NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

CURRICULUM & SYLLABUS

OF

Bachelor of Technology and Master of Technology (Dual Degree) in Chemical Engineering

2023 ONWARD ADMISSION BATCH

V0:

First Year Curriculum Recommended by members of UGAC	19.08.2023
First Year Curriculum Approved by the Chairman, Senate	19.08.2023
First Year Curriculum & Syllabus ratified in the 71st Senate meeting (Item No. 71.5(b))	18.12.2023
Entire Curriculum and Syllabus Recommended by UGAC	09.12.2024
Entire Curriculum and Syllabus Approved by the 73rd Senate (Item No. 73.8)	23.03.2025

DEPARTMENT OF CHEMICAL ENGINEERING

Program Name: Bachelor of Technology and Master of Technology (Dual Degree) in Chemical Engineering

DETAILED CURRICULUM

CURRICULUM OF 2023 ONWARD UNDERGRADUATE ADMISSION BATCH FOR CHEMICAL ENGINEERING - B.TECH. AND M.TECH (DUAL DEGREE)

L= Lecture hour/ week; T= Tutorial hour/ week; S= Sessional/ practical hour/ week

C= Subject credit point; H= Subject contact hour/ week.

GROUP – 1

FIRST SEMESTER

Semester - I							
Sl. No	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	MAC01	Mathematics - I	3	1	0	4	4
2	CSC01	Computer Programming	2	1	0	3	3
3	XEC01	Engineering Mechanics	2	1	0	3	3
4	XEC02*	Basic Electrical and Electronics Engineering	3	0	0	3	3
5	ESC01	Ecology and Environment	2	0	0	2	2
6	CYC01	Engineering Chemistry	3	0	0	3	3
7	CSS51	Computer Programming Laboratory	0	0	3	2	3
8	XES52	Basic Electrical and Electronics Engineering Laboratory	0	0	3	2	3
9	CYS51	Engineering Chemistry Laboratory	0	0	2	1	2
		TOTAL	**15**	**3**	**8**	**23**	**26**

***From the AY2025-26,** L-T-P of XEC02 is 3-1-0, Credit = 4

SECOND SEMESTER

Semester - II							
Sl. No	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	MAC02	Mathematics - II	3	1	0	4	4
2	CSC02	Data Structure and Algorithms	2	1	0	3	3
3	PHC01	Engineering Physics	2	1	0	3	3
4	HSC01	Professional Communication	2	0	2	3	4
5	CSS52	Data Structure and Algorithms Laboratory	0	0	3	2	3
6	XES51	Engineering Graphics	0	1	3	3	4
7	PHS51	Engineering Physics Laboratory	0	0	2	1	2
8	XXS51	Extra Academic Activities	0	0	2	1	2
		TOTAL	9	4	12	20	25

GROUP – 2

FIRST SEMESTER

Semester - I							
Sl. No	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	MAC01	Mathematics - I	3	1	0	4	4
2	CSC01	Computer Programming	2	1	0	3	3
3	XEC01	Engineering Mechanics	2	1	0	3	3
4	PHC01	Engineering Physics	2	1	0	3	3
5	HSC01	Professional Communication	2	0	2	3	4
6	CSS51	Computer Programming Laboratory	0	0	3	2	3
7	XES51	Engineering Graphics	0	1	3	3	4
8	PHS51	Engineering Physics Laboratory	0	0	2	1	2
9	XXS51	Extra Academic Activities	0	0	2	1	2
		TOTAL	**11**	**5**	**12**	**23**	**28**

SECOND SEMESTER

Semester - II							
Sl. No	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	MAC02	Mathematics - II	3	1	0	4	4
2	CSC02	Data Structure and Algorithms	2	1	0	3	3
3	XEC02*	Basic Electrical and Electronics Engineering	3	0	0	3	3
4	ESC01	Ecology and Environment	2	0	0	2	2
5	CYC01	Engineering Chemistry	3	0	0	3	3
6	CYS51	Engineering Chemistry Laboratory	0	0	2	1	2
7	CSS52	Data Structure and Algorithms Laboratory	0	0	3	2	3
8	XES52	Basic Electrical and Electronics Engineering Laboratory	0	0	3	2	3
		TOTAL	**13**	**2**	**8**	**20**	**23**

***From the AY2025-26,** L-T-P of XEC02 is 3-1-0, Credit = 4

Semester - III							
Sl. No.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CHC301	Process Calculations	3	1	0	4	4
2	CHC302	Chemical Engineering Thermodynamics	3	1	0	4	4
3	CHC303	Fluid Mechanics	3	1	0	4	4
4	CHC304	Numerical Methods in Chemical Engineering	3	0	0	3	3
5	CYC331	Industrial Chemistry	3	0	0	3	3
6	CYS381	Instrumental Analysis Laboratory	0	0	3	2	3
7	CHS351	Fuel Laboratory	0	0	3	2	3
		TOTAL	**15**	**3**	**6**	**22**	**24**
Semester - IV							
Sl.No.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CHC401	Heat Transfer	3	1	0	4	4
2	CHC402	Mechanical Operations	3	1	0	4	4
3	CHC403	Mass Transfer- I	3	1	0	4	4
4	CHC404	Chemical Reaction Engineering	3	1	0	4	4
5	CHE4**	Depth Elective-1	3	0	0	3	3
6	CHS451	Reaction Engineering Laboratory	0	0	3	2	3
7	CHS452	Fluid Mechanics Laboratory	0	0	3	2	3
		TOTAL	**15**	**4**	**6**	**23**	**25**
Semester - V							
Sl. No.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CHC501	Instrumentation and Process Control	3	1	0	4	4
2	CHC502	Mass Transfer- II	3	1	0	4	4
3	CHC503	Chemical Process Technology	3	1	0	4	4
4	CHC504	Industrial Safety and Risk Management	3	0	0	3	3
5	CHE5**	Depth Elective-2	3	0	0	3	3
6	CHS551	Heat Transfer Laboratory	0	0	3	2	3
7	CHS552	Mechanical Operations Laboratory	0	0	3	2	3
		TOTAL	**15**	**3**	**6**	**22**	**24**
Semester - VI							
Sl. No.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	HSC631	Economics and Accountancy	3	0	0	3	3
2	CHC601	Chemical Plant Design and Economics	3	0	0	3	3
3	CHC602	Petroleum Refining and Petrochemicals	3	1	0	4	4
4	CSC631	AI & ML	3	1	0	4	4
5	CHE6**	Depth Elective - 3	3	0	0	3	3
6	CHS651	Process Control Laboratory	0	0	3	2	3
7	CHS652	Mass Transfer Laboratory	0	0	3	2	3
8	CHS653	Chemical Process Equipment Design	0	0	3	2	3
		TOTAL	**15**	**2**	**6**	**23**	**26**
Semester – VII							
Sl. No.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	MSC731	Principles of Management	3	0	0	3	3
2	CHC702	Transport Phenomena	3	1	0	4	4

3	CH1001	Advanced Process Dynamics and Control	2	0	2	4	4
4	CHE7**	Depth Elective - 4	3	0	0	3	3
5	CH 901*	Depth Elective – I (MTech Basket)	3	0	0	3	3
6	YYO901*	Open Elective – 1 (MTech Basket of CSE/ME/BT/MA)	3	0	0	3	3
7	CHS751	Process Modelling and Simulation Laboratory	0	0	3	2	3
8	CHS752	Industrial Training / Internship and Seminar (6 weeks)	0	0	3	2	3
		TOTAL	**15**	**1**	**9**	**24**	**27**
Semester – VIII							
Sl.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CH2001	Computer-aided Design	4	0	0	4	4
2	CH2002	Advanced Materials for Chemical Engineering Applications	4	0	0	4	4
3	CH902*	Dept. Elective-II (MTech Basket)	3	0	0	3	3
4	CH903*	Dept. Elective-III (MTech Basket)	3	0	0	3	3
5	CH2051	Environment and Membrane Laboratory	0	0	4	2	4
6	CH2052	Industrial Project-I	0	0	6	3	6
7	CH2053	Technical Communication-I	0	0	0	1	0
		Total	**0**	**0**	**20**	**20**	**12**
Semester – IX							
Sl.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CH3001	Multi-Scale Simulation of Chemical Processes	4	0	0	4	4
2.	CH3002	Advance Separation Processes	3	1	0	4	4
2	CH904*	Depth Elective - IV	3	0	0	3	3
3	CH3051	Industrial Project - II	0	0	12	6	12
4	CH3052	Technical Communication-II	0	0	0	1	0
		TOTAL	10	1	12	18	23
Semester – X							
Sl.	**Code**	**Subject**	**L**	**T**	**S**	**C**	**H**
1	CH4051	Dual Degree Capstone Project/Internship Thesis	0	0	24	12	24
2	CH4052	Project/Internship Seminar	0	0	0	2	0
3	CH4053	Grand Viva Voce	0	0	0	1	0
		TOTAL	**4**	**0**	**24**	**15**	**24**

