	30	50	100
	Total		**26**	**18**	**4**	**8**				

Semester IV

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

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

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

Semester V

Course Code	Subjects	Course Type	Credits	Hrs/Week			Marks for various Exams			
				L	T	P	C. A.	M. S.	E. S.	Total
CET4351	Chemical Reaction Engineering	PCC	2	1	1	0	20	30	50	100
CET4352	Momentum Transfer	PCC	2	1	1	0	20	30	50	100
CET4353	Chemical Engineering Thermodynamics	PCC	4	3	1	0	20	30	50	100
CEP4253	Chemical Engineering Lab: III	PCC	2	0	0	4	0	50	50	100
CEP4255	Process Simulation Lab: I	PCC	2	0	0	4	0	50	50	100
CETxxxx	Chemical Engineering Elective-II	PEC	4	3	1	0	20	30	50	100
CETxxxx	Chemical Engineering Elective-III	PEC	4	3	1	0	20	30	50	100
XXT	From sciences and/or any other Engineering Discipline	MDM	2	1	1	0	20	30	50	100
XXP	From sciences and/or any other Engineering Discipline	MDM	2	0	0	2	0	50	50	100
CET4361	Honors Course -1/Research-1	PCC	4	3	1	0	20	30	50	100
	Total		**28**	**15**	**7**	**10**				

Semester VI

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

Semester VII

Course Code	Subjects	Course Type	Credits	Hrs/Week			Marks for various Exams			
				L	T	P	C. A.	M. S.	E. S.	Total
CET4451	Chemical Process Development and Engineering	PCC	3	2	1	0	20	30	50	100
CET4452	Chemical Industrial Management	PCC	2	2	0	0	20	30	50	100
CETxxxx	Chemical Engineering Elective V	PEC	4	3	1	0	20	30	50	100
CEP4451	Chemical Process Equipment Design and drawing	PCC	2	0	0	4	0	50	50	100
CET4364	Honours Course-4/Research-4	PCC	2	2	0	0	20	30	50	100
CET4365	Honours Course-5/Research-5	PCC	4	3	1	0	20	30	50	100
XXT	From sciences and/or any other Engineering Discipline	MDM	2	2	0	0	20	30	50	100
CEP4452	Literature Review	RM	2	1	0	2	0	50	50	100
CEP4453	Design and Analysis of Experiments	RM	2	1	0	2	0	50	50	100
CEP4461	Design Project - I	Project	4	0	0	8	20	30	50	100
	Total		**27**	**16**	**3**	**16**				

Semester VIII

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

Semester IX

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

Semester X

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

BSC: Basic Science Course

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

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

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

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

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

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

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

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

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

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

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

EXIT Options

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

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

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

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

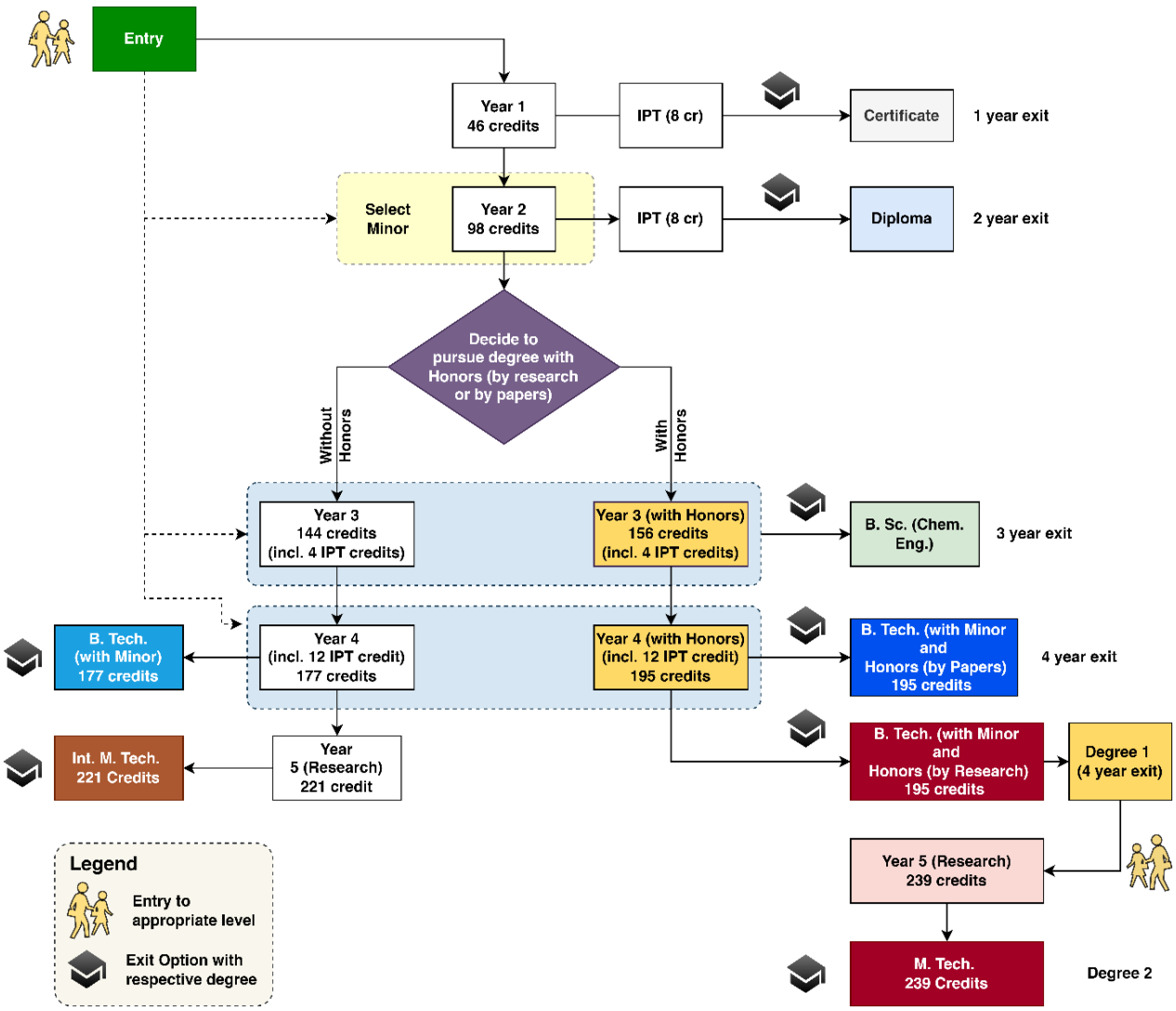


Figure 2. A map of options available for entry to Integrated Master of Technology in Chemical Engineering.

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

Sem	Course Code	Course Name	Course Type	Mapping of Course Outcomes (COs) with Programme Outcomes (POs)											
				PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
First Year															
I	CHT4151	Applied Chemistry	BSC	3	2	1	1	2	-	-	-	-	1	1	1
	CHP4151	Applied Chemistry Lab	BSC	3	3	1	2	2	1	-	-	-	2	2	1
	MAT4151	Mathematics-I	BSC	3	2	2	2	2	2	2	-	-	2	1	1
	PHT4151	Applied Physics	BSC	3	3	2	1	1	1	-	1	-	1	1	1
	PHP4151	Applied Physics Lab	BSC	3	1	1	2	1	-	-	-	-	1	-	-
	EST4151	Structural Mechanics	ESC	3	2	2	1	1	2	1	-	-	2	-	-
	ESP4151	Structural Mechanics Lab	ESC	3	1	1	-	-	-	-	-	-	1	-	-
	ESP4152	Engineering Graphics with Computer Aided Modelling	VSEC	2	1	1	1	2	-	1	-	-	1	1	1
	HUP4151	Communication Skills- English	AEC	-	-	2	1	1	1	-	-	-	3	1	-
	HUP4152	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	-	-	-	-	-	-	-	3	3	-	3	-
II	CHT4152	Applied Chemistry II	BSC	3	2	1	1	2	-	-	-	-	2	2	-
	MAT4152	Mathematics: II	BSC	3	2	1	2	2	1	-	-	-	-	1	1
	EST4153	Electrical Engineering and Basic Electronics	ESC	3	2	1	1	1	1	1	-	-	1	1	-
	ESP4153	Electrical Engineering and Basic Electronics Lab	ESC	3	2	1	1	1	1	1	-	-	1	-	-
	EST4152	Mechanical Engineering	ESC	3	2	1	1	1	2	2	-	-	-	-	-
	EST4154	Introduction to Chemical Engineering	ESC	2	2	1	2	1	1	1	1	-	2	1	1
	CEP4151	Material Balance and Energy Balance Calculations	PCC	2	2	1	2	1	1	1	1	-	1	1	1
	ESP4154	Engineering Applications of Digital computers	VSEC	-	2	2	2	2	1	-	1	-	1	-	1
	HUT4153	MOOC- Indian Knowledge System	IKS	-	-	-	-	-	2	1	3	1	3	-	-
	HUP4154	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	-	-	-	-	-	-	-	3	3	-	3	-
Second Year															
III	CET4251	Fluid Flow	PCC	3	3	1	1	1	1	1	1	-	1	2	1

	CET4252	Heat Transfer	PCC	-	3	1	2	2	1	2	1	-	1	1	1
	EST4155	Engineering Thermodynamics	PCC	3	3	-	2	1	1	1	1	-	1	1	-
	CET4253	Industrial Chemistry and Reaction Engineering	PCC	3	2	1	2	2	1	1	-	-	1	1	2
	CEP4251	Chemical Engineering Lab-I	PCC	3	2	2	2	2	1	1	-	-	2	1	1
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	1	-	-	-	2	3	-	1	2	1	1
	CET	From Basic Sciences (Chemistry/ Physics/Biology / Maths)	OE	3	1	-	1	-	2	2	-	2	1	-	-
	XXT	From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science)	OE	3	1	-	2	-	2	2	-	2	1	-	-
	HUT4155	Communication Skills-Marathi (Any other language will be using MOOCS)	AEC	-	-	-	-	-	-	-	-	-	3	-	-
	HUT4156	Basic Principles of Finance & Economics	Management	-	1	3	2	-	1	1	-	-	1	1	1
	CET4257	Environmental Sciences	VEC	1	1	1	2	1	-	1	-	2	1	1	1
IV	CET4254	Chemical Engineering Operations	PCC	3	3	3	3	-	1	3	-	-	2	2	1
	CET4255	Process Safety	PCC	3	3	3	3	-	1	3	-	-	1	1	-
	CET4256	Instrumentation and Process Dynamics	PCC	3	2	2	2	2	2	1	-	-	2	2	-
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	2	1	2	1	3	2	1	2	1	2	2
	XXP	From sciences and/or any other Engineering Discipline	MDM	3	1	2	1	2	3	3	2	2	1	2	2
	XXT	From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science)	OE	3	1	-	2	-	2	2	-	2	1	-	-
	CEP4252	Chemical Engineering Lab-II	PCC	3	2	2	2	2	1	1	-	-	2	1	1
	HUT4157	Industrial Management	Management	2	3	3	2	2	1	-	-	2	1	3	1
	ESP4157	Digital Computation in Emerging areas (AI/ML/DA)	VEC	-	-	-	-	-	3	-	1	-	2	2	-
	HUP4158	Community Projects	Field Project	-	2	1	1	2	1	-	-	1	2	3	3
	CETxxxx	Chemical Engineering Elective: I	PEC	2	3	3	2	2	1	1	-	-	1	1	1
Third Year															

V	CET4351	Chemical Reaction Engineering	PCC	3	2	2	1	2	2	3	-	-	1	1	-
	CET4352	Momentum Transfer	PCC	3	2	2	2	1	2	2	-	-	1	1	-
	CET4353	Chemical Engineering Thermodynamics	PCC	3	2	1	2	1	2	1	-	-	-	2	-
	CEP4253	Chemical Engineering Lab: III	PCC	3	2	2	2	2	1	1	-	-	2	1	1
	CEP4255	Process Simulation Lab: I	PCC	2	2	2	1	1	1	-	2	-	-	2	-
	CETxxxx	Chemical Engineering Elective-II	PEC	3	2	1	1	2	2	1	1	3	-	2	-
	CETxxxx	Chemical Engineering Elective-III	PEC	3	2	1	1	2	2	1	1	3	-	2	-
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	1	2	1	2	3	3	2	2	1	2	2
	XXP	From sciences and/or any other Engineering Discipline	MDM	3	1	2	1	2	3	3	2	2	1	2	2
	CET4361	Honors Course -1/Research-1	PCC	3	2	3	2	2	1	3	-	-	2	2	-
VI	CET4362	Honors Course 2/Research-2	PCC	3	2	1	2	2	2	2	-	-	2	2	-
	CET4354	Chemical Process Control	PCC	3	2	2	1	2	2	1	-	1	-	3	-
	CET4356	Separation Processes	PCC	3	2	2	1	2	2	2	-	-	1	2	-
	CET4357	Heat Transfer Equipment design	PCC	3	2	2	1	2	2	2	-	-	1	1	-
	CETxxxx	Chemical Engineering Elective-IV	PEC	3	2	1	1	2	2	1	1	3	-	2	-
	CET4363	Honours Course-3/Research-3	PCC	3	2	2	2	2	1	2	-	-	1	2	-
	XXT	From Sciences and/or any other Engineering Discipline	MDM	3	2	3	2	1	2	2	3	3	3	3	2
	CEP4256	Process Simulation Lab-II	VSEC	2	2	2	1	1	1	-	2	-	-	2	-
	CEP4254	Chemical Engineering Lab-IV	PCC	3	2	2	2	2	1	1	-	-	2	1	1
	CET4358	Chemical Project Economics	PCC	3	1	2	1	2	3	2	-	-	1	2	1
	CET4373	IPT (after Semester VI exams for Eight weeks)	IPT	3	2	2	2	1	2	2	1	2	1	3	2
Fourth Year																
VII	CET4451	Chemical Process Development and Engineering	PCC	3	1	2	1	2	1	2	-	-	3	2	1
	CET4452	Chemical Industrial Management	PCC	-	-	2	1	-	1	-	3	1	2	2	2
	CETxxxx	Chemical Engineering Elective V	PEC	3	2	1	1	2	2	1	1	3	-	2	-
	CEP4451	Chemical Process Equipment Design and drawing	PCC	3	1	1	1	2	3	3	-	-	2	2	2

	CET4364	Honours Course-4/Research-4	PCC	1	2	3	2	2	3	3	1	1	1	2	-
	CET4365	Honours Course-5/Research-5	PCC	2	3	2	2	3	2	3	-	-	1	2	-
	XXT	From sciences and/or any other Engineering Discipline	MDM	2	1	1	2	2	3	3	2	2	2	3	3
	CEP4452	Literature Review	RM	2	3	3	2	1	1	2	1	-	3	2	-
	CEP4453	Design and Analysis of Experiments	RM	3	1	1	1	2	2	2	-	-	3	1	-
	CEP4461	Design Project - I	Project	3	2	2	2	2	1	2	1	2	3	2	-
VIII	CEP4474	IPT (4-6 months)	IPT	3	2	2	2	1	2	2	1	2	1	3	2
Fifth Year															
IX	CET4551	Advanced Transport Phenomena	PCC	3	2	2	2	2	1	1	-	-	2	2	-
	CET4552	Advanced Separation Processes	PCC	2	3	2	2	2	1	2	-	-	1	1	-
	CET4553	Advanced Reaction Engineering	PCC	3	2	2	2	2	2	2	-	-	1	1	-
	CET4554	Advanced Mass transfer	PCC	3	2	2	2	2	2	2	-	-	2	1	-
	CEP4563	Thesis	Research	3	2	2	2	2	1	2	1	2	2	3	3
X	CEP4564	Thesis	Research	3	2	2	2	2	1	2	1	2	2	3	3

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

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

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

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

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

Sem	Course Code	Course Name	Course Type	Mapping of Course Outcomes (COs) with Programme Outcomes (POs)				
				PSO1	PSO2	PSO3	PSO4	PSO5
		First Year						
I	CHT4151	Applied Chemistry	BSC	2	2	3	2	1
	CHP4151	Applied Chemistry Lab	BSC	3	2	1	1	1
	MAT4151	Mathematics-I	BSC	3	2	3	3	1
	PHT4151	Applied Physics	BSC	2	3	2	2	1
	PHP4151	Applied Physics Lab	BSC	3	3	2	1	1
	EST4151	Structural Mechanics	ESC	3	2	2	2	1
	ESP4151	Structural Mechanics Lab	ESC	3	2	1	1	-
	ESP4152	Engineering Graphics with Computer Aided Modelling	VSEC	3	2	1	2	1
	HUP4151	Communication Skills- English	AEC	2	2	3	1	-
	HUP4152	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	3	-	-	-	-
II	CHT4152	Applied Chemistry II	BSC	2	2	2	1	-
	MAT4152	Mathematics: II	BSC	3	2	2	1	1
	EST4153	Electrical Engineering and Basic Electronics	ESC	3	2	2	1	1
	ESP4153	Electrical Engineering and Basic Electronics Lab	ESC	2	1	1	1	-
	EST4152	Mechanical Engineering	ESC	3	2	1	1	1
	EST4154	Introduction to Chemical Engineering	ESC	3	3	2	2	1
	CEP4151	Material Balance and Energy Balance Calculations	PCC	2	2	2	1	1
	ESP4154	Engineering Applications of Digital computers	VSEC	2	2	1	1	1
	HUT4153	MOOC- Indian Knowledge System	IKS	3	2	-	-	-
	HUP4154	OPEN Activity- Sports/ Fine arts/Yoga/ Music/NSS	CCA	3	-	-	-	-
		Second Year						
III	CET4251	Fluid Flow	PCC	2	2	2	2	1
	CET4252	Heat Transfer	PCC	3	2	3	3	1
	EST4155	Engineering Thermodynamics	PCC	2	3	2	2	1
	CET4253	Industrial Chemistry and Reaction Engineering	PCC	2	3	2	2	1
	CEP4251	Chemical Engineering Lab-I	PCC	1	2	1	2	2
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	3	3	2	1
	CET	From Basic Sciences (Chemistry/ Physics/Biology / Maths)	OE	3	2	1	-	-
	XXT	From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science)	OE	3	2	1	-	-
	HUT4155	Communication Skills-Marathi (Any other language will be using MOOCS)	AEC	2	-	-	-	-
	HUT4156	Basic Principles of Finance & Economics	Management	3	3	2	1	1

	CET4257	Environmental Sciences	VEC	2	3	3	1	-
IV	CET4254	Chemical Engineering Operations	PCC	3	3	2	1	1
	CET4255	Process Safety	PCC	2	2	2	1	1
	CET4256	Instrumentation and Process Dynamics	PCC	3	2	1	1	1
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	2	1	2	-
	XXP	From sciences and/or any other Engineering Discipline	MDM	3	2	1	2	1
	XXT	From Basic Sciences (Chemistry/ Physics/Biology / Maths/ material Science)	OE	3	2	1	-	-
	CEP4252	Chemical Engineering Lab-II	PCC	1	2	1	2	2
	HUT4157	Industrial Management	Management	2	2	2	1	3
	ESP4157	Digital Computation in Emerging areas (AI/ML/DA)	VEC	2	-	-	-	-
	HUP4158	Community Projects	Field Project	3	2	2	2	3
	CETxxxx	Chemical Engineering Elective: I	PEC	3	2	3	3	2
		Third Year						
V	CET4351	Chemical Reaction Engineering	PCC	2	2	3	3	1
	CET4352	Momentum Transfer	PCC	3	2	2	1	1
	CET4353	Chemical Engineering Thermodynamics	PCC	2	3	2	2	1
	CEP4253	Chemical Engineering Lab: III	PCC	1	2	1	2	2
	CEP4255	Process Simulation Lab: I	PCC	2	2	3	3	1
	CETxxxx	Chemical Engineering Elective-II	PEC	2	3	3	2	1
	CETxxxx	Chemical Engineering Elective-III	PEC	2	3	3	2	1
	XXT	From sciences and/or any other Engineering Discipline	MDM	3	2	1	2	1
	XXP	From sciences and/or any other Engineering Discipline	MDM	3	2	1	2	1
	CET4361	Honors Course -1/Research-1	PCC	2	2	3	3	2
VI	CET4362	Honors Course 2/Research-2	PCC	2	2	3	3	2
	CET4354	Chemical Process Control	PCC	2	2	3	3	1
	CET4356	Separation Processes	PCC	2	2	1	2	1
	CET4357	Heat Transfer Equipment design	PCC	2	1	2	2	1
	CETxxxx	Chemical Engineering Elective-IV	PEC	2	3	3	2	1
	CET4363	Honours Course-3/Research-3	PCC	2	3	3	3	2
	XXT	From Sciences and/or any other Engineering Discipline	MDM	3	2	1	2	1
	CEP4256	Process Simulation Lab-II	VSEC	1	2	3	3	1
	CEP4254	Chemical Engineering Lab-IV	PCC	2	1	2	2	2
	CET4358	Chemical Project Economics	PCC	2	2	3	1	1
	CET4373	IPT (after Semester VI exams for Eight weeks)	IPT	3	2	2	3	3
		Fourth Year						
VII	CET4451	Chemical Process Development and Engineering	PCC	2	2	3	3	2

	CET4452	Chemical Industrial Management	PCC	2	3	2	1	1
	CETxxxx	Chemical Engineering Elective V	PEC	2	3	3	2	1
	CEP4451	Chemical Process Equipment Design and drawing	PCC	3	2	3	2	2
	CET4364	Honours Course-4/Research-4	PCC	2	2	2	2	1
	CET4365	Honours Course-5/Research-5	PCC	3	1	2	2	1
	XXT	From sciences and/or any other Engineering Discipline	MDM	2	1	2	2	3
	CEP4452	Literature Review	RM	3	2	2	2	1
	CEP4453	Design and Analysis of Experiments	RM	3	2	2	2	-
	CEP4461	Design Project - I	Project	2	2	2	3	2
VIII	CEP4474	IPT (4-6 months)	IPT	2	2	3	3	2
		Fifth Year						
IX	CET4551	Advanced Transport Phenomena	PCC	1	2	3	3	1
	CET4552	Advanced Separation Processes	PCC	2	3	3	2	2
	CET4553	Advanced Reaction Engineering	PCC	2	3	3	2	1
	CET4554	Advanced Mass transfer	PCC	2	3	3	2	1
	CEP4563	Thesis	Research	2	3	3	3	3
X	CEP4564	Thesis	Research	2	3	3	3	3

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

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

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

Sem	Course Code	Course Name	Course Type	Mapping of Course Outcomes (COs) with Programme Outcomes (POs)				
				PSO1	PSO2	PSO3	PSO4	PSO5
		Elective Course						
V	CET 2769E	Process Intensification	PEC	3	2	3	3	2
V	CET2161	Chemical Safety and Risk Management	PEC	3	2	2	1	1

First Year

Semester-I

Semester I					
	Course Code: CHT4151	**Course Title:** Applied Chemistry	**Credits 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**0**	**0**
List of prerequisite courses					
	Standard XII (Chemistry)				
List of courses where this course will be prerequisite					
	Material Balance and Energy Calculations (CEP4151); Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Operation (CET4254), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451), Catalytic Science and Engineering (Hon.)				
Description of relevance of this course in the Int. M. Tech. Program					
To introduce the students to the principles of analytical chemistry and physical chemistry Describe the fundamental concepts related to Basic instrumentation and chromatographic analysis. To the Thermodynamics of surfaces and kinetics of the chemical reactions To study the role of heterogeneous catalysis in chemical reactions					
	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 SNAr 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		
	Total		**30**		
List of Textbooks/ Reference 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				
Course Outcomes (students will be able to….)					
CO1	Students will learn basic principles of applied chemistry		K2		
CO2	Student will be able to select apply the knowledge of applied chemistry.		K3		
CO3	Student will learn concept of organometallic chemistry and its application in organic transformation		K3		
CO4	Student will apply the basic concept in solving the engineering and science problem		K3		
CO5	Student will estimate and analyze the fundamental knowledge of basic science		K5		
CO6	Student will be able to create an idea and thought to apply knowledge of applied chemistry		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

Applied Chemistry: CHT4151 Mapping of Course Outcomes (COs) with Programme Outcomes (POs)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	1	1	-	-	-	-	2	1	1
CO2	-	2	1	1	2	-	-	-	-	1	1	-
CO3	3	2	1	1	-	-	-	-	-	1	-	-
CO4	3	2	1	1	2	-	-	-	-	1	1	1
CO5	3	3	2	2	1	-	-	-	-	1	-	-
CO6	2	2	1	1	2	-	-	-	-	-	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Applied Chemistry: CHT4151 Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	1	-
CO2	2	1	2	1	-
CO3	1	2	3	2	1
CO4	2	2	3	2	1
CO5	3	2	2	1	-
CO6	2	3	2	1	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