CREDIT UNIT OF THE PROGRAM:

Semester	I+II	III	IV	V	VI	VII	VIII	IX	X	TOTAL
Credit Unit	43	22	23	22	23	24	20	18	15	210

DEPTH ELECTIVE COURSE BASKETS

THE STUDENTS PRIMARILY WILL OPT FROM THE DEPTH ELECTIVE SUBJECT(S) THAT ARE OFFERED IN A PARTICULAR SEMESTER BY HIS/ HER OWN DEPARTMENT. HOWEVER, A STUDENT CAN OPT FOR DEPTH ELECTIVE SUBJECT(S) THAT ARE OFFERED BY OTHER DEPARTMENT IN A PARTICULAR SEMESTER, WITH THE PERMISSION/ CONSENT FROM HIS/ HER HEAD OF THE DEPARTMENT AND THE CONCERNED TEACHER OF THAT SUBJECT.

4th Semester

Sl. No	Code	Subject
1	CHE410	Fuels and Combustion
2	CHE411	Non-conventional Energy Engineering
3	CHE412	Colloids and Interface Engineering
4	CHE413	Industrial Pollution Control and Treatment

5th Semester

Sl. No	Code	Subject
1	CHE510	Process Intensification and Membrane Technology
2	CHE511	Material Science and Engineering
3	CHE512	Energy Management and Process Optimization
	CHE513	Bioprocess & Bioreactor Engineering

6th Semester

Sl. No.	Code	Subject
1	CHE610	CFD Applications in Chemical Engineering
2	CHE612	Combustion Engineering
3	CHE613	Process Modelling, Simulation, and Optimization
4	CHE614	Treatment and management of water resources

7th Semester

Sl. No	Code	Subject
1	CHE710	Multiphase Flow
2	CHE711	Pinch Technology for Process Heat Integration
3	CHE712	Nanotechnology
4	CHE713	Polymer Technology
5	CHE720	Applied Microfluidics in Chemical Engineering
6	CHE721	Waste Management and Resource Recovery
7	CHE722	Innovation and Entrepreneurship in Chemical Processes
8	CHE723	Fuel Cell Technology

(M Tech Elective Basket)

Sl. No.	Subject Code	Name of the Subject
1.	CH9010	Biochemical and Bio Engineering
2.	CH9011	Reactive Multiphase System
3.	CH9012	Advanced Process Integration and Optimization

8th Semester (M Tech Elective Basket)

Sl. No.	Subject Code	Name of the Subject
1.	CH9020	Bubble and Droplet Dynamics
2.	CH9021	Environmental Engineering
3.	CH9022	Chemical Processes for Micro-electronic Fabrication
4.	CH9030	Advanced Fluid Dynamics
5.	CH9031	Circular Economy and Waste Valorization
6.	CH9032	Catalysis in Chemical Industry

9th Semester (M Tech Elective Basket)

Sl. No.	Subject Code	Name of the Subject
1.	CH9040	Biofuel Technology
2.	CH9041	Artificial Intelligence and Optimization for Chemical Processes
3.	CH9042	Sustainable Process Technology

DETAILED SYLLABUS (1st Year)

Sl. No	Code	Subject	L	T	S	C	H
1	MAC01	Mathematics - I	3	1	0	4	4
2	CSC01	Computer Programming	2	1	0	3	3
3	XEC01	Engineering Mechanics	2	1	0	3	3
4	PHC01	Engineering Physics	2	1	0	3	3
5	CYC01	Engineering Chemistry	3	0	0	3	3
6	ESC01	Ecology and Environment	2	0	0	2	2
7	HSC01	Professional Communication	2	0	2	3	4
8	MAC02	Mathematics - II	3	1	0	4	4
9	CSC02	Data Structure and Algorithms	2	1	0	3	3
10	XEC02	Basic Electrical and Electronics Engineering	3	0	0	3	3
11	PHS51	Engineering Physics Laboratory	0	0	2	1	2
12	CSS51	Computer Programming Laboratory	0	0	3	2	3
13	XES51	Engineering Graphics	0	1	3	3	4
14	CYS51	Engineering Chemistry Laboratory	0	0	2	1	2
15	CSS52	Data Structure and Algorithms Laboratory	0	0	3	2	3
16	XES52	Basic Electrical and Electronics Engineering Laboratory	0	0	3	2	3
17	XXS51	Extra Academic Activities	0	0	2	1	2
		TOTAL	**24**	**7**	**20**	**43**	**51**

DETAILED SYLLABUS

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MAC01	**MATHEMATICS - I**	PCR	3	1	0	4	4
Pre-requisites		Basic concepts of function, limit, differentiation and integration.					
Course Outcomes	• CO1: learn the fundamentals of differential calculus of single and several variables. • CO2: learn the basic concepts of convergence of infinite series. • CO3: understand the basic concepts of integral calculus along with its various applications. • CO4: acquire the theoretical knowledge of vector calculus and its engineering applications.						
Topics Covered	**Functions of Single Variable:** Review of limit, continuity and differentiability. Mean value theorems: Rolle's Theorem, Lagrange's Mean Value Theorem (MVT), Cauchy's MVT, Taylor's theorem, Taylor's and Maclaurin's series. (8) **Functions of several variables:** Limit, continuity and differentiability of functions of several variables, partial derivatives and their geometrical interpretation, derivatives of composite and implicit functions, derivatives of higher order and their commutativity, Homogeneous function, Euler's theorem and its converse, Exact differential, Jacobian, Taylor's & Maclaurin's series, Maxima and Minima, Necessary and sufficient condition for maxima and minima (no proof). (11) **Sequences and Series:** Real sequences and their convergence, Series of positive terms, Necessary and sufficient condition for convergence, p-series, geometric series, Comparison test, D Alembert's ratio test, Cauchy's root test, Alternating series, Leibnitz's rule, Absolute and conditional convergence. (6) **Integral Calculus:** Review of the idea of integration as a limit of a sum, Mean value theorems of integral calculus, Area and length in Cartesian and polar co-ordinates, Volume and surface area of solids of revolution in Cartesian and polar forms, Improper integrals and their convergence, Beta and Gamma functions. (12) **Multiple Integrals:** Evaluation of double and triple integrals, Change of order of integration, Change to better coordinates, Area and volume by double integration, Volume by triple integration. (10) **Vector Calculus:** Vector valued functions and its differentiability, Line integral, Surface integral, Volume integral, Gradient, Curl, Divergence, Green's theorem in the plane (including vector form), Stokes' theorem, Gauss's divergence theorem and their engineering applications. (9)						
Text Books, and/or reference material	**Text Books:** 1. Kreyszig, E., Advanced Engineering Mathematics: 10th edition, Wiley India Edition, 2010. 2. Murray, D.A., Differential and Integral Calculus, FB & C Limited, 2018. 3. Marsden, J. E; Tromba, A. J.; Weinstein: Basic Multivariable Calculus, Springer, 2014. 4. Murray Spiegel, Schaum's Outline of Vector Analysis, .Tata McGraw Hill Education, 1980 **Reference Books:** 1. Tom Apostal, Calculus-Vol-I & II, Wiley Student Edition, 2011. 2. Thomas and Finny: Calculus and Analytic Geometry, 11th Edition, Addison Wesley.						