Semester I					
	Course Code: CHP4151	**Course Title:** Applied Chemistry Laboratory	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	Standard XII Chemistry				
List of Courses where this course will be prerequisite					
	Applied Mathematics: II (MAT4151)				
Description of relevance of this course in the Int. M. Tech. Program					
To learn to prepare standard solutions and volumetric titration. To learn the quality and quantitative of a sample through different analytical methods To learn to collect, collate, and interpret results					
	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 derivatization. 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-meter c) Detection / quantitative determination of cations / anions in salts.		20		
	Total		**60**		
List of Textbooks/ Additional Reading Material / Reference Books					
1	Practical Organic Chemistry, by I.L. Finar				
2	Practical physical Chemistry: B. Viswanathan and P.S. Raghavan				
3	Practical physical Chemistry- Alexander Findlay				
Course Outcomes (students will be able to….)					
	Students will be able to				
CO1	Able to prepare and standardized analytical solutions		K3		
CO2	Able to plan simple analytical experiments for analyte determination		K3		
CO3	Able to perform qualitative and quantitative analysis of given sample using chromatographic techniques		K4		
CO4	Able to clearly communicate the results of experimental work in oral and written formats.		K5		
CO5	Able to estimate and evaluate the experimental finding of performed experiments		K5		
CO6	Able to prepare the report and assess the results		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

Applied Chemistry Laboratory: CHP4151 Mapping of Course Outcomes (COs) with Programme Outcomes (POs)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	1	-	2	1	-	-	-	1	2	1
CO2	2	2	1	1	1	-	-	-	-	2	1	-
CO3	3	2	1	2	2	-	-	-	-	-	-	-
CO4	3	3	1	2	2	1	-	-	-	2	2	1
CO5	2	2	2	1	1	-	-	-	-	-	-	-
CO6	3	3	2	-	-	-	-	-	-	-	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Applied Chemistry Laboratory: CHP4151 Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1	1	-
CO2	2	2	1	-	-
CO3	3	2	1	-	1
CO4	3	2	1	1	1
CO5	2	3	2	-	-
CO6	2	2	2	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

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

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

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

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

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

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

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

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

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

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

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

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

Semester I					
	Course Code: PHP4151	**Course Title:** Applied Physics Laboratory	**Credits 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
1	Standard XI and XII Physics course; Applied Physics (theory) in tandem				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
The hands-on experience gained by the students in the Applied Physics laboratory course will equip them with basic experimental skills related to measurement of various important physical quantities. These skills will act as a useful foundation for other laboratory and theory courses in their area of specialization.					
	Course Contents (List of Experiments)				
1	Determination of Co-efficient of Viscosity by Poiseuille's method		4		
2	Thermistor characteristics: Determination of Bandgap of a semiconductor		4		
3	Determination of compressibility of liquids using an Ultrasonic Interferometer		4		
4	Measurement of thermal conductivity of a solid: Lee's disc method		4		
5	Photoelectric effect: Determination of h/e		4		
6	Hall effect-I (sample current variation) Determination of carrier type and concentration in a semiconductor		8		
7	Hall effect-II (magnetic field variation) Determination of carrier type and concentration in a semiconductor		4		
8	Newton's rings: Determination of wavelength of light		4		
9	Laser Diffraction: Determination of particle size		4		
10	Studying variation of compressibility of liquid as function of temperature		8		
11	Estimating resistivity of semiconductor using four probe method		8		
12	Determination of magnetic susceptibility of paramagnetic liquid using Quincke's method		4		
	Total		**60**		
List of Textbooks/Reference books					
1	Fundamentals of Physics - Halliday, Resnick, Walker - 6th Edition - John Wiley				
2	Sears and Zeemansky's University Physics - Young and Freedman - Pearson Education				
4	Engineering Physics - V Rajendran - 6th Edition - McGraw Hill Publishers				
5	Concepts of Modern Physics - A. Beiser, McGraw-Hill.				
6	Ultrasonics: Methods and Applications - J. Blitz, Butterworth.				
7	Optics - Ajoy Ghatak - 7th Edition - McGraw Hill				
8	Fundamentals of Optics - F. Jenkins and H. White - 4th Edition McGraw Hill				
9	ICT Physics Laboratory Manual (supplied to students)				
Course Outcomes (students will be able to….)					
	Students will be able to				
CO1	Understand monochromatic light source and its applications.		K2		
CO2	Understand engineering applications of lasers		K2		
CO3	Measure thermal conductivity, photoelectric current, effect of magnetic field on electric current and its applications		K4		
CO4	Analyze and estimate the experimental data		K4		
CO5	Evaluate the experimental value by analyzing the experimental data		K5		
CO6	Prepare and write the report		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

Applied Physics Laboratory: PHP4151 Mapping of Course Outcomes (COs) with Programme Outcomes (POs)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	-	1	-	-	-	-	1	-	-
CO2	3	1	2	-	1	-	-	-	-	1	-	-
CO3	2	1	1	2	1	-	-	-	-	-	-	-
CO4	3	1	1	2	1	-	-	-	-	1	-	-
CO5	3	2	2	-	-	-	-	-	-	-	-	-
CO6	2	1	2	-	-	-	-	-	-	-	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Applied Physics Laboratory: PHP4151 Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	1	-
CO2	2	2	1	-	-
CO3	2	3	2	2	1
CO4	3	3	2	1	1
CO5	3	2	1	-	-
CO6	2	1	2	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

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

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

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

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

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

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

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

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

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

Semester I					
	Course Code: ESP4152	**Course Title** Engineering Graphics and Computer Aided Drafting (CAD)	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	Basic Geometry				
List of Courses where this course will be prerequisite					
	Engineering Graphics: II (ESP4152), Equipment Design and Drawing (CEP4451), Structural Mechanics (EST4151)				

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

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

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Orthographic projections:** 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 software, 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 software.	08
6	**Assembly drawing using CAD:** Basics of Assembly drawing, preparation of 3d components and assembling on CAD software, labelling and table creation for bill of materials	12
	Total	**60**

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

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

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

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

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

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

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

Semester I					
	Course Code: HUP4151	**Course Title:** Communication Skills - English	**Credits = 2**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Basic English Language of the XII Grade Level				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
This is an important course for the effective functioning of an Engineer. Communication skills are required in all courses.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Communication as a way of life 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? Presenting 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		
	Total		**30**		
List of Text Books					
1	THE SCIENCE OF EFFECTIVE COMMUNICATION: Improve Your Social Skills and Small Talk, Develop Charisma and Learn How to Talk to Anyone- Ian Tuhovsky				
2	The Quick and Easy Way to Effective Speaking- Dale Carnegie				
List of Additional Reading Material / Reference Books					
1	The Hindu Businessline				
2	National Newspapers' editorials				

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

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

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

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

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

First Year

Semester-II

Semester II					
	Course Code: CHT4152	**Course Title:** Applied Chemistry II	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Standard XII Chemistry				
List of Courses where this course will be prerequisite					
	Material and Energy Balance Calculations (CEP4151), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Operation (CET4251), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451), Biochemical Engineering (Hon.), Catalytic Science and Engineering (Hon.)				
Description of relevance of this course in the Int. M. Tech. Program					
Understand reactions and structure activity relationship in organic molecules. Write simple mechanisms of aromatic reactions.					
	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		10		
3	**Aromatic compounds:** Problems associated with SNAr reactions and how to overcome them. Mechanism for aromatic nucleophilic substitutions		4		
4	**Organometallics:** Metal-ligand bonding, Concepts of sigma and pi bond formation. Types of ligands, CO and PPh3 ligands.		6		
5	**Basic reactions of organometallic compounds:** insertion, migration, oxidative addition, reductive elimination. E.g., Wilkinsons, Grignard Reagent etc.		6		
	Total		**30**		
List of Textbooks/ Reference Books					
1	Organic chemistry: T. W. G Solomons, C. B. Fryhle, John Wiley and Sons				
2	Organic chemistry, Clayden, Greeves, Warren, Oxford publication				
3	Organic Chemistry, Paula Y. Bruice, Pearson Education				
4	The Organometallic Chemistry of the Transition Metals by Robert H. Crabtree				
5	March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure 7 Edition (English, Paperback, Michael B. Smith)				
6	Basic Inorganic Chemistry, F.A. Cotton and G. Wilkinson, John Wiley and Sons				
Course Outcomes (students will be able to…..)					
CO1	Understand reactions and structure activity relationship in organic molecules.		K2		
CO2	Write simple mechanisms of aromatic reactions.		K3		
CO3	Describe the fundamental concepts related to name reactions, organometallics, Metal-ligand bonding, and types of ligands		K3		
CO4	Role of Wilkinsons, Grignard Reagent in chemical reactions		K2		
CO5	Student will estimate and analyze the fundamental knowledge of basic science		K5		
CO6	Student will be able to create an idea and thought to apply knowledge of applied chemistry		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

Applied Chemistry II: CHT4152 Mapping of Course Outcomes (COs) with Programme Outcomes (POs)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	1	1	-	-	-	-	2	1	-
CO2	-	2	1	1	2	-	-	-	-	2	2	-
CO3	3	2	1	1	-	-	-	-	-	2	2	-
CO4	3	1	-	-	-	-	-	-	-	-	1	-
CO5	3	2	1	1	2	-	-	-	-	2	2	-
CO6	2	3	2	1	-	-	-	-	-	-	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Applied Chemistry II: CHT4152 Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	-	-
CO2	1	2	2	1	1
CO3	1	2	1	3	1
CO4	2	1	2	1	-
CO5	2	2	2	1	-
CO6	3	2	1	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

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

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

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

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

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

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

Semester II					
	Course Code: EST4153	**Course Title:** Electrical Engineering and Basic Electronics	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics courses, Applied Physics: II (PHT4151)				
List of Courses where this course will be prerequisite					
	Chemical Process Control (CET4354), Energy Engineering				
Description of relevance of this course in the Int. M. Tech. Program					
Students will get an insight into the importance of Electrical Energy in Chemical Plants. The students will understand the basics of electricity, and the selection of diverse types of drives for a given application process. They will get basic knowledge as regards to Power supplies, instrumentation amplifiers and thyristor application in industries.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	**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		
	Total		**30**		
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….)					
CO1	Understand the basic concepts of D.C., single phase and three phase AC supply and circuits Solve basic electrical circuit problems		K2		
CO2	Understand the basic concepts of transformers and motors used as various industrial drives.		K2		
CO3	Understand the basic concepts of electronic devices and their applications in power supplies, amplification, and instrumentation		K2		
CO4	Understand the basic concepts of Data acquisition, signal conditioning		K2		
CO5	Analyze and evaluate the electrical engineering fundamental principle		K5		
CO6	Create the electrical instrumentation		K6		

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

Electrical Engineering and Basic Electronics: EST4153 **Mapping of Course Outcomes (COs) with Programme Outcomes (POs)**												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	-	1	1	-	-	1	1	-
CO2	3	2	1	2	1	1	1	-	-	1	-	-
CO3	1	2	1	1	1	1	-	-	-	-	1	-
CO4	3	-	-	1	-	-	2	-	-	1	1	-
CO5	3	2	1	1	1	1	1	-	-	1	1	-
CO6	3	2	1	1	1	2	1	-	-	-	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Electrical Engineering and Basic Electronics: EST4153 **Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	2	-
CO2	2	2	2	2	-
CO3	2	3	2	1	1
CO4	2	2	1	-	-
CO5	3	2	2	1	1
CO6	2	2	1	-	-
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

Semester II					
	Course Code: ESP4153	**Course Title:** Electrical Engineering and Basic Electronics Laboratory	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	XIIth Standard Mathematics and Physics courses, Applied Physics I (PHT4151), Electrical Engineering and Electronics (EST4153)				
List of Courses where this course will be prerequisite					
	Chemical Process Control (CET4354)				
Description of relevance of this course in the Int. M. Tech. Program					
Students will get an insight into the importance of Electrical Energy in Chemical Plants. The students will understand the basics of electricity, and the selection of diverse types of drives for a given application process. They will get basic knowledge as regards to Power supplies, instrumentation amplifiers and thyristor application in industries.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Suitable no. of experiments related the following concepts will be conducted: **Introduction to various Instruments and components in Electrical Engineering and Electronics**		10		
2	**Electrical Engineering**: Verification of Network Theorems Study of RLC circuits		10		
3	Load test on transformer. Load test on induction motor (demo) Study of 3 phase circuits		10		
4	**Electronics:** Study of half wave, full wave rectifier circuits		10		
5	Study of input and output characteristics of a transistor.		10		
6	Study of operational amplifier circuits Study of sensors and transducers		10		
	Total		**60**		
List of Textbooks/ Reference Books					
1	Electrical Engineering Fundamentals by Vincent Deltoro				
2	Electronic devices and circuits by Boylstead, Nashelsky				
3	Electrical Machines by Nagrath, Kothari				
4	Electrical Machines by P.S. Bhimbra				
5	Electrical Technology by B. L. Theraja, A. K. Theraja vol I, II, IV				
Course Outcomes (students will be able to…..)					
CO1	Understand the basic concepts of D.C., single phase and three phase AC supply and circuits Solve basic electrical circuit problems		K2		
CO2	Understand the basic concepts of transformers and motors used as various industrial drives.		K2		
CO3	Understand the basic concepts of electronic devices and their applications in power supplies, amplification, and instrumentation		K2		
CO4	Understand the basic concepts of Data acquisition, signal conditioning		K2		
CO5	Estimating and evaluate the data		K5		
CO6	Prepare the report and create the idea and thoughts		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

Semester II					
	Course Code: EST4154	**Course Title:** Introduction to Chemical Engineering	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Standard X+XII (Chemistry, Physics, Mathematics)				
List of Courses where this course will be prerequisite					
	Material and Energy Balance Calculations (CEP4151); Fluid Flow (CET4151); Heat Transfer (CET4252); Engineering Thermodynamics (EST4155); Industrial Chemistry and Reaction Engineering (CET4253); Environmental Science (CET4258); Chemical Engineering Operations (CET4254); Process Safety (CET4255); Instrumentation and Process Dynamics (CET4256); Chemical Reaction Engineering (CET4351); Momentum Transfer (CET4352); Chemical Process Control (CET4354); Separation Processes (CET4356); Chemical Process Development and Engineering (CET4451); Chemical Process Equipment Design and Drawing (CEP4451), Chemical Engineering Laboratory: I (CEP4251), Chemical Process Development and Engineering (CET4451)				
Description of relevance of this course in the Int. M. Tech. Program					
Students will be able to understand role of chemical engineering and chemical engineering principle and operation along with design and economics.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Chemical Engineer and Chemical Engineering Profession		4		
2	Indian Chemical Industry: (a) Petroleum and petrochemical industry (b) Pharmaceutical industry (c) Agrochemicals and Pesticides industry (d) Specialty Chemicals industry (e) Inorganic Chemicals … etc.		8		
3	Chemical Engineering Principles: Chemical reaction engineering, separation processes, automation and process control		4		
4	Overview of chemical process equipment: Reactors, Distillation, Absorption, Filters, Dryer and solid handling		4		
5	Global trends of chemicals		4		
6	Life cycle assessment and environmental impact		4		
7	Modern Chemical Engineering Plants: Batch to Continuous processing		2		
	Total		**30**		
List of Textbooks					
1	Introduction to Chemical Engineering: Tools for Today and Tomorrow: A First-Year Integrated Course 5th Edition (English, Paperback, Kenneth A. Solen, John N. Harb), Wiley, 2014				
2	Introduction To Chemical Engineering (English, Paperback, S. Pushpavanam)				
3	Chemical Engineering: An Introduction (Cambri…(Paperback) by Morton Denn (Cambridge University Press)				
List of Additional Reading Material / Reference Books					
1	Ministry of Commerce and Industry reports				
2	A History of The International Chemical Industry by Fred Aftalion				
Course Outcomes (students will be able to….)					
	Students will be able to				
CO1	Identify the role of chemical engineer in industry and society		K2		
CO2	Understand the Unit process and Unit Operation in chemical Engineering		K2		
CO3	Understand the design of industrial process and equipment		K2		
CO4	Use some of the engineering basic calculations		K3		
CO5	Perform basic process calculations		K3		
CO6	Create and develop the idea and thought in problem solving in chemical engineering priciple				
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

Semester II					
	Course Code: ESP4154	**Course Title:** Engineering Applications of Digital Computers	**Credits = 2**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	XIIth Standard Mathematics and Physics Courses, Applied Mathematics: I and II (MAT4151 and MAT4152)				
List of Courses where this course will be prerequisite					
	Digital Computation in Emerging areas (AI/ML/DA)				
Description of relevance of this course in the Int. M. Tech. Program					
Students will be able to understand engineering applications of digital computers and data interpretation and presentation.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Spreadsheet calculations: Use of cells, formulas, table calculations, graphs, matrix operations, goal seek, solver, curve fitting, regression, statistical analysis, excel important formulas, visual basic programming		20		
2	Any programming language (preferably python): Basics, array types, conditional statements, iterative loops, functions		20		
3	Programming case studies involving solution of single non-linear equation (Equation of state such as Van der Waal, Peng Robinson, RKS, friction factor equation, Ergun equation, Estimation of Drag Coefficient etc)		6		
4	Solution of ordinary differential equations (IVP and BVP)		8		
5	Data visualization (2D plots, 3D plots, contours, surface plots)		6		
	Total		**60**		
List of Text Books/ Reference Books					
1	Microsoft Office help				
2	Python: The Complete Reference, Martin Brown				
3	Unit Operations of Chemical Engineering, McCabe, Smith and Harriott (for case studies)				
Course Outcomes (students will be able to….)					
CO1	Students would be able to carry out Spreadsheet calculations for chemical engineering problems		K3		
CO2	Students would be able to develop programming logic and code it in software		K4		
CO3	Student would be able to apply the software skill in making code		K4		
CO4	Student would be able to analyze the result using data solving		K4		
CO5	Student would be able to evaluate result using formulae in computer		K5		
CO6	Student would be able to create and write the program		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

Second Year

Semester-III

Semester III					
	Course Code: CET4251	**Course Title:** Fluid Flow	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics, Applied Physics (PHT4151), Applied Mathematics: I and II (MAT4151 and MAT4152); Introduction to Chemical Engineering (EST4154)				
List of Courses where this course will be prerequisite					
	Momentum Transfer (CET4352), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Instrumentation and Process Dynamics (CET4256), Chemical Reaction Engineering (CET4351), Chemical Process Development and Engineering (CET4451)				
Description of relevance of this course in the Int. M. Tech. Program					
This basic course introduces concepts of fluid transfer to students. Various concepts such as pressure, momentum, energy are introduced.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Fluid Statics and applications to engineering importance.		4		
2	Bernoulli's Equation and engineering applications, Pressure drop in pipes and Fittings, Piping systems		6		
3	Utility network in chemical process industries: Cooling water, Steam, Chilled water, Thermic fluid system		8		
4	Types and design of Fluid moving machinery such as pumps, blowers, compressors, vacuum systems, etc.		6		
5	Particle Dynamics, Boundary layer separation: skin and form drag, Flow through Fixed and Fluidized Beds, Flow through porous media		6		
	Total		**30**		
List of Text Books/ Reference Books					
1	Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N.				
2	Fluid Mechanics, Kundu Pijush K.				
3	Fluid Mechanics, F. W. White				
4	Unit Operations of Chemical Engineering, McCabe, Smith and Harriott				
Course Outcomes (students will be able to….)					
CO1	Calculate pressure drop in pipelines and equipment for different situations such as single- and two-phase flow, fixed and fluidized beds		K3		
CO2	Calculate forces on particles and terminal velocities of particles		K3		
CO3	Design pumps and piping systems for simple situations		K6		
CO4	Estimate and analyze the fluid mechanics problem in chemical industry		K4		
CO5	Evaluate the fluid flow calculation in design the pumps and piping systems		K5		
CO6	Design and create the fluid piping systems in chemical industry				
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

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

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

Semester III					
	Course Code: EST4155	**Course Title:** Engineering Thermodynamics	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Mechanical Engineering (EST4152); Material and Energy Balance Calculations (CEP4151); Introduction to Chemical Engineering (EST4154)				
List of Courses where this course will be prerequisite					
	Chemical Engineering Lab I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4253), Chemical Engineering Thermodynamics (CEP4353), Industrial Chemistry and Reaction Engineering (CET4253), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Engineering Operation (CET4254), Chemical Reaction Engineering (CET4351), Separation Processes (CET4356), Chemical Process Development and Engineering (CET4451)				
Description of relevance of this course in the Int. M. Tech. Program					
Thermodynamics sets hard limits on performance of processes and equipment. This course gives students the formalism and insights necessary to do a preliminary thermodynamic analysis of a process for the purpose of establishing feasibility assuming ideal mixing.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Revision of basic Concepts of thermodynamics. State functions; Equilibrium; Phase Rule; Reversible process; Constant P, V, T processes; Energy conservation & first law of thermodynamics; Mass and energy balances for open systems, nozzles, diffuser, turbines, and pump		6		
2	Statements of the second law; Heat engines, Carnot's theorem, Thermodynamic Temperature Scales; Entropy; Entropy changes of an ideal gas; Mathematical statement of the second law; Entropy balance for open systems Industrial Applications of Second Law of Thermodynamics using Ideal Gas Law and Thermodynamic Property Charts and Tables		6		
3.	Thermodynamic analysis of flow process, steam power plants; Rankine cycle; Internal combustion engine, Otto engine, diesel engine; Jet engine.		6		
4.	Carnot refrigerator; Vapor-compression cycle; Absorption refrigeration; Heat pump, Liquefaction processes.		6		
5	Phases, phase transitions, PVT behavior; description of materials: Ideal gas law, van der Waals, virial and cubic equations of state; Reduced conditions & corresponding states theories; correlations in description of material properties and behavior		6		
	Total		**30**		
List of Text Books/ Reference Books					
1	Introduction to Chemical Engineering Thermodynamics: Smith, van Ness, Abbott				
2	Chemical, Biochemical and Engineering Thermodynamics: S. I. Sandler				
3	Properties of Gases and Liquids: Reid, Prausnitz, Pauling				
Course Outcomes (students will be able to…..)					
CO1	Calculate Enthalpy, Entropy and Gibbs energy changes in fluids with changes in temperature and pressure		K3		
CO2	Analyze process efficiencies using first law and second law of thermodynamics concepts		K4		
CO3	Calculate saturation temperature and pressure relationship for pure fluids from equations of state		K3		
CO4	Analyze process efficiencies of various engines and refrigeration units		K4		
CO5	Estimate and evaluate the thermodynamics calculation		K5		
CO6	Develop and create the thermodynamic model equation		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

Semester III					
	Course Code: CET4253	**Course Title:** Industrial Chemistry and Reaction Engineering	**Credits = 4**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Chemistry (CHT4151 and CHT4152), Material & Energy Balance Calculations (CEP4151), Applied Mathematics I and II (MAT4151 and MAT4152), Momentum Transfer (CET4352)				
List of Courses where this course will be prerequisite					
	Separation process and Membrane (CET4356), Chemical Engineering Thermodynamics (CET4353), Process Safety (CET4255), Chemical Engineering Laboratory I, II, III and IV (CEP4251, CEP4252, CEP4253 and CEP4254), Chemical Process Development and Engineering (CET4451)				
Description of relevance of this course in the Int. M. Tech. Program					
This course gives information about the chemical industry information and different types of production of fuels and inorganic products. This course also provides the information about the batch and semi batch reactors, other types of reactors, types of single phase and multiphase reactors.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Raw material and energy sources, Organic and inorganic intermediates and final products, Bulk and specialty chemicals		10		
2	Production costs of fuels and chemicals		2		
3	Industrial gases and inorganic products		4		
4	Examples of major industrial processes		6		
5	Types of chemical reactions: elementary/non-elementary, single/multiple, irreversible/reversible		8		
6	Types of chemical reactors: batch and semi-batch reactors, continuous reactors (CSTR and PFR)		8		
7	Reaction kinetics (homogeneous reactions)		8		
8	Isothermal, adiabatic and non-isothermal operation modes		8		
9	Different types of single phase and multiphase reactors		6		
	Total		**60**		
List of Text Books					
1	Elements of Chemical Reaction Engineering: H. Scott FOGLER				
2	Chemical Reaction Engineering: Octave LEVENSPIEL				
3	The Engineering of Chemical Reactions: Lanny D. SCHMIDT				
4	An introduction to Chemical Engineering Kinetics and Reactor Design: Charles HILL				
List of Additional Reading Material / Reference Books					
1	Encyclopedia of Chemical Technology, Kirk-Othmer				
2	Ulmann's Encyclopedia of Industrial Chemistry				
3	Industrial Organic Chemistry, Weissermel & Arpe				
4	Chemical Process Industries, Shreve B. Austin				
5	Chemical Process Technology, Moulijn, M. and van Dippen				
6	Dryden's Outlines of Chemical Technology				
7	Elements of Fuels, Furnaces and Refractories, O.P. Gupta				
8	Fuels handbook, Johnson				
Course Outcomes (students will be able to…..)					
CO1	Draw process flow diagrams/process block diagrams for the manufacture of various chemicals from process description		K2		
CO2	List out various alternatives for carrying out a particular process and provide recommendations for the best choice		K3		