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MAC01	CO1	2	3	2	3	1	1	-	-	1	1	1	2
	CO2	2	3	2	3	-	1	-	-	1	1	2	2
	CO3	2	3	2	3	-	1	1	-	-	2	2	2
	CO4	3	3	2	3	1	1	-	1	-	2	1	2

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSC01	**COMPUTER PROGRAMMING**	PCR	2	1	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Basic knowledge of computer.		CT+MT+EA					

Course Outcomes	• CO1: To understand basics of computer programming, program flow, and programming constructs. • CO2: Develop concepts on basic and complex data types, conditional and iterative statements. • CO3: Exercise the concepts of user defined functions to solve real time problems. • CO4: Inscribe C programs that use Pointers to access arrays, strings and functions. • CO5: Exercise user defined data types including structures and unions to solve problems.
Topics Covered	**Introduction to C**: Phases of developing a running computer program in C. (2L) Data types, size and values. Char, Unsigned and Signed data types. Number systems and representations. Constants, Overflow. (3L) Data concepts in C: Constants, Variables, Expressions, Operators, and operator precedence in C. (2L) Statements: Declarations, Input-Output Statements, Compound statements, Selection Statements. (2L) Conditions, Logical operators, Precedences. Repetitive statements, While construct, Do-while Construct, For construct. (3L) Arrays. Strings. Multidimensional arrays and matrices. (3L) **Pointers:** Pointer variables. Declaring and dereferencing pointer variables. Pointer Arithmetic. Examples. Accessing arrays through pointers. Pointer types, Pointers and strings. String operations in C. (6L) Dynamic memory allocation. (2L) **Modular Programming:** Functions: The prototype declaration, Function definition. (3L) Function call: Passing arguments to a function, by value, by reference. Scope of variable names. Recursive function calls, Tail recursion. (4L) Sorting problem: Sorting in arrays with an example of Bubble sort. Sorting in strings. (3L) Search problem: Linear search and binary search. (2L) **More Data-types in C:** Structures in C: Motivation, examples, declaration, and use. Operations on structures. Passing structures as function arguments. type defining

	structures. (4L) File input-output in C. Streams. Input, output and error streams. Opening, closing and reading from files. Programming for command line arguments. (3L)
Text Books, and/or reference material	**Text Books:** 1. P. Deitel, H. Deitel. C How to Program. Pearson Education India, 7th Ed. 2. B. W. Kernighan, Dennis M. Ritchie. The C Programming. Prentice Hall Software Series, 2nd Ed. **Reference Books:** 1. P. Dey and M. Ghosh. Computer fundamentals and programming in C. Oxford press, 2013. 1. Y. Kanetkar. Let Us C. BPB Publications, Sixteenth edition, 2017.

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CSC01	CO1	2	2	1	-	1	2	-	-	-	-	-	-
	CO2	3	2	1	-	1	1	1	-	-	-	-	-
	CO3	2	2	1	-	-	2	-	-	-	-	-	-
	CO4	3	2	2	-	-	1	-	-	-	-	-	-
	CO5	3	1	2	-	1	2	-	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
XEC01	**ENGINEERING MECHANICS**	PCR	2	1	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
		CT+MT+EA					
Course Outcomes	• CO1: Acquire knowledge of mechanics and ability to draw free body diagrams. • CO2: Apply knowledge of mechanics for solving special problems like truss and frame analysis. • CO3: Ability to calculate centroid, moments of inertia for various shapes. • CO4: Learn momentum and energy principles. • CO5: Knowledge on virtual Work Principle and its application						
Topics Covered	Engineering Mechanics; measurement and SI units. [1] Vectors and force as a vector; Resultant of a system of forces on a particle; free body diagram and conditions of equilibrium of a particle; problems on particles; equilibrium of particles in space. [2] Resultant of a system of forces and couples on a rigid body; conditions of equilibrium of a rigid body; free body diagrams of rigid bodies subjected to different types of constraints; simple space problems of rigid bodies. [4] Coefficients of static and kinetic friction; problems involving friction; theories of friction on square threaded power screw and flat belt. [5] Simple trusses; analysis of trusses by method of joints and method of sections. [5]						

	Centre of gravity and centre of mass; centroids of lines, curves and areas; first moment of area; second moment of area; polar moment of inertia; radius of gyration of an area; parallel axis theorem; mass moment of inertia. [4] Path, velocity, acceleration; rectilinear and curvilinear motion; motion of system of particles; introduction to the concept of plane kinematics of rigid bodies. [6] Newton's second law of motion; dynamic equilibrium and D'Alembert's principle; linear momentum; angular momentum; rectilinear and curvilinear motion; principles of work–energy and impulse–momentum; impact of system of particles; introduction to the concept of plane kinetics of rigid bodies. [12] Principle of Virtual Work, Solution of Problems on Mechanics using Principle of Virtual Work [3]
Text Books, and/or reference material	1) S P Timoshenko and D H Young, Engineering Mechanics, 5th Edition 2) J L Meriam and L G Kraige, Engineering Mechanics, 5th Edition, Wiley India 3) F P Beer and E R Johnston, Vector Mechanics for Engineers 4) I H Shames, Engineering Mechanics

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
XEC01	CO1	1	-	-	-	-	-	-	-	-	-	-	1
	CO2	1	1	1	1	-	-	-	-	-	-	-	1
	CO3	1	1	-	-	-	-	-	-	-	-	-	1
	CO4	1	2	-	-	-	-	-	-	-	-	-	1
	CO5	-	2	2	2	2	1	-	-	-	1	-	1

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PHC01	**Engineering Physics**	**PCR**	**2**	**1**	**0**	**3**	**3**
Pre-requisites:		Course Assessment methods: (Continuous (CT), mid-term (MT) and end assessment (EA))					
NIL		CT+MT+EA					

Course Outcomes	• CO1: To realize and apply the fundamental concepts of physics such as superposition principle, simple harmonic motion to real world problems. • CO2: Learn about the quantum phenomenon of subatomic particles and its applications to the practical field. • CO3: Gain an integrative overview and applications of fundamental optical phenomena such as interference, diffraction and polarization. • CO4: Acquire basic knowledge related to the working mechanism of lasers and signal propagation through optical fibers.
Topics Covered	**Harmonic Oscillations** - Linear superposition principle, Superposition of two perpendicular oscillations having same and different frequencies and phases, Free, Damped and Forced vibrations, Equation of motion, Amplitude resonance, Velocity resonance, Quality factor, sharpness of resonance, [8]

	Wave Motion: Longitudinal waves, Transverse waves, Wave equation, phase velocity and group velocity, Maxwell's equations, Electro-magnetic waves in free space. [3] **Introductory Quantum Mechanics** - Inadequacy of classical mechanics, Blackbody radiation, Planck's quantum hypothesis, de Broglie's hypothesis, Heisenberg's uncertainty principle and applications, Schrodinger's wave equation and applications to simple problems: Particle in a one-dimensional box, Simple harmonic oscillator, Tunnelling effect. [8] **Interference & Diffraction** - Huygens' principle, Young's experiment, Superposition of waves, Conditions of sustained Interference, Concepts of coherent sources, Interference by division of wavefront, Interference by division of amplitude with examples, The Michelson interferometer and some problems; Fraunhofer diffraction, Single slit, Multiple slits, Resolving power of grating. [13] **Polarisation** - Polarisation, Qualitative discussion on Plane, Circularly and elliptically polarized light, Malus law, Brewster's law, Double refraction (birefringence) - Ordinary and extra-ordinary rays, Optic axis etc.; Polaroid, Nicol prism, Retardation plates and analysis of polarized lights. [5] **Laser and Optical Fiber** - Spontaneous and stimulated emission of radiation, Population inversion, Einstein's A & B co-efficient, Optical resonator and pumping methods, He-Ne laser. Optical Fibre– Core and cladding, Total internal reflection, Calculation of numerical aperture and acceptance angle, Applications. [5]
Text Books, and/or reference material	**TEXT BOOKS**: 1. The Physics of Vibrations and Waves, H. John Pain, Willy and Sons 2. A Text Book of Oscillations and Waves, M. Goswami and S. Sahoo, Scitech Publications 3. Engineering Physics, H. K. Malik and A. K. Singh, McGraw-Hill. **REFERENCE BOOKS**: 1. Vibrations and Waves in Physics, Iain G. Main, Cambridge University Press 2. Quantum Physics, R. Eisberg and R. Resnick, John Wiley and Sons 3. Fundamental of Optics, Jankins and White, McGraw-Hill 4. Optics, A. K. Ghatak, Tata McGraw-Hill 5. Waves and Oscillations, N. K. Bajaj, Tata McGraw-Hill 6. Lasers and Non-linear Optics, B. B. Laud, New Age International Pvt Lt