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

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

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

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

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

Semester III					
	Course Code: CEP4251	**Course Title:** Chemical Engineering Laboratory - I	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	Introduction to Chemical Engineering (EST4154), Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT5141 and MAT5142), Applied Physics (PHT4151), Applied Chemistry (CHT4151)				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	6-8 Experiments on Fluid Flow		40		
2	2-3 Experiments on Heat Transfer		10		
3	2-3 Experiments on Kinetics		10		
	Total		**60**		
List of Text Books/ Reference Books					
1	McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014				
2	Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007				
3	Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996.				
4	Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007.				
Course Outcomes (students will be able to…..)					
CO1	Student would be able to Learn to experimentally verify various theoretical principles		K3		
CO2	Student would be able to Visualize practical implementation of basic chemical engineering principles		K2		
CO3	Student would be able to Develop experimental skills		K4		
CO4	Student would be able to Connect classroom teaching with the laboratory practical		K3		
CO5	Student would be able to Improve understanding about safety in the laboratory		K4		
CO6	Student would be able to evaluate and write the report based on results		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

Semester III					
	Course Code: HUT4156	**Course Title:** Basic Principles of Finance and Economics	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Applied Mathematics: I and II (MAT4151 and MAT4152)				
List of Courses where this course will be prerequisite					
	Project economics (CET4358); Fundamentals of marketing management and market research				
Description of relevance of this course in the Int. M. Tech. Program					
This course gives the information about Basic Principles of Finance and Economics.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	INTRODUCTION 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 Income and expenditure Expired costs and income Final accounts Manufacturing accounts Trading accounts Profit and Loss account. Suspense account Balance sheet		5		
7	CONCEPT OF DEPRECIATION		2		
	Total		**30**		
List of Textbooks					
1	Finance and Accounting for Nonfinancial Managers: All the Basics You Need to Know -William G. Droms and Jay O. Wright Microeconomics: Basic Principles and Applications- A A Temu, D W Ndyetabula, et al PRINCIPLES OF ECONOMICS(12e)- E. Case Karl, C. Fair Ray, et al				
List of Additional Reading Material / Reference Books					
1	Basic Finance for Nonfinancial Managers: A Guide to Finance and Accounting Principles for Nonfinancial Managers- Kendrick Fernandez				

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

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

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

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

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

Semester III					
	Course Code: CET4257	**Course Title:** Environmental Sciences	**Credits = 2**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Environmental Studies of Standard XII				
List of Courses where this course will be prerequisite					
	Chemical Project Economics (CET4358), Chemical Engineering Elective III - Environmental Engineering and Chemical Process Safety (CETxxx)				
Description of relevance of this course in the Int. M. Tech. Program					
This course gives the information about Basic Principles of Environmental Sciences.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	(a) Concept of circular economy, EHS management (b) Environment management systems in the chemical industry (c) Legal provisions for environmental management: EP Act 1986; Air Act, 1981; Water Act, 1974; Hazardous waste management Rules, 2019		6		
2	Importance of ecology, effluent treatment and discharging norms for treated water		6		
3	SPCB consent parameters, monitoring, and analysis		4		
4	External monitoring of ambient air, noise, stacks, etc		4		
5	Air pollutants, sources and effects on human health and environment, monitoring, and analysis		6		
6	Life cycle analysis, environmental impact assessment		4		
	Total		**30**		
List of Text Books/ Reference Books					
1	Introduction to Environmental Engineering and Science by Gilbert M Masters and Wendell P Ela				
2	Environmental Pollution Control Engineering, C. S. Rao				
3	Principles of Instrumental Analysis by D. A. Skoog, F. James Holler and S. R. Crouch, Cengage Learning, 2007				
Course Outcomes (students will be able to…..)					
CO1	Describe the methods of industrial effluent treatment		K2		
CO2	apply the learning for selection and implementation of appropriate waste management technique for sustainable development		K2		
CO3	Basic understanding and awareness about the components of environment		K2		
CO4	Gaining knowledge about Climate patterns of India		K3		
CO5	Awareness about diseases caused due to polluted environment		K3		
CO6	Understanding the different strategies used to control pollution.		K5		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

Second Year

Semester-IV

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

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

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

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

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

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

Semester IV					
	Course Code: CET4255	**Course Title:** Process Safety	**Credits = 2**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Industrial Engineering Chemistry and Engineering (CET4253)				
List of Courses where this course will be prerequisite					
	Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety (CETxxx), Chemical Process Control (CET4354), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety				
Description of relevance of this course in the Int. M. Tech. Program					
The principles learnt in this course are learnt the process safety inters of handing and performing the experiment in laboratory, as well as handing, storage, and transportation of hazardous chemicals.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Safety management in chemical industry (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		
	Total		**30**		
List of Text Books/ Reference Books					
1	Chemical Process Safety: Fundamentals with Applications: Daniel A. CROWL and Joseph F. LOUVAR				
2	Guidelines for Process Safety Management, Environment, Safety, Health, and Quality: Centre for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)				
3	Chemical Process Safety Learning from Case Histories: Roy E. SANDERS				
4	Guidelines for Process Safety Documentation: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)				
Course Outcomes (students will be able to…..)					
CO1	Identify hazards in a given process and assess the same and provide solutions for operating safely.		K2		
CO2	Specify safety requirements for storage and handling of a given chemical.		K2		
CO3	Students learn what process safety is, the consequences of poor process safety, and the factors that influence it.		K3		
CO4	Students learn how to manage risk and define critical controls, or barriers, to prevent unintentional releases of dangerous materials.		K5		
CO5	Students learn how to implement sustainable improvements in PSM.		K5		
CO6	Students may gain hands-on experience with bowtie diagrams and other tools and learn to apply critical thinking skills to analyze scenarios.		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

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

Semester IV					
	Course Code: CEP4252	**Course Title:** Chemical Engineering Laboratory - II	**Credits = 2**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	Material Balance and Energy Balance Calculations (CEP4151), Fluid Flow (CET4151), Heat Transfer (CET4252), Engineering Thermodynamics (EST4155), Mathematics I and II (MAT4151 and MAT4152), Chemical Engineering Operations (CET4154), Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256)				
List of Courses where this course will be prerequisite					
	Chemical Engineering Laboratory III and IV (CEP4253 and CEP4254)				
Description of relevance of this course in the Int. M. Tech. Program					
Chemical Engineering lab provides students the firsthand experience of verifying various theoretical concepts learnt in theory courses. It also exposes them to practical versions of typical chemical engineering equipment and servers as a bridge between theory and practice. This lab focuses on fluid dynamics, thermodynamics, and mass transfer.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
2	2-3 Experiments on Heat Transfer		12		
4	6-8 Experiments on Chemical Engineering Operations		40		
5	1-2 Experiments on Instrumentation		8		
	Total		**60**		
List of Text Books/ Reference Books					
1	McCabe W.L., Smith J.C., and Harriott P. Unit Operations in Chemical Engineering, 2014				
2	Bird R.B., Stewart W.E., and Lightfoot, E.N. Transport Phenomena, 2007				
3	Coulson J.M., Richardson J.F., and Sinnott, R.K. Coulson & Richardson's Chemical Engineering: Chemical engineering design, 1996.				
4	Green D. and Perry R. Perry's Chemical Engineers' Handbook, Eighth Edition, 2007.				
Course Outcomes (students will be able to…..)					
CO1	Student would be able to Learn to experimentally implement various theoretical principles		K2		
CO2	Student would be able to Utilize the chemical engineering equipment to generate experimental data		K4		
CO3	Student would be able to Calculate experimental results		K3		
CO4	Student would be able to Improve ability to write laboratory reports		K3		
CO5	Student would be able to Improve ability for oral communication		K3		
CO6	Student would be able to write and conclude the experiment data		K5		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

Semester IV					
	Course Code: HUT4157	**Course Title:** Industrial Management	**Credits = 2**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Industrial Chemistry and Reaction Engineering (CET4253), Instrumentation and Process Dynamics (CET4256), Process Safety (CET4255)				
List of Courses where this course will be prerequisite					
	Chemical Process Control (CET4354), Chemical Project Economics (CET4358), Chemical Process Development and Engineering (CET4451), Chemical Industrial Management (CET4452), Chemical Process Equipment Design and drawing (CEP4451), Chemical Process Development and Engineering (CET4451)				
Description of relevance of this course in the Int. M. Tech. Program					
This course equips students with human resource management skills to be able to function effectively in their professional career					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	The production functions. 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		
	Total		**30**		
List of Text Books/ Reference Books					
1	Modern Production / Operations Management, (8e)- Buffa and Sarin				
2	Operations Management,12e-Jay Heizer, Barry Render, et al.				
3	OPERATIONS MANAGEMENT 13TH EDITION by William J. Stevenson				
4	Operations and Supply Chain Management (SIE) | 15th Edition by Richard B. Chase, Ravi Shankar, et al.				
Course Outcomes (students will be able to…..)					
CO1	Student would be able to explain the concepts of management and explore the management practices in their domain area within society.		K4		
CO2	Student would be able to evaluate different types of organizational structures and design them.		K6		

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

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

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

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

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

Third Year

Semester-V

Semester V					
	Course Code: CET4351	**Course Title:** Chemical Reaction Engineering	**Credits = 2**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Chemistry (CHT4151 and CHT4152), Material & Energy Balance Calculations (CEP4151), Applied Mathematics I and II (MAT4151 and MAT4152), Fluid Flow (CET4251), Engineering Thermodynamics (EST4155)				
List of Courses where this course will be prerequisite					
	Chemical Process Control (CET4354), Chemical Process Development and Engineering (CET4451), Chemical Engineering Lab - III and IV (CEP4253 and CEP4254), Process Simulation Lab - I and II (CEP4255 and CEP4256), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety, Biochemical Engineering (Hon.), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.), Refinery Science and Engineering (Hon.), Catalytic Science and Engineering (Hon.)				
Description of relevance of this course in the Int. M. Tech. Program					
This course is very relevant but not limited to the following industries: Inorganic chemicals, organic chemicals, petroleum & petrochemicals, Pulp & paper, Pigments & paints, rubber, plastics, synthetic fibers, Foods, Dyes and intermediates, Oils, oleochemicals, and surfactants, Minerals, cleansing agents, Polymers and textiles, Biochemicals and biotechnology, pharmaceuticals and drugs, Microelectronics, energy from conventional and non-conventional resources, Metals					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Sizing and analysis of chemical Reactors (single and multiple reactions (series/parallel))		6		
2	Series of reactors, Recycle reactors, Use of energy balance in reactor sizing and analysis, non-isothermal reactor design		6		
3	Non-idealities in chemical reactors: RTD, Axial dispersion models		6		
4	Gas-Solid reactions: Catalytic and Non-catalytic		4		
5	Heterogeneous catalysis: internal and external transport, kinetics, and mechanisms		4		
6	Gas-solid reactions (non-catalytic), Kinetics of fluid-fluid reactions		4		
	Total		**30**		
List of Text Books/ Reference Books					
1	Elements of Chemical Reaction Engineering: H. Scott FOGLER				
2	Chemical Reaction Engineering: Octave LEVENSPIEL				
3	The Engineering of Chemical Reactions: Lanny D. SCHMIDT				
4	An introduction to Chemical Engineering Kinetics and Reactor Design: Charles HILL				
5	Heterogeneous Reactions, Vol. I and II: L. K. Doraiswamy, M. M. Sharma				
Course Outcomes (students will be able to…..)					
CO1	Design chemical reactors optimally, using minimum amount of data		K4		
CO2	Design experiments in a judicious way to get the required data, if not available		K4		
CO3	Fix some problems related to operability and productivity		K4		
CO4	Select appropriate single and multiphase reactor configuration for given application		K3		
CO5	Students may learn to develop skills to choose the right reactor for isothermal, non-isothermal, or adiabatic reactions.		K6		
CO6	Students may learn to calculate conversion and extent values for different systems, including constant volume systems.		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

Semester V					
	Course Code: CET4352	**Course Title:** Momentum Transfer	**Credits = 2**		
			L	**T**	**P**
	Semester: V	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics, Applied Physics: I and II (PHT4151), Fluid Flow (CET4255), Applied Mathematics: I and II (MAT4151 and MAT4152), Chemical Engineering Operations (CET4254)				
List of Courses where this course will be prerequisite					
	Chemical Engineering Lab - III and IV (CEP4253 and CEP4254), Separation Processes + Membrane (CET4356), Heat Transfer Equipment design (CET4357), Chemical Process Development and Engineering (CET4451), Chemical Eng Elective III-Environmental Engineering and Chemical Process Safety (CETxxx), Multiphase Reaction Engineering (Non.), Mathematical Methods & Optimization in Chemical Engineering (Hon.)				
Description of relevance of this course in the Int. M. Tech. Program					
This basic course introduces concepts of momentum transfer to students. Various concepts such as pressure, momentum, energy are introduced. Laws related to conservation of momentum; energy are taught. Applications of these laws to various engineering situations and process equipment is explained with the help of several problems					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Equations of Continuity and Motion (Cartesian, cylindrical, and spherical coordinates) in laminar flows and its applications for the calculation of velocity profiles, shear stresses, power, etc. in various engineering applications.		8		
2	Boundary Layer Flows: Blasius equations and solution, Von-Karman integral equations and solutions,		6		
3	Introduction to turbulence: turbulent pipe flow, basis of Universal velocity profile and its use		6		
4	Similarities in Momentum, Heat and Mass Transfer		6		
5	Introduction to experimental and computational fluid dynamics: HFA, LDA, PIV, UVP, tomography etc., Turbulence modelling, multiphase system modelling etc.		4		
	Total		**30**		
List of Textbooks/ Reference Books					
1	Transport Phenomena, Bird R.B., Stewart W.E., Lightfoot E.N.				
2	Fluid Mechanics, Kundu Pijush K.				
3	Fluid Mechanics, F. W. White				
4	Unit Operations of Chemical Engineering, McCabe, Smith				
Course Outcomes (students will be able to…..)					
CO1	Calculate velocity profiles, forces, pressure drops for simple 1 –D laminar flow situations		K2		
CO2	Calculate forces on particles and terminal velocities of particles		K2		
CO3	Apply Momentum, Heat and mass transfer concepts to simple situations		K3		
CO4	Select appropriate measurement technique for detailed characterization in chemical process equipment		K3		
CO5	Analyze compressible fluids.		K4		
CO6	Select different equipment for transportation and metering of fluids.		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Chemical Engineering Laboratory - III: CEP4253 **Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)**					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	2	3	1
CO2	3	1	1	3	-
CO3	1	2	3	1	2
CO4	2	1	2	2	2
CO5	2	1	2	2	2
CO6	1	2	1	2	2
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

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

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

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

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

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

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

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

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

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

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

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

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

Third Year

Semester-VI

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

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

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

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

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

Semester VI					
	Course Code: CET4356	**Course Title:** Separation Processes	**Credits = 2**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 30**	**1**	**1**	**0**
List of Prerequisite Courses					
	Material & Energy Balance Calculations (CEP4151), Chemical Engineering Operations (CET4254), Engineering Thermodynamics (EST4155), Momentum Transfer (CET4352), Applied Mathematics I and II (MAT4151 and MAT4152), Chemical Engineering Laboratory I, II and III (CEP4251, CEP4252 and CEP4253), Process Simulation Lab: I (CEP4255)		
List of Courses where this course will be prerequisite					
	Chemical Engineering Laboratory IV (CEP4254), Process Simulation Lab - II (CEP4256), Chemical Process Development and Engineering (CET4451), Chemical Process Development and Engineering (CET4451), Multiphase Reaction Engineering (Non.)				
Description of relevance of this course in the Int. M. Tech. Program					
This is a course further built up on and in continuation with Chem. Eng. operations. It forms the basis of Chemical Engineering Principles and hence it is required in almost all the courses and throughout the professional career of a Chemical Engineer.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Extraction and Leaching of ternary systems: Ternary diagrams, Hunter-Nash graphical method and Maloney–Schubert graphical equilibrium-stage method, Solvent Selection, Operating point, number of stages, maximum solvent to feed ratios, minimum reflux, minimum number of stages, Introduction to reactive extraction, aqueous two phase extraction, extraction of biomolecules, supercritical fluid extraction, Solid-liquid extraction: Solid - liquid equilibria, efficiency, performance evaluation, Equipment for extraction, leaching and their sizing, Design considerations		10		
2	Adsorption and Ion exchange: Liquid Adsorption, Ion-Exchange Equilibria, Equilibria in Chromatography, Breakthrough Curves, Kinetic and transport considerations, Convection-Dispersion Model, Separation Efficiency (Plate Height or Bandwidth), Correlations for Transport-Rate Coefficients, Equipment for sorption operations, Scale-Up and Process Alternatives, Adsorptive Membranes, simulated-moving-bed operation, modes of operation		5		
3	Crystallization: Theory of solubility and crystallization, phase diagram (temp/solubility relationship), Supersaturation, Nucleation, Crystal Growth, Population balance analysis, method of moments for rate expressions for, volume, area and length growth, CSD distribution, MSMPR operation, evaporative and cooling (rate expressions), most dominant size, ideal classified bed, Precipitation, Melt crystallization, Process design of crystallizers and their operation		5		
4	Humidification and Cooling Towers: Method of changing humidity and equipment, Cooling tower process design, counter-current, concurrent, and cross current, mass and heat balances in bulk and interfaces, Estimation of air quality, performance evaluation of cooling towers.		5		
5	Membrane Separations: Types of separations, reverse osmosis, ultrafiltration, gas separation, vapour permeation and pervaporation, dialysis, electrodialysis, nanofiltration, Transport Through Porous Membranes, Resistance Models, Liquid Diffusion Through Pores, Gas Diffusion Through Porous Membranes, Transport Through Nonporous Membranes, Solution-Diffusion for Liquid Mixtures, Gas Mixtures, Concentration Polarization and Fouling, Membrane modules, arrangement of modules in cascades, performance criteria and design considerations		5		
	Total		**30**		
List of Textbooks/ Reference Books					
1	Richardson, J.F., Coulson, J.M., Harker, J.H., Backhurst, J.R., 2002. Chemical engineering: Particle technology and separation processes. Butterworth-Heinemann, Woburn, MA.				
2	Seader, J.D., Henley, E.J., 2005. Separation Process Principles, 2 ed. Wiley, Hoboken, N.J.				
3	McCabe, W., Smith, J., Harriott, P., 2004. Unit Operations of Chemical Engineering, 7 ed. McGraw-Hill Science/Engineering/Math, Boston.				
4	Green, D., Perry, R., 2007. Perry's Chemical Engineers' Handbook, Eighth Edition, 8 ed. McGraw-Hill Professional, Edinburgh.				

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

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

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

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

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

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

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

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

Semester VI					
	Course Code: CEP4256	**Course Title:** Process Simulation Laboratory - II	**Credits = 2**		
			L	**T**	**P**
	Semester: VI	**Total contact hours: 60**	**0**	**0**	**4**
List of Prerequisite Courses					
	XIIth Standard Physics and Mathematics, Applied Physics (PHT4151), Applied Mathematics: I and II (MAT4151-52), Process Simulation Lab-II (CEP4255), Chemical Engineering Operations (CET4254)				
List of Courses where this course will be prerequisite					
	Advanced Reaction Engineering (CET4553), Advanced Transport Phenomena (CET4551)				
Description of relevance of this course in the Int. M. Tech. Program					
To learn to write programs on Chemical Engineering processes and equipment. To learn the design aspects equipment through programming To learn the solving process of Chemical Engineering problems through computational techniques					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Design of multicomponent distillation		6		
2	Design of shell and tube heat exchanger		6		
3.	Design of evaporator		4		
4.	design of adiabatic drier		4		
6	2-3 experiments on momentum transport		8		
7.	1-2 experiment of multicomponent reaction		4		
8.	Design of reactor		4		
9	2-3 process flow sheet calculation		20		
	Total		**60**		
List of Text Books/ Reference Books					
1	Coker, Ludwig's Applied Process Design for Chemical and Petrochemical Plants				
2	Perry's Chemical Engineering Handbook				
3	Albright's Chemical Engineering Handbook				
Course Outcomes (students will be able to…..)					
CO1	Solve chemical engineering design problems involving iterative calculations		K4		
CO2	Solve chemical engineering problems involving non-linear equations coupled with differential equations		K4		
CO3	Solve chemical engineering problems using computers		K4		
CO4	Design a chemical engineering equipment for separation process		K4		
CO5	Students will acquire skills in building and running a process simulation model to predict the behavior of a process and to conduct technical-economic optimization.		K4		
CO6	Pursue by using a commercial simulation software.		K5		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Fourth Year

Semester-VII

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

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

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

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

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

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

Semester VII					
	Course Code: CET4452	**Course Title:** Chemical Industrial Management	**Credits = 2**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 30**	**2**	**0**	**0**
List of Prerequisite Courses					
	Chemical Process Development and Engineering (CET 4451), Industrial Management (HUT4157)				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
This course integrates all chemical industrial process and their management.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Basics of management 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 predisposition 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		
	Total		**30**		
List of Text Books/ Additional Reading Material / Reference Books					
1	Human Resource Management (15e) - Gary Dessler, Biju Varrkey gement(15e)-Robbins				
2	Select HBR articles				
3	Industrial/Organizational Psychology: An Applied Approach- Michael Aamodt				
Course Outcomes (students will be able to…..)					
CO1	Student would be able to understand the process of corporate recruitment.		K2		
CO2	Student would be able to use the information while applying for jobs		K3		
CO3	Student would be able to gain knowledge on how to perform well in an interview process.		K3		
CO4	Student would be able to gain knowledge on how goals are set in any organization and performance is measured.		K3		

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

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

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

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

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

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

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

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

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

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

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Introduction to all prevailing international standards of Health, Safety, and Environment (HSE); Environmental laws and regulations; Standards (air quality, noise, water), ISO 14000+	4
2	Environmental impact assessment, Life cycle assessment (LCA)	4
3	Pollution prevention in chemical manufacturing, effluent valorisation	4
4	Air pollution; Air pollutants: sources (specific pollutants), effects, and dispersion modelling, air pollution, air quality, pollutants minimisation and control, fugitive emissions (source and control),	4
5	Noise pollution	6

6	Wastewater treatment; Groundwater and surface water pollution, removal of specific water contaminants; Solid waste; Hazardous waste	8
7	Inherent safety; Major disasters (e.g. Flixborough, UK; Bhopal, India; Seveso, Italy; Pasadena, Texas; Texas City, Texas; Jacksonville, Florida; Port Wentworth, Georgia)	6
8	Toxicology; Industrial hygiene	4
9	Source models; Toxic release and dispersion models	4
10	Fires and explosions; Concepts to prevent fires and explosions	2
11	Chemical reactivity	4
12	Reliefs and reliefs sizing; Hazard identification; Risk assessment	4
13	Safety procedures and designs	4
15	Some case histories	2
	Total	**60**
List of Text Books/ Reference Books		
1	Chemical Process Safety: Fundamentals with Applications: Daniel A. CROWL and Joseph F. LOUVAR	
2	Guidelines for Process Safety Management, Environment, Safety, Health, and Quality: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)	
3	Environmental Engineers' Handbook: Irene LIU (Editor)	
4	Chemical Process Safety Learning from Case Histories: Roy E. SANDERS	
5	Guidelines for Process Safety Documentation: Center for the Chemical Process Safety of the American Institute of Chemical Engineers (AIChE)	
6	Environmental and Health and Safety Management: A Guide to Compliance: Nicholas P. CHEREMISINOFF, Madelyn L. GRAFFA	
7	Environmental Pollution Control Engineering: C. S. Rao	
8	Environmental Engineering: H. S. Peavy	
Course Outcomes (students will be able to…..)		
CO1	Calculate BOD / COD for a given composition of effluent stream, Estimation of bio-Kinetics	K5
CO2	Calculate adiabatic lapse rate and determine conditions for suitability of atmospheric dispersion, effective stack height, chimney design	K5
CO3	Calculate concentrative of pollutant at any point in the neighbourhood of emission given atmospheric conditions like wind, dispersion, environmental factors etc.	K5
CO4	Calculate size/time/power required for primary clarifier, secondary treatment, tertiary treatment, sizing of different types of biological treatments etc.	K5
CO5	Identify hazards in a given process and assess the same and provide solutions for operating safely.	K4
CO6	Specify safety requirements for storage and handling of a given chemical.	K2
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating		

Chemical Engineering Elective V: Environmental Engineering and Chemical Process Safety: CETXXX
Mapping of Course Outcomes (COs) with Programme Outcomes (POs)