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
PHC01	CO1	3	2	1	1	1	-	-	1	-	-	-	1
	CO2	3	2	-	2	-	-	-	-	-	-	-	1
	CO3	3	2	2	2	1	1	1	1	1	-	1	1
	CO4	3	2	2	2	1	1	1	-	1	-	1	1

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CYC01	**Engineering Chemistry**	PCR	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))
None	CT+MT+EA

Course Outcomes	• CO1: Students will get the knowledge of fundamentals as well industrial applications of polymer, petroleum products, organometallic compounds and others. • CO2: Students will be able to elucidate the structure of different organic compounds and to analyze the structure-property correlation. • CO3: Students will be aware on the role played by different metals in biological systems and also the ecological impact of metals. • CO4: Students will be able to understand and analyze thermodynamical, kinetic as well as electrochemical aspects of chemical systems and apply the understanding in the technical field.
Topics Covered	**ORGANIC CHEMISTRY** i. **Polymer chemistry and polymer engineering:** Fundamental concept on polymer chemistry; synthesis and application of important polymers, Rubber and plastic materials; vulcanization, structure-property correlation: Concept of Molecular weight of polymer, Glass transition temperature. Engineered polymer: Thermally stable, flame retardant, Conducting polymer. (5L) ii. **Petroleum Engineering and oil refinery:** Origin of petroleum, separation principle and techniques of distillation of crude oil, thermal and catalytic cracking of petroleum, uses of different fractions, knocking, anti-knock compounds, octane number and cetane number. High octane and Aviation fuel. Bio-diesel. (3L) iii. **Structure elucidation of organic compounds by modern spectroscopic methods:** Application of UV-Visible (Lambert-Beers law), concept of chromophore, auxochrome, hypso-, hyper-, bathochromic, red shift. FT-IR spectroscopy and Mass spectroscopy (including instrumentation). (4L) **INORGANIC CHEMISTRY** i. **Coordination Chemistry:** Crystal Field Theory of octahedral and tetrahedral complexes, colour and magnetic properties, LMCT, MLCT, IVCT. Isomerism and stereochemistry.(5L) ii. **Bioinorganic Chemistry:** Metal ions in biological systems: Fe, Cu (2L) iii. **Industrial applicationof Organometallic complexes:** π-acid ligands, stabilization of metal low oxidation state and 18 electron rules, metal carbonyls and nitrosyls, metal-alkene complexes, Various catalytic cycles of industrial importance. (4L) iv. **Environmental Chemistry:** Metal toxicity (As, Hg, Pb and Cd) and its remediation (1L) **PHYSICAL CHEMISTRY** i. **Chemical Thermodynamics:** 2nd law of thermodynamics: Concept of thermodynamic engine (Carnotand reverse Carnot cycle), entropy, free energy. Temperature and pressure dependence of entropy and free energy. Change in phase: phase diagram of single component system. Cryogenics: Joule Thomson experiment. (5L) ii. **Chemical Kinetics:**Rate expression of Reversible reaction, parallel reaction,and Consecutive reaction with proper examples. Temp effect on reaction rate.(3L) iii. **Catalysis:** Types of catalysis, Rate expression for Catalysed reaction, Acid-base and Enzyme catalysis.(2L)

	iv. **Electrochemistry:**EMF, Nernst Equation, Application of electrochemistry in chemical processes. Electrochemical cell, Fuel cell, Li-ion battery (3L).
Text Books, and/or reference material	Suggested Text Books: (i) Physical Chemistry by P. Atkins, Oxford (ii) A guidebook to mechanism in Organic chemistry: Peter Sykes; Pearson Edu. (iii) Inorganic Chemistry Part-I & II, R. L. Dutta, The new book stall Suggested Reference Books: **Organic Chemistry**: (i) Basic stereochemistry of organic molecules: S. Sengupta; Oxford University press (ii) Engineering Chemistry: Wiley (iii) Elementary Organic Spectroscopy: William Kemp, ELBS with Macmillan **Inorganic Chemistry:** (i) Inorganic Chemistry: Principle structure and reactivity, J. E. Huheey, E. A. Keiter and R. L. Keiter, Pearson Education (ii) Bioinorganic Chemistry -- Inorganic Elements in the Chemistry of Life: An Introductionand Guide, 2nd Edition, Wolfgang Kaim, Brigitte Schwederski, Axel Klein. (iii) Inorganic Chemistry Fourth Edition, Shriver & Atkins, Oxford **Physical Chemistry:** (i) Physical Chemistry by G.W Castellan (ii) Physical Chemistry by P. C. Rakshit

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CYC 01	CO1	1	2	-	-	-	-	-	-	-	-	-	-
	CO2	1	-	-	-	-	-	2	-	-	-	-	-
	CO3	1	2	1	1	1	-	-	-	-	-	-	-
	CO4	-	1	-	-	2	-	1	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ESC01	**Ecology and Environment**	PCR	2	0	0	2	2
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
NIL		CT+MT+EA					
Course Outcomes	• CO1: Understand the importance of environment and ecosystem. • CO2: Understand the fundamental aspect of pollutant tracking and its implementation in natural and anthropogenic pollution of air and water system. • CO3: Understand the scientific basis of local and as well as global issues. • CO4: Apply of knowledge to develop sustainable solution.						
Topics Covered	**UNIT – I: INTRODUCTION (2)** Multidisciplinary nature of Environmental Studies: Definition, Scope, and Importance.						

	UNIT–II: FUNDAMENTALS OF ECOLOGY (9) Definition, Components of Environment; Fundamentals of Ecology and Ecosystem; Components and Classification of Ecosystem; Energy flow in Ecosystem: Tropic level, Food Chain, Food Web, Ecological Pyramid; Biogeochemical cycles: Carbon, Nitrogen, Sulphur, Phosphorus, and Water Cycle; Biosphere and Biodiversity; Conservation. **UNIT–III: FUNDAMENTALS OF ENVIRONMENT (10)** **Environmental Pollution:** Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution, Solid Wastes, and Natural hazards: Floods, earthquakes, cyclones, and landslides. **Environmental Issues:** Climate change and global warming; acid rain; and ozone layer depletion. **Environment Quality:** Ambient air quality standards, Water quality parameters and standards: pH, Turbidity, Hardness, Sulphate, Phosphates, Iron, Dissolved Oxygen, BOD, and COD. **UNIT– IV: NATURAL RESOURCES (3)** Mineral Resources, Energy Resources: Conventional and Non-Conventional. **UNIT- V- GREEN TECHNOLOGY & ENVIRONMENTAL ETHICS (4)** Sustainability: Carbon Sequestration, Green building practices, Green computing; Carrying capacity; and Environment Protection Acts/laws.
Text Books, and/or reference material	1. A Basic Course in Environmental Studies. Deswal & Deswal. Pub. Dhanpat Rai & Sons 2. Ecology. Odum. Pub. Oxford & IBH 3. Environmental Engineering. Peany et.al. Pub. McGraw Hill 4. A Text Book of Environmental Engg. Venugpal Rao. Pub. PHI 5. A Basic Course in Environmental Studies. Deswal & Deswal. Pub. Dhanpat Rai & Sons 6. Environmental Studies. Bharucha. Pub. University of Press 7. Environmental Chemistry and Pollution, S. S. Dara & D. D. Mishra, S. Chand Publishing

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
ESC01	CO1	3	-	-	-	-	-	2	-	-	-	-	-
	CO2	1	-	-	-	-	-	2	-	-	-	-	-
	CO3	2	-	-	-	-	-	2	-	-	-	-	-
	CO4	1	-	3	-	-	2	1	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
HSC01	**Professional Communication**	PCR	2	0	2	4	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
None	CT+EA

Course Outcomes	• CO1: Learners will acquire linguistic proficiency in terms of improvement in their listening, speaking, reading, and writing skills. • CO2: Learners will acquire better communicative ability. • CO3: The course will help learners improve their social connectivity skill.
Topics Covered	Vocabulary 1. Word Formation, Use of Prefixes and Suffixes (1) 2. Synonyms, Antonyms (1) 3. Prefixes and Suffixes from Foreign Languages, Words from Foreign Languages (1) 4. Abbreviations and Acronyms (1) 5. Technical Vocabulary (1) Grammar 1. Identifying Common Errors in Articles and Prepositions (1) 2. Common Errors in Noun-Pronoun Agreement and Subject-Verb Agreement (1) 3. Misplaced Modifiers and Tenses (1) 4. Redundancies and Clichés (1) Reading 1. Reading and Its Importance, Techniques of Effective Reading (1) 2. Improving Comprehension Skills, Techniques for Good Comprehension (1) 3. Skimming and Scanning (1) 4. Comprehension, Intensive and Extensive Reading (2) Writing 1. Sentence Structures, Phrases and Clauses, Punctuation (2) 2. Organising Principles of Paragraphs (2) 3. Formal Letters, Letters of Complaint, Requisition Letters, Job Application, and Résumé (2) 4. Nature and Style of Sensible Writing, Defining, Describing, Classifying, Providing Examples and Evidence (2) 5. Essay Writing (2) 6. Précis Writing (2) 7. Report Writing (2) Oral Communication 1. Listening Comprehension (4) 2. Pronunciation, Intonation, Stress, and Rhythm (4) 3. Communication at the Workplace (4) 4. Everyday Conversation (4) 5. Group Discussion (4) 6. Interviews (4) 7. Formal Presentations (4)
Text Books, and/or reference material	**Text Book:** 1. English for Engineers –Sudharshana & Savitha (Cambridge UP) **Reference Books:** 2. *English*—Kulbhushan Kumar (Khanna Book Publishing) 3. *Remedial English Grammar*—F. T. Wood (Macmillan)

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
HSC01	CO1	1	--	--	1	--	1	--	1	2	3	1	--
	CO2	1	--	--	1	--	2	--	2	2	3	2	--
	CO3	--	--	--	1	--	3	--	3	3	3	2	--

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MAC02	**MATHEMATICS - II**	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))
Basic concepts of set theory, differential equations, and probability.	CT+MT+EA

Course Outcomes	• CO1: learn the basic concepts of linear algebra and be able to apply the same to solve various engineering problems. • CO2: understand fundamentals of ordinary differential equations and their applications. • CO3: acquire the theoretical knowledge of Fourier Series, Fourier & Laplace transforms, and learn about their applications. • CO4: learn the basic concepts of probability theory.
Topics Covered	**Introduction to Algebraic structures:** Group, subgroup, ring, subring, integral domain, and field. (3) **Linear Algebra:** Vector spaces over field, linear dependence and independence of vectors, linear span of a set of vectors, basis and dimension of finite dimensional vector space, elementary row/column operations, rank of a matrix, solutions of system of linear (homogeneous and non-homogeneous) equations, eigenvalues and eigenvectors, characteristic polynomials, Cayley-Hamilton theorem (without proof), Diagonalization of matrices. (15) **Ordinary Differential Equations (ODE):** Review of first order ODE, Picard's theorem (Statement Only), ODE of first order and of the first degree (exact ODE, rules for finding integrating factors), ODE of first order and of the higher degree (ODE solvable for x, solvable for y; Clairaut's equation, singular solution), homogeneous and non-homogeneous linear ODE with constant coefficients and variable coefficients (Euler–Cauchy type), linear dependence of solutions, Wronskian determinant, Solution of simultaneous ODEs $(dx/P = dy/Q = dz/R;\ dx/dt = ax + by,\ dy/dt = cx + dy)$, properties of nonlinear ODEs, phase plane analysis. (18) **Fourier series:** Piecewise smooth and periodic functions, Fourier series of a function in an interval, Dirichlet conditions, Convergence of Fourier series, Fourier sine and cosine series, Complex form of Fourier series. (4) **Fourier Transforms:** Fourier Integral Theorem (statement only), Different forms of Fourier Integrals, Fourier Transform and its inversion formula, Properties of Fourier Transform, Convolution. (7) **Laplace Transforms:** Laplace transforms and its Properties, Inverse Laplace transforms, Convolution theorem, Applications to ODE. (4) **Probability:** Random variables and probability distributions (discrete and continuous), Binomial, Poisson, Uniform and Normal distributions. (5)
Text Books, and/or reference material	**Text Books:** 1. Kreyszig, E., Advanced Engineering Mathematics: 10^{th} edition, Wiley India Edition (2010). 2. Strang, G., Linear algebra and its applications (4th Edition), Thomson (2006). 3. Murray, D.A., Introductory Course in Differential Equations, Khosla Publishing House (2021). 4. Debnath, L., Integral Transforms and Their Applications, CRC Press (1995).

	5. Baisnab, A.P., Jas, M., Elements of Probability and Statistics, McGraw Hill Education (2017). **Reference Books:** 1. Kumaresan, S., Linear algebra - A Geometric approach, Chaukhamba Auriyantaliya (2017). 2. Ross, S.L., Differential Equations, 3rd Edition, Wiley Student Edition (2017). 3. Shivamoggi, A., Integral Transforms for Engineers, PHI (2003). 4. Grinstead, C.M., Snell, J.L., Introduction to probability, American Mathematical Society (2012).

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
MAC02	CO1	3	3	2	1	2	-	2	-	-	-	1	2
	CO2	3	3	2	2	2	-	2	-	-	1	-	2
	CO3	3	3	2	2	3	1	1	-	1	1	1	2
	CO4	3	2	1	3	2	1	1	1	1	-	-	2

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSC02	Data Structure and Algorithms	PCR	2	1	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
CSC01 (Computer Programming)		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					

Course Outcomes	• CO1: Understanding the fundamental concepts of abstract data types, data structures, algorithms and time complexity analysis of algorithms. • CO2: Implementation of different abstract data types (array, linked list, stack, queue, tree, graph). • CO3: Implementation of different sorting and searching techniques along with their performance evaluation. • CO4: Analysis of the suitability/compatibility of different data structures based on the types of applications. • CO5: Design and development of algorithms for real-life applications.
Topics Covered	**Introduction:** Abstract Data Type (ADT), Data Structures, Concept of static and dynamic memory allocation, Algorithm, Analysis of time and space complexity of algorithms, Asymptotic notations: Big Oh, Big Omega and Big Theta notations, Impact of data structure on the performance of an algorithm. (6L) **Array:** Array as an ADT, Single and multi-dimensional array, Memory representation (row major and column major) of array, Address calculation for array elements. (2L) **Linked list:** Linked list as an ADT, Memory allocation and deallocation for a linked list, Linked list versus array, Types of linked lists: singly linked list, doubly linked list and circular linked

	list, Operations on linked list: creation, display, insertion and deletion (in different positions), Concatenation, Searching, Sorting, Applications of linked list: Representations and operations on polynomials, sparse matrices, etc., Array vs. Linked List. (6L)
	Stack: Stack as an ADT, Push and pop operations on stacks, Array implementation of stack, Linked list implementation of stack, Applications of stack: Recursion, Function call, Evaluation of postfix expression using stack, Conversion of infix to postfix using stack. (5L) **Queue:** Queue as an ADT, Enqueue and dequeue operations, Array implementation of queue, Limitation of array implementation, Circular queue, Linked list implementation of queue, Priority queue. (4L) **Binary Tree:** Binary Tree, Definition and properties, Representation of binary tree in memory: linked representation, array representation, Binary tree traversal (Preorder, Inorder and Postorder), Binary search tree, Heap (8L) **Searching Algorithms:** Linear search and binary search. (2L) Sorting Algorithms: Selection sort, Insertion sort, Quick sort, and Merge sort. (5L) **Graphs Algorithms:** Graph representation using Adjacency matrix and Adjacency list, Breadth First Search and Depth First Search algorithms. (4L)
Text Books, and/or reference material	**Text Books:** 1. R. F. Gilberg and B. A. Forouzan, "Data Structures: A pseudocode approach with C", 2nd Edition, CENGAGE Learning. 2. A. V. Aho, J. D. Ullman and J. E. Hopcroft, "Data Structures and Algorithms", Addition Wesley. 3. Lipschutz, "Data Structures (Schaum's Outline Series)", Tata Mcgraw Hill. 4. E. Horowitz, S. Sahni, S. Anderson-Freed, "Fundamentals of Data Structures in C", Universities Press; Second edition (2008). **Reference Books:** 1. Y. Langsam, M. J. Augenstein and A. N. Tanenbaum, "Data Structures using C and C++", Pearson, 2006. 2. Knuth, Donald E. The Art of Computer Programming. 3rd ed. Vols 1&2. Reading, MA: Addison-Wesley, 1997. ISBN: 0201896834. ISBN: 0201896842. ISBN: 0201896850. 3. Kleinberg and Eva Tardos. Algorithm Design. Addison-Wesley 2005 ISBN-13: 978-0321295354.

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CSC02	CO1	3	-	1	1	1	-	-	-	-	-	-	-
	CO2	3	2	1	2	2	-	-	-	-	-	-	1
	CO3	3	2	1	2	2	-	-	-	-	-	-	1
	CO4	3	3	2	3	3	-	-	-	-	-	-	1
	CO5	3	3	3	3	3	-	-	-	-	-	-	2

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
XEC02	**Basic Electrical and Electronics Engineering**	PCR	3	0	0	3	3

Pre-requisites	Course Assessment methods
(10+2) level mathematics and physics	CT+MT+EA

Course Outcomes	CO1: Learn the fundamentals of electric circuits and analyze the circuits using laws and network theorems. CO2: Gain the knowledge about magnetic circuits, electromagnetism and the basics of generation of alternating voltage. CO3: Understand the behaviour of single phase and poly-phase AC circuits. CO4: Understand the fundamentals of semiconductor devices. CO5: Analyze the design and characteristics of transistor-based electronic circuits. CO6: Evaluate operational amplifier-based circuits and logic gates.
Topics Covered	1. Introduction to Electrical systems, Fundamentals of Electric Circuits: Ohm's laws, Kirchhoff's laws, Independent and Dependent sources, Analysis of simple circuits. (4) 2. Network theorems (DC): Superposition Theorem, Thevenin's Theorem, Norton's Theorem, Maximum Power Transfer Theorem. (5) 3. Magnetic circuits: Review of fundamental laws of electromagnetic induction, Self and mutual inductances, Solution of magnetic circuits. (3) 4. Generation of alternating voltage and current, E.M.F. equation, Average and R.M.S. value, Phase and phase difference, Phasor representation of alternating quantity, Behaviour of AC circuits, Resonance in series and parallel R-L-C circuits. (6) 5. Poly-phase system, Advantages of 3-phase system, Generation of 3-phase voltages, Voltage, current and power in a star and delta connected systems, 3-phase balanced and unbalanced circuits. (3) 6. Semiconductor Devices: Construction, working and V-I characteristics of diode, Zener diode, Zener diode as a voltage regulator, LED. (6) 7. Transistors: Introduction to BJT, FET, MOSFET; CMOS, working principle, and V-I characteristics of Transistors, biasing of BJT circuits-fixed bias, emitter bias, feedback bias, voltage divider bias, transistor as an amplifier. (8) 8. Operational amplifier: Introduction, applications: inverting, non-inverting amplifier, unity follower, integrator, differentiator, summing circuit .(4) 9. Introduction of logic gates, memory: ROM, RAM. (3)
Text Books, and/or reference material	**TEXT BOOKS** 1. Electrical & Electronic Technology by Hughes, Pearson Education India. 2. Introduction Electronic Devices & Circuit Theory, 11/e, 2012, Pearson: Boylestad & Nashelsky. 3. Electronics: Fundamentals and Applications By D. Chattopadhyay, P. C. Rakshit; New Age Int. Publication. **REFERENCE BOOKS** 1. Advanced Electrical Technology by H. Cotton, Reem Publication Pvt. Ltd. 2. Electrical Engineering fundamentals by Vincent Deltoro, Pearson Edu. India. 3. The Art of Electronics 3e, by Paul Horowitz, Winfield Hill. 4. Electronics - Circuits and Systems, Fourth Edition by Owen Bishop. 5. Electronics Fundamentals: Circuits, Devices & Applications (8e) by Thomas L. Floyd & David M. Buchla.

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
XEC02	CO1	3	3	3	3	3	1	1	1	1	1	1	1
	CO2	3	3	3	3	2	1	2	1	1	1	1	1
	CO3	3	3	3	3	3	2	2	1	1	1	1	1
	CO4	2	3	2	2	-	1	-	-	-	-	-	1
	CO5	3	2	1	2	2	1	-	-	2	-	-	1
	CO6	3	2	2	2	3	-	-	-	2	-	-	1

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSS51	**COMPUTER PROGRAMMING LABORATORY**	PCR	0	0	3	3	2

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Outcomes	CO1: To understand the principle of operators, loops and branching statements. CO2: Implementation of function, recursion, arrays, and pointers based several types of assignments. CO3: To detail out the operations of strings. CO4: To understand structure and union. CO5: Application of C-programming to solve various types of problems.
Topics Covered	**List of Experiments:** 1. Programs on expression evaluation. 2. Programs on conditional statements and branching 3. Programs on iterations/loops. 4. Applications of Arrays 5. Programs on basics of functions and pointers. 6. Programs on string using array and pointers. 7. Programs on recursion. 8. Programs on structures, union. 9. Programs on File Operations. 10. Case Studies.
Text Books, and/or reference material	**Text Books:** 1. Y. Kanetkar, "Let Us C", BPB Publications, Sixteenth edition, 2017. 2. B. S. Gottfried, "Programming with C", McGraw Hill Education, 4th Ed., 2018. 3. E. Balagurusamy, "Computing Fundamentals and C Programming", McGraw Hill Education; Second edition, 2017. **Reference Books:** 1. P. Dey and M. Ghosh, "Computer fundamentals and programming in C", Oxford press, 2013. 2. R. Thareja, "Computer fundamentals and programming in C", Oxford press, 2013. 3. Schaum's Outline, Programming with C.

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CSS51	CO1	3	3	2	-	-	2	-	-	-	-	-	-
	CO2	2	2	1	-	-	1	-	-	-	-	-	-
	CO3	3	2	2	-	-	1	-	-	-	-	-	-
	CO4	2	3	2	-	-	2	1	-	-	-	-	-
	CO5	3	3	3	-	1	2	1	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PHS51	**Physics Laboratory**	PCR	**0**	**0**	**2**	**2**	**1**
Pre-requisites		Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA))					
NIL		CE+EA					
Course Outcomes	CO1: To realize and apply different techniques for measuring refractive indices of different materials. CO2: To realize different types of waveforms in electrical signals using CRO. CO3: To understand charging and discharging mechanism of a capacitor. CO4: To understand interference, diffraction and polarization related optical phenomena. CO5: To acquire basic knowledge of light propagation through fibers.						
Topics Covered	1. Find the refractive index of a liquid by a travelling microscope. 2. Determine the refractive index of the material of prism using spectrometer. 3. Determination of amplitude and frequency of electrical signals by oscilloscope. 4. To study the characteristics of RC circuits. 5. To study Brewster's law/Malus' law using laser light. 6. To study the diffraction of light by a grating. 7. To study the interference of light by Newton's ring apparatus. 8. To determine numerical aperture of optical fiber. 9. Determination of Planck constant.						
Text and/or reference material	**SUGGESTED BOOKS**: 1) A Text Book on Practical Physics – K. G. Mazumdar and B. Ghosh 2) Practical Physics – Worsnop and Flint						

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
PHS51	CO1	3	2	1	-	-	-	-	-	2	1	-	1
	CO2	3	2	1	-	-	1	-	-	2	1	-	1
	CO3	3	1	-	-	-	-	-	-	2	1	-	1
	CO4	3	2	-	1	-	1	1	-	2	1	-	1
	CO5	3	2	1	-	1	1	1	-	2	1	-	1

Correlation levels 1, 2 or 3 as defined below: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CYS51	**CHEMISTRY LABORATORY**	PCR	0	0	2	2	1
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
None		CT+EA					
Course Outcomes	• CO1: To learn basic analytical techniques useful for engg applications. • CO2: Synthesis and characterization methods of few organic, inorganic and polymer compounds of industrial importance. • CO3: Learn chromatographic separation methods. • CO4: Applications of spectroscopic measurements.						
Topics Covered	1. Experiments based on pH metry: Determination of dissociation constant of weak acids by pH meter. 2. Experiments based on conductivity measurement: Determination of amount of HCl by conductometric titration with NaOH. 3. Estimation of metal ion: Estimation of Fe^{2+} by permangnomentry 4. Estimation of metal ion: Determ. of total hardness of water by EDTA titration. 5. Synthesis and characterization of inorganic complexes: e. g. $Mn(acac)_3$, $Fe(acac)_3$, cis-bis(glycinato)copper (II) monohydrate and their characterization by m. p. , FTIR etc. 6. Synthesis and charact. of organic compounds: e.g.Dibenzylideneacetone. 7. Synthesis of polymer: polymethylmethacrylate 8. Verification of Beer-Lamberts law and determination of amount of iron present in a supplied solution. 9. Chromatography: Separation of two amino acids by paper chromatography 10. Determination of saponification value of fat/ vegetable oil						
	Suggested Text Books: 1. Vogel's Quantitative Chemical Analysis (6th Edition) Prentice Hall 2. Advanced Physical Chemistry Experiments: By Gurtu&Gurtu 3. Comprehensive Practical Organic Chemistry: Qualitative Analysis By V. K. Ahluwalia and S. Dhingra Suggested Reference Books: 1. Practical Chemistry By R.C. Bhattacharya 2. Selected experiments in Physical Chemistry By N. G. Mukherjee						

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CYS51	CO1	2	1	-	1	-	-	-	-	-	-	-	-
	CO2	-	1	-	1	1	2	-	-	-	-	-	-
	CO3	2	-	-	1	1	-	-	-	-	-	-	-
	CO4	-	1	-	1	1	-	-	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
XES51	**ENGINEERING GRAPHICS**	PCR	1	0	3	4	2.5
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	• CO1: Ability of mental visualization of different objects • CO2: Theoretical knowledge of orthographic projection to solve problems on one/two/three dimensional objects • CO3: Able to read/interpret industrial drawing and to communicate with relevant people
Topics Covered	Graphics as language of communication; technical drawing tools and their up-keep; types of lines; construction of geometrical figures; lettering and dimensioning. [6] Construction and use of scales; construction of curves of engineering importance such as curves of conic section; spirals, cycloids, involutes and different loci of points; use of equations for drawing some curves. [9] Descriptive geometry: necessity and importance of orthographic projection; horizontal and vertical reference planes; coordinate of points; orthographic projection of points and lines situated in different quadrants, viz. 1^{st}, 2^{nd}, 3^{rd} and 4^{th} quadrants; traces of lines. First angle and third angle projection of lines and planes; views from top, front and left (or right); true length and true inclination of lines with planes of projections; primary auxiliary projection of points, lines and planes; auxiliary plan and auxiliary elevation. [9] Projection of simple regular solids, viz. prisms, cubes, cylinders, pyramids, cones, tetrahedrons, spheres, hemi-spheres etc. [6] Section of solids; section by perpendicular planes; sectional views; true shapes of sections. [6] Dimensional techniques; international and national standards (ISO and BIS). [3] Freehand graphics. [3]
Text and/or reference material	1)… Engineering Drawing and Graphics – K Venugopal 2)… Engineering Drawing – N D Bhat 3)… Practical Geometry and Engineering Graphics – W Abbott

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
XES51	CO1	1	-	-	-	-	-	-	-	-	-	-	-
	CO2	1	1	-	-	-	-	-	-	-	-	-	-
	CO3	1	-	1	-	-	-	-	-	-	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>XES52</td><td>Basic Electrical and Electronics Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>3</td><td>3</td><td>2</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
</table>

Course Outcomes	CO1: Learn to analyse the electric circuits using network theorems. CO2: Understand the characteristics of fluorescent lamp and compact fluorescent lamp. CO3: Analyze the behaviour of single phase and three phase AC circuits. CO4: Understand the application of electronics components, diode circuits as rectifier circuits and voltage regulators. CO5: Evaluate and study the performance of the transistor as a switch. CO6: Create inverting and non-inverting amplifier circuits using Op-Amp.
Labs Conducted.	1. Verification of the network theorems (DC). 2. Study of the characteristics of fluorescent and compact fluorescent lamp. 3. Analysis of the three phase system for star and delta connected load. 4. Study of the series and parallel R-L-C circuit. 5. Identify and understand the use of different electronic and electrical instruments, various electronic components. 6. Study of half-wave and full-wave (bridge) rectifier with and without capacitor filter circuit. Zener diode as a voltage regulator. 7. Study the performance of a transistor as a switch through NOT gate. 8. Realization of Inverting and Non-inverting amplifier using Op-Amp.
Text Books, and/or reference material	**TEXT BOOK** 1. Handbook of Laboratory Experiments in Electronics and Electrical Engineering by A M Zungeru , J M Chuma, H U Ezea. 2. Experiments Manual for use with Electronic Principles (Engineering Technologies and the Trades) by Albert Paul Malvino Dr., David J. Bates, et al. **REFERENCE BOOKS** 1. Laboratory Courses in Electrical Engineering (5th Edition) by S. G. Tarnekar, P. K. Kharbanda, S. B. Bodhke, S. D. Naik, D. J. Dahigaonkar (S. Chand Publications). 2. The Art of Electronics 3e, by Paul Horowitz, Winfield Hill. 3. Electronic Principles, by Albert Paul Malvino Dr. and David J. Bate.

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
XES52	CO1	3	3	3	3	3	1	1	1	2	2	2	3
	CO2	3	3	2	3	3	3	1	1	2	2	2	3
	CO3	3	3	2	3	3	2	1	1	2	2	2	3
	CO4	3	3	3	3	3	1	1	1	2	2	2	3
	CO5	3	2	1	2	2	1	-	-	2	-	-	-
	CO6	3	2	2	2	3	-	-	-	2	-	-	-
	CO7	3	3	2	2	-	-	-	-	2	-	-	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSS52</td><td>DATA STRUCTURES AND ALGORITHMS LABORATORY</td><td>PCR</td><td>0</td><td>0</td><td>3</td><td>3</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Understanding the suitability and compatibility of array and linked list implementations for different application problems.
CO2: Understanding the concept of abstract data types from real-life scenarios and their implementation in computing system.
CO3: Identify, design and implementation of stack, queue, binary tree, and graph as applicable for given problem.
CO4: Implementation of different searching and sorting techniques using appropriate data structures and perform efficiency analysis.
CO5: Create efficient algorithms for real-life applications.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">List of Experiments:
1. Application of arrays using dynamic memory allocation.
2. Implementation and Applications of linked lists.
3. Implementation of stack, and applications of stack.
4. Implementation of queue, applications of queue: Priority queue.
5. Implementation of Binary tree, Binary tree traversal: Preorder, Inorder and Postorder traversal.
6. Implementation of binary search tree and operations on it.
7. Implementation of linear search, binary search (recursive, non-recursive).
8. Implementation of different sorting algorithms.
9. Implementation of graph algorithms: Breadth first search, Depth first search.
10. Case Studies.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. S. Lipschutz, “Data Structures (Schaum’s Outline Series)”, McGraw Hill Education; First edition (2017).
2. E. Horowitz, S. Sahni, S. Anderson-Freed, “Fundamentals of Data Structures in C”, Universities Press; Second edition (2008).
3. E. Balagurusamy, "Programming in ANSI C", McGraw Hill Education India Private Limited, Seventh edition (2017).
Reference Books:
1. B. S. Gottfried, "Programming with C", McGraw Hill Education, 4th Ed. (2018).</td></tr>
</table>

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CSS52	CO1	-	1	1	1	-	-	-	-	-	-	-	-
	CO2	-	1	1	3	-	-	-	-	-	-	-	-
	CO3	2	2	3	2	1	-	-	-	-	-	-	-
	CO4	2	2	2	1	1	-	-	-	-	-	-	-
	CO5	3	3	3	3	3	-	1	1	-	-	1	2

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
XXS51	Extra Academic Activities	PCR	0	0	2	2	1

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Outcomes

- CO1: Social Interaction through the medium of sports
- CO2: Team building and self defence

Topics Covered

YOGA

- Introduction of Yoga- Suryanamaskar. 1L
- Sitting Posture / Asanas – Padmasana, Vajrasana, Ardha Kurmasana, Ustrasana, Janusirshasana, Gomukhasana, Bhadrasana. 7L
- Mudra- Gyana Mudra, Chin Mudra. 1L
- Laying Posture/ Asana-Pavana Mukhtasana, Uttana Padasana, Sarpasana, Bhujangasana (Cobra Pose), Eka Pada Salabhasana, Dhanurasana, Chakrasana, Viparitkarani, Ardha Halasana (Half Plough Pose), Naukasana (Boat Posture), Shavasana (Relaxing Pose) , Makarasana. 7L
- Meditation-Om Chant. 1L
- Standing Posture / Asana-Tadasana (Mountain Pose), Vrikshana (Tree Pose), Ardha Chandrasana, Padahastasana, Ardha Chakrasana (Half Wheel Posture). 5L
- Pranayama-Deep Breathing, Anulom Vilom, Shitali, Bhramari. 5L
- Kriya- Kapalbhati 1L

TAEKWONDO

- Introduction About Taekwondo- Meaning Of Taekwondo, Korean Language Of Dress, Fighting Area, Punch, Block, Kicks Etc. 1L
- Stance- Ready Stance, Walking Stance, Front Stance, Back Stance. 2L
- Punch Technique- Front Fist Punch, Double Fist Punch, With Stance Etc. Blocks- Upper Blocks, Middle Block, Side Block, Suto Etc. 4L
- Foot Technique- Standing Kick, Front Kick, Doliyo, Back Kick Etc. 6L
- Poomsae (Forms)- Jang, Yi Jang.6L
- Self Defense Technique- Self Defense from Arms, Fist and Punch. 4L
- Sparring (Kyorugi)- One Step Sparring 2L
- Combination Technique- Combined Kick And Punch. 2L
- Project Work 1L

Mapping of CO (Course outcome) and PO (Programme Outcome)

Course	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
XXS51	CO1	-	-	-	-	-	2	-	-	2	-	-	1
	CO2	-	-	-	-	-	-	-	2	3	-	-	1

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

THIRD SEMESTER

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC301	**PROCESS CALCULATIONS**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (CT) and End Sem Assessment (EA)					
Nil		CT+EA					

Course Outcomes	• CO1: Learn fundamentals of units and dimension, dimensionless groups, and their implications. • CO2: Graphical interpretation of experimental data, use of log-log and semi-log plots for non-linear equations • CO3: Understanding of mass and energy balance for various chemical processes • CO4: Understanding the Ideal gas equation, Raoult's law, Henry's law, and psychrometric property
Topics Covered	**Module - I** Units and dimension, Dimensionless groups and their significance, Dimensional homogeneity and analysis: Buckingham's pi theorem and its application, repeating variables, Rayleigh methods, Stepwise methodology Adiabatic Flame Temperature and its importance, Energy balance in thermal reactor, Computation of AFT, effect of temperature and pressure Basic understanding of application of semi-log and log-log graph, Unit operation and experimental data fittings in log-log and semi-log graph paper, Problem-solving techniques [9 hrs.] **Module - II** Ideal gas laws and its significance, Molar concept, Concept of partial pressure & partial volume, Dalton's law and Amagat's law and Numerical problems on their applications Fundamental concept of vapor pressure & boiling point, Clausius-Clapeyron equation, Antoine equation and numerical problems on their applications, Numerical problems on Duhring& Cox plots. Ideal& non-ideal solutions, Raoult's law, Henry's law and their applications in numerical problems. [8 hrs.] **Module - III** Concept of Material balance, basis of calculation, bypass and recycling operation, various problems on material balance- drying, evaporation, crystallization, leaching. Material balance with chemical reaction. Atmospheric air and its composition, the property of moist air and ideal gas law, Humidity and its significance, various humidity/saturation terms like molar, absolute, relative & percentage saturation Fundamental concept of dry-bulb, wet-bulb, adiabatic saturation temperatures, and dew point. Psychometric/humidity chart and its application Humid volume, enthalpy and specific heat of moist air, humidification and de-humidification operation and material balance. Theoretical analysis and Energy balance during adiabatic saturation and wet bulb temperature [13

	hrs.] **Module - IV** Energy conservation laws, Energy balance, Laws of thermodynamics with examples, Enthalpy calculation for systems without Chemical Reaction, Estimation of Heat Capacities of solids, Estimation of Heat Capacities: liquids and gases. Heat of fusion and vaporization. Enthalpy calculation for systems with Chemical Reaction, Calculations of heat of reaction, heat of combustions, heat of formation and heat of neutralization, Kopps rule Effect of Temperature and Pressure on Heat of Reaction, Hess's Law, Application of Energy balance to problems of various chemical processes [12 hrs.] **Tutorial on above topics and class tests (14)**
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Basic Principles and Calculations in Chemical Engineering – David Himmelblau, PHI <u>Suggested Reference Books:</u> 1. Chemical Process Principles – Hougen and Watson, Part-I, CRC Press, CBS. 2. Stoichiometry-4thedn, Bhatt and Vora, Tata Mc-Graw Hill

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC302	**CHEMICAL ENGINEERING THERMODYNAMICS**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Nil		CT+EA					
Course Outcomes	●CO1: Apply the laws of thermodynamics to chemical engineering processes and conversion devices.						

	●CO2: Calculate thermodynamic properties using equations of state, charts and tables. ●CO3: Apply the concept of phase equilibrium to multi-phase systems. ●CO4: Solve problems of single and multi-phase chemically reactive systems using the concept of chemical reaction equilibrium.
Topics Covered	**Module – I** Scope of thermodynamics and fundamental concepts. Microscopic and microscopic view. First law of thermodynamics: Applications to batch and flow systems. Second and third law of thermodynamics: Reversibility and irreversibility, Carnot cycle, entropy, free energies, exergy [5 hrs.] **Module – II** Real gases: Equations of state, compressibility charts, departure functions Thermodynamics of flow processes: Single and multi-stage compression, expansion through nozzles. Refrigeration and liquefaction of gases: Vapour compression, cascade, absorption and gas refrigeration cycles, Choice of refrigerants, Linde