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

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

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

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

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

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

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

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

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

Semester VII					
	Course Code: CEP4452	**Course Title:** Literature Review (Research Methodology: I)	**Credits = 2**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 30**	**1**	**0**	**2**
List of Prerequisite Courses					
	NA				
List of Courses where this course will be prerequisite					
	Design and Analysis Experiments (CEP4453), Design Project - I (CEP4461), Thesis (CEP4474 and CEP4475)				
Description of relevance of this course in the Int. M. Tech. Program					
The formal exposure to various elements of research methods such as problem formulation, literature search, planning of various activities, documentation, budgeting, purchase, report/thesis compilation, manuscript writing, patent drafting, is critical for polishing the naïve research attitude and aptitude in the PG students of the programme. The course is designed to formally introduce various concepts of research methodology in stepwise manner to the students.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction of Course 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? How to solve research problems, designing work plan, importance of objectives, activity and strategizing research work. Design of timeline for work plan (Gnatt Chart etc), Grant Writing Guidelines		4		
7	Experimental Research, Inventory Management, Material Management 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, proficient 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
	Total	**30**
List of Textbooks/ Reference Books		
1	Menzel, D.; Writing a Technical Paper; McGraw-Hill, United States (1961).	
2	Best, J. W., Kahn, J. V., Jha, A. K.; Research in Education; 10th ed.; Pearson, New Delhi, India (2005)	
Course Outcomes (students will be able to…..)		
CO1	Understand the basic concepts of research and the components therein, formally	K2
CO2	Understand and appreciate the significance of statistics in Chemical Technology, Pharmacy and Chemical Engineering	K2
CO3	Understand and apply importance of literature survey in research design and understand an in-depth knowledge on the documentation in research	K3
CO4	Evaluate importance of various parts of a research report/paper/thesis in presentation of research results	K5
CO5	Understand the significance of several types of IPRs in research	K1
CO6	Create a model research project	K6
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating		

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

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

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

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

Semester VII					
	Course Code: CEP4453	**Course Title:** Design and Analysis of Experiments (Research Methodology: II)	**Credits = 2**		
			L	**T**	**P**
	Semester: VII	**Total contact hours: 30**	**1**	**0**	**2**
List of Prerequisite Courses					
	Literature Review (CEP4452), Applied Mathematics I (MAT4151 and MAT4152)				
List of Courses where this course will be prerequisite					
	This course is required for graduating engineers to function effectively in Industry, Academia, and other professional spheres. This course is in Semester VIII				
Description of relevance of this course in the Int. M. Tech. Program					
Modern day manufacturing activities and R&D activities need decisions taken with a scientific rigor and should be well-supported by 'statistics. Chemical engineering graduates who will serve industry as well as postgraduate research students who will serve industry, R&D organizations, or academic research should have a good background of statistical decision making. This also involves extraction of meaningful data from well-designed minimal number of experiments at the lowest possible material costs. This course will also help the students in all domains of their life by imparting them a vision for critical appraisal and analysis of data.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Fundamental principles of classical design of experiments 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		
	Total		**30**		
List of Text Books / Reference Books					
1	Douglas C. Montgomery, Design and Analysis of Experiments, 8th Edition, John Wiley & Sons, Inc. 2013				
2	Box, G. E., Hunter, W.G., Hunter, J.S., Hunter, W.G., Statistics for Experimenters: Design, Innovation, and Discovery, 2nd Edition, Wiley, 2005.				
3	John Lawson, Design and Analysis of Experiments with R, CRC Press, 2015				
4	Dieter Rasch, Jürgen Pilz, Rob Verdooren, Albrecht Gebhardt Optimal Experimental Designs with R. CRC Press, 2011.				
5	José Unpingco, Python for Probability, Statistics, and Machine Learning, Springer, 2019				
6	Response Surface Methodology: Process and Product Optimization using Designed Experiments: R. H. Myers, D. C. Montgomery.				

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

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

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

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

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

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

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

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

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

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	3	3	2

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

Fourth Year

Semester-VIII

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

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

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

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

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

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

Fifth Year

Semester-IX

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

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

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

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

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

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

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

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

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

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

Advanced Reaction Engineering: CET4553
Mapping of Course Outcomes (COs) with Programme Outcomes (POs)

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

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

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

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

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

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

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

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

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

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

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

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

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

Fifth Year

Semester-X

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

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

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

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

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

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

Honors Syllabus

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

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

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

Semester					
	Course Code: CETxxxx	**Course Title: Multiphase Reaction Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Chemical Reaction Engineering (CET4351), Momentum Transfer (CET4352), Heat Transfer (CET4252), Chemical Engineering Operations (CET4254), Separation Processes (CET4356), Chemical Engineering Thermodynamics (CET4353)				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
This course integrates reaction engineering and chemical engineering and a requisite for chemical and biochemical Industry					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Classification of multiphase reactors, qualitative description, examples of industrial importance		8		
2	Hydrodynamics, scale-up, process design and performance of the following major classes of multiphase reactors, case studies and problems, w.r.t:				
2a	Stirred tank reactors,		10		
2b	Bubble columns, packed bubble columns, sectionalized bubble columns,		10		
2c	Internal loop and external loop air-lift reactors, jet loop reactors,		8		
2d	Fluid-fluid reactors such as spray columns, packed columns, plate columns, static mixers, rotating disc contactors		8		
2e	Fixed bed reactors, trickle bed reactors,		8		
2f	Solid-liquid and gas-solid fluidized bed reactors, solid-gas transport reactors		8		
	Total		**60**		
List of Textbooks/ Reference Books					
1	Heterogeneous Reactions, Vol. I and II: L. K. Doraiswamy, M. M. Sharma				
2	Fluid Mixing and Gas Dispersion in Stirred Reactors: G. B. Tatterson				
3	Bubble Column Reactors: W. D. Deckwer				
4	Fluidisation: D. Kunni and O. Levenspiel				
5	Gas Liquid Reactions: P. V. Danckwerts				
6	Fluidisation: J. F. Davidson and D. Harrison				
7	Random Packings and Packed Tower Design: R. F. Strigel				
Course Outcomes (students will be able to…..)					
CO1	Calculate operating regime for a given reaction.		K5		
CO2	Calculate intrinsic kinetics from the data on model contactors.		K5		
CO3	Calculate conversion / selectivity / size / temperature / pressure / power required for conducting a given multiphase reaction equipment.		K5		
CO4	Ability to solve problems of mass transfer with reaction in solid catalyzed reactions		K4		
CO5	sign and sizing of industrial scale reactor on the basis of kinetic data obtained at lab scale		K6		
CO6	Designing experiments involving chemical reactors, and analyzing and interpreting data		K6		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

Semester					
	Course Code: CETxxxx	**Course Title: Mathematical Methods & Optimization in Chemical Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**2**	**0**	**4**
List of Prerequisite Courses					
	Applied Mathematics: I (MAT4151) and Applied Mathematics II (MAT4152), Momentum Transfer (CET4352), Chemical Engineering Operations (CET4254), Chemical Engineering Thermodynamics (EST4253), Heat transfer (CET4252), Chemical Reaction Engineering (CET4351)				
List of Courses where this course will be prerequisite					
	Transport Phenomena, Chemical Process Control (CET4354), Optimization of Chemical Engineering Systems				
Description of relevance of this course in the Int. M. Tech. Program					
In this course advanced mathematical tools are covered which will help students to solve complex problems in Chemical Engineering. This course will serve as a bridge between the applied mathematics courses and their application to Chemical Engineering problems. Specifically, the techniques learnt in this course will help problem formulation and solution in Chemical Reaction Engineering, Chemical Process Control, Heat Transfer and Transport Phenomena. Many Chemical Engineering problems encounter trade-offs between two or more parameters and thus formulation and solution of an optimization problem helps a Chemical Engineer to obtain the best solution.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Vector algebra: scalar & vector product (application to fluid flow problems) and Linear algebra.		12		
2	PDEs: Types, solution (penetration theory, 2D conduction, counter-current heat exchanger, reaction-diffusion, dispersion model, etc.)		8		
3	Fourier series, transforms (diffusion equations), Laplace, Z transform		8		
4	Equation scaling, normalization, convergence		4		
5	Integer, linear and quadratic programming (simple scheduling, simple production planning, fuel blending, data fitting, optimal control)		10		
6	Nonlinear programming (Reflux ratio optimization, consecutive reaction, reactor-separator recycle systems)		6		
7	Mixed integer linear programming (flowsheet optimization, supply chain optimization)		6		
8	Multi-objective optimization (design and operation of chemical processes)		6		
	Total		**60**		
List of Text Books/ Reference Books					
1	Kreyszig, E. Advanced Engineering Mathematics.				
2	Pushpavanam, S. Mathematical Methods in Chemical Engineering				
3	Collette, Y. and Siarry, P. Multi-objective optimization				
4	Vanderbei, R.J. Linear programming: Foundations and extensions				
5	Jenson, V.G. and Jeffreys, G.V. Mathematical Methods in Chemical Engineering				
Course Outcomes (students will be able to…..)					
CO1	Formulate a Chemical Engineering problem into a mathematical problem		K4		
CO2	Solve (analytically or numerically) ODE and PDE equations encountered in Chemical Engineering Applications		K5		
CO3	Assess stability of Chemical Engineering systems		K3		
CO4	Formulate a Chemical Engineering problem into an optimization problem		K4		
CO5	Solve (analytically or numerically) optimization problems encountered in Chemical Engineering Applications		K5		
CO6	Provide knowledge of advanced numerical methods and their applications to chemical engineering problems		K3		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

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

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

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

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

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

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

Semester					
	Course Code: CETxxxx	**Course Title: Catalytic Science and Engineering**	**Credits = 4**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Applied Chemistry (CHT4151), Chemical Reaction Engineering (CET4351)				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
In this course will learn to apply their knowledge of catalysis process and it's engineering along with synthesis process and characterization for the catalytic process. This course will also deal the several applications of catalyst and their process as well.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Relevance and examples, Atom economy and green chemistry concepts, Homogenous and heterogeneous catalysis		10		
2	Fundamentals of homogeneous catalysis and mechanisms and kinetics, Fundamentals of adsorption, isotherms, energetics, structural and dynamic considerations,		10		
3	Mechanisms, models and kinetics of surface reactions, Fractal models, Determination of surface structure though modern methods, Significance of Pore structure and models		10		
4	Catalysts Characterization methods: Surface area and pore volume determinations, XRD, various Spectroscopic techniques, Temperature programmed reduction & oxidation, Electron microscopy.		10		
5	Solid and surface chemistry of catalysis, Quantum mechanical, molecular mechanical and hybrid models, Catalyst design through artificial intelligence and computer modelling		5		
6	Poisoning, promotion, deactivation and selectivity, Catalytic process engineering, Measurement of catalytic rates and kinetic parameters, Types of reactors		5		
	Total		**60**		
List of Text Books/ Reference Books					
1	G. Ertl, H. Knozinger and J. Weitkamp, "Handbook of Heterogeneous Catalysis" Vol 1-5, Wiley - VCH.				
2	J.J. Carberry, "Chemical and catalytic reaction Engineering", Dover Publications.				
3	C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley-VCH.				
Course Outcomes (students will be able to…..)					
CO1	Understand synthesis, characterization, activity and deactivation of heterogeneous catalyst		K2		
CO2	Understand the mechanisms of homogeneous catalysis		K2		
CO3	Understand the role of catalysis in industrial processes		K2		
CO4	To plan, develop and test catalyst for given application		K3		
CO5	Suggest strategies for catalyst development		K3		
CO6	Select and design multiphase catalytic reactors		K4		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

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

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

Semester					
	Course Code: CETxxxx	**Course Title: Statistical Thermodynamics**	**Credits = 4**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Applied Mathematics especially probability, vectors and linear algebra, Computer Programming especially working with arrays and vectors (MAT4151) and (MAT4152), Chemical Engineering Thermodynamics (CET4353)				
List of Courses where this course will be prerequisite					
	NA				
Description of relevance of this course in the Int. M. Tech. Program					
In this course will learn to apply their knowledge of statistical mechanics and its application in engineering thermodynamics and their problem solution.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction to statistical mechanics: a first look at the Canonical Ensemble. Introduction to the Boltzmann Distribution		4		
2	Introduction to the microcanonical, PVT and Grand Canonical Ensembles		4		
3	Macroscopic Thermodynamic Quantities as Functions of Ensembles with particular emphasis on the microscopic level difference between Heat Transfer and Work Transfer.		4		
4	a) Derivation of the Ideal Gas Law using Schrodinger's Equation applied to Particle-in-a-box and extended to many particle systems using statistical mechanics b) Derivation of Pressure for an Ideal Gas and introduction to the Virial Theorem		8		
5	Introduction to the pair interaction energy, pair correlation function (radial distribution function) and determination of macroscopic thermodynamic quantities including derivation of the van der Waals equation of state.		10		
6	Introduction to Importance Sampling, detailed balance and the Metropolis Monte Carlo Algorithm		4		
7	Writing a code for Monte Carlo simulations in 1D using periodic boundary conditions		4		
8	Phase Space, the Liouville Theorem and Molecular Dynamics Simulations		6		
9	Symplectic integrators and writing a code for molecular dynamics simulations in 1D using periodic boundary conditions		4		
10	Fluctuation Dissipation theorem and the Green Kubo relations to determine transport properties from MD simulations. Writing code to determine thermodynamic and transport properties of a system from fluctuations and autocorrelations thereof.		8		
11	Introduction to Transition State Monte Carlo Simulations for Phase Equilibria		4		
	Total		**60**		
List of Textbooks/ Reference Books					
1.	An Introduction to Statistical Thermodynamics by Terrence Hill (Dover Books)				
2.	Understanding Molecular Simulations by Daan Frenkel and Berend Smit (Academic Press)				
3.	Classical Dynamics of Particles and Systems S.T. Thornton and J. B. Marion (Cengage Learning)				
4.	Statistical Mechanics D. A. McQuarrie (University Science Books)				
Course Outcomes (students will be able to…..)					
CO1	Student would be able to understand and use the concept of microcanonical, canonical, grand-canonical and PVT ensembles and the partition functions thereof		K3		
CO2	Student would be able to relate macroscopic thermodynamic quantities like entropy and free energy to the partition functions		K4		
CO3	Student would be able to understand the algorithms behind Monte Carlo simulations and write a simple Monte Carlo Simulation		K4		

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

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

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

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

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

Electives Syllabus

Semester					
	Course Code: CET 2769E	**Course Title:** Process Intensification	**Credits = 4**		
			L	**T**	**P**
	Semester:	**Total contact hours: 60**	**3**	**1**	**0**
List of Prerequisite Courses					
	Momentum transfer (CET4352), Chemical Engineering operations (CET4254), Heat transfer (CET4252), Chemical reaction engineering (CET4351), Advanced mass transfer (CET4554), Advanced transport phenomena (CET4551)				
List of Courses where this course will be prerequisite					
	Thesis (CEP4563 and CEP4564)				
Description of relevance of this course in the Int. M. Tech. Program					
The course is intended to be useful for students in applying intensified reactor and/or separator systems in chemical industries. The course will cover some intensified technologies, with particular emphasis on their application in chemical processes.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
1	Introduction on Process Intensification: History, Philosophy and Concept, Principle Features, Strategies and domain based techniques.		6		
2	Mechanism involved in the process intensification: Intensification by fluid flow process, Mechanism of Intensification by mixing, Intensification in Reactive system		4		
3	Role of Process intensification in sustainable development: Problems leading to sustainable development, Concept, Issues and Challenges, Strategies in process design		4		
4	Process intensification by cavitation: Introduction and Mechanism of Cavitation-based PI, Acoustic cavitation, Hydrodynamic cavitation, Cavitation Reactor Configurations, Application of cavitation in reaction, wastewater treatment, crystallization, emulsification etc.,		10		
5	Process intensification by micro-reactors: Introduction to microprocess technology, Types of Micro-reactors, Hydrodynamics, and transport in microchannel based microreactor, Application of micro-reactors in reaction, nanomaterial synthesis etc.		10		
6	Microwave-assisted process intensification technique, Applications of microwaves in extraction, reaction and nanomaterials.		10		
7	Process intensification by membrane: Introduction to membrane and its principles, Membrane engineering in process intensification		6		
	Total		**60**		
List of Textbooks/ Reference Books					
1.	Process Intensification in Chemical Engineering Design Optimization and Control, by Juan Gabriel Segovia, Hernández Adrián and Bonilla Petriciolet, 2016, Springer.				
2.	Process Intensification: Engineering for efficiency, sustainability and flexibility, by David Reay, Colin Ramshaw, and Adam Harvey, 2nd edition, 2013, Elsevier.				
3.	3. The Fundamentals of Process Intensification by Andrzej Stankiewicz, TomVan Gerven and Georgios Stefanidis, 2019, Willey VCH.				
Course Outcomes (students will be able to…..)					
CO1	Contemplate new design concepts and analyze design alternatives for any process		K3		
CO2	Propose improvements in a process by integration of unit operations,		K4		
CO3	Apply their knowledge to the design and implementation of green processing technologies based on process intensification principles.		K5		
CO4	Improve processes without sacrificing product quality by increasing efficiency, reducing energy consumption, costs, volume, and waste as well as improving safety.		K4		
CO5	Identify process intensification for the enhancement of chemical processes		K2		
CO6	Solve process challenges using intensification technologies and analyze scale up issues in the process industries.		K5		
K1: Remembering, K2: Understanding, K3: Applying, K4: Analyzing, K5: Evaluating, K6: Creating					

Chemical Engineering Elective: CET 2769E Process Intensification Mapping of Course Outcomes (COs) with Programme Outcomes (POs)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	1	2	1	-	-	1	-	1
CO2	2	3	2	3	2	1	-	-	-	2	-	-
CO3	1	2	3	2	1	-	-	-	-	1	2	2
CO4	2	3	3	2	2	1	1	-	-	1	1	1
CO5	2	3	1	2	2	-	-	-	1	2	1	1
CO6	2	2	1	2	2	1	-	-	-	1	2	1
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;												

Chemical Engineering Elective: CET 2769E Process Intensification Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)					
	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	1	-
CO2	3	2	2	3	2
CO3	2	1	3	3	3
CO4	3	2	3	3	2
CO5	2	1	2	1	2
CO6	2	2	1	1	1
3-Strong Contribution; 2-Moderate Contribution; 1-Low Contribution;					

Semester					
	Course Code: CET2161	**Course Title:** Chemical Safety and Risk Management	**Credits = 4**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**0**

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

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

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

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

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

Chemical Engineering Elective - CET2161 Chemical Safety and Risk Management
Mapping of Course Outcomes (COs) with Programme Outcomes (POs)

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

Chemical Engineering Elective - CET2161 Chemical Safety and Risk Management
Mapping of Course Outcomes (COs) with Programme Specific Outcomes (PSOs)

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

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

Sr No.	Elective	Credit
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 molecules 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	4
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: microstates 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.	4
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, isotopes	4

	H1 NMR: Chemical shifts and factors affecting the same, spin-spin coupling of different systems, 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 connectivity: 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, rearrangement of ions, Maclaferty rearrangement, retro Diels-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 Chemistry (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; Organocuprates, 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, metallocene Importance of organometallic compounds in biological systems	**4**
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	**4**

	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, **Computational methods:** Molecular mechanics, MO theory, semi empirical and ab initio methods, SCF theory, Hartree Fock method, DFT.	**4**
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 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 film (forced convection mass transfer).	**4**
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.)	**4**
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, behavior of thin cylinders. Problems on thin cylindrical and spherical shells. Behavior 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 their 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	**4**

	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. Diverse 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 maximization, 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/ liberalization/ privatization/ globalization	**4**
11	**CET 1506E: Engineering Aspects of Manufacturers of Organic Chemicals (Chemical Engineering Department)** Specific 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, Sandmeyer's reaction, Drazen's 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.	**4**
12	**CET 1204E: Electrochemical Engineering (Chemical Engineering Department)** Introduction to electrochemical engineering. Theoretical aspects and special features of electrochemical processes. Role of mass transfer in a variety of electrochemical processes. Some aspects of electrochemical reactor design. Scale-up and optimization of reactors.	**4**
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.	**4**
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.	**4**
15	**CET 1103E: Heat Transfer Equipment Design (Chemical Engineering Department)** Classification of Heat Transfer Equipment, direct, indirect, boiling, fired, Fluidized, geometry, construction.	**4**

	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. Fluidized 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	**4**
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 behavior, 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	**4**
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 behavior 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	**4**
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, Geo-statistics	**4**
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,	**4**

	Thermal cracking, Catalytic cracking, Hydro processing, 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	**4**
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, Heterogenization of homogeneous catalysts, Catalysis by microwaves and ultrasound, Catalyst recovery and reuse	**4**
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, Immobilized enzymes, zeozymes, complexes, Electrochemical catalysis, Photocatalysis, Microwave catalysis, Ultrasound catalysis, Synergistic catalysis, Important examples from, Refinery industry -FCC, reforming, platforming, hydroforming, polymerization, alkylation, isomerization; hydro-desulfurization, hydro-nitrogenation, Pharmaceutical and fine chemical industry, Dyestuff and intermediate industries, Perfume and flavor industry, Polymer industry, Textile industry, Paint industry, Edible oil industry, Food industry, Waste water treatment, Catalysis for auto-exhaust pollution abatement, DeNox, DeSOx technologies	**4**
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 equation, Surface Excess, Monolayer phase Adsorption: Localized 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, Hydrotropic Solubilization in micelles: Location of solubilize 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	**4**
25	**CET 1603E: Interfacial Science and Engineering (Chemical Engineering Department)**	**4**

	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 Debye-Huckel 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.	
26	**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	**4**
27	**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	**4**

	Bioreactor design, Scale up of bioreactions/reactors, Downstream processing in biochemical industry. Organic synthesis using enzymes	
28	**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.	**4**
29	**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. Dissociation Extraction, Reactive Extraction	**4**
30	**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 polymerization, Kinetic schemes, Orders of reactions, Cross-linking, Co-polymerization, Heat effects Polymerization Processes and methods of manufacture: Bulk, Solution, Suspension and emulsion polymerization with examples, polystyrene, polyethylene/propylene, styrene-Butadiene, poly urethane, Epoxy, PET, Kinetics, reaction rates, diffusional limitations, Biodegradable polymers.	**4**
31	**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, fiber spinning and after treatment. Equipment design and operating conditions Elastomer Technology: Vulcanization, Reinforcement compounding Equipment- design & operating conditions, environmental impact	**4**

	Recycle of polymers: Reprocessing techniques and limitations Selection of polymers: domestic & engineering usage Rheological and mechanical measurements concept of solution viscosity	
32	**CET 1211E: Polymer Reactor Engineering (Chemical Engineering Department)** Kinetic modelling, concept of reactor design, optimization and control of polymerization process, isolation, and separation of monomers/catalyst/by products etc. for Bulk polymerization, Solution polymerization, Emulsion polymerization, suspension polymerization with case studies Kinetic modelling of co-polymerization processes.	**4**
33	**CET 1605E: Advanced topics in Polymer Chemistry/Physics Characterization/Analysis of Polymers (Chemical Engineering Department)** Structure/property relationship: Morphology & Crystallinity 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.	**4**
34	**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 pipeline specs CO_2/H_2S/COS Removal Gas dehydration Gas compression for pipeline transport Coal bed methane, Biogas (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	**4**

	- 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** - Coal, Indian Coal - Biomass - Refinery Heavy Residue **Power generation**, combined cycle, cogeneration	
35	**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	**4**
36	**CET 1512E: Project Management: Case Study Approach (Chemical Engineering Department)** Project: meaning, Different types, why to manage, cost overruns centers, various stages of project execution: conception to commissioning. Project execution as a 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.	**4**

	Bar charts and Network diagram. Project commissioning: mechanical and process.	
37	**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 of superconductors Smart Materials: Shape memory alloys, Auxetic materials and Biomimmicking materials. Stimuli for sensors and actuators.	**4**
38	**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	**4**
39	**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) Open FOAM 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)	**4**

40	**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. 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.	**4**
41	**CET 1408 Advanced Membrane Separations** Introduction: classification and definitions Membrane Processes and their applications: Microfiltration, Ultrafiltration and micelle-enhanced ultrafiltration, Nanofiltration, Reverse osmosis, Dialysis, piezo dialysis, electrodialysis, Pervaporation and membrane distillation, Gas permeation, Liquid membranes, Ion exchange membranes Transport mechanisms, and mathematical modelling. Membranes: Design of membranes, Characterization Polarization and fouling: Polarization phenomena and fouling concentration polarization, Characteristic flux behavior in pressure driven membrane operation, Membrane fouling, Methods to reduce fouling Process design: modules and configurations: Capillary, hollow fiber, tubular, Plate and frame, Spiral wound. Membrane reactors and their applications in biotechnology ***Textbooks:*** 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.	**4**
42	**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	**4**

	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 ***Textbooks:*** Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine. 2nd ed. Burlington, MA: Academic Press, 2004. ISBN: 9780125824637.	
43	**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 behavior of Training and Test MSE. Case study of linear regression with K-nearest neighbor 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. ***Textbooks:*** 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)	**4**
44	**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	**4**

	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	
45	**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, technology, and society Environmental degradation, global warming and their effect on science, technology, and society IPR issues and their relevance to science, technology, and society Some aspects of the 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	**4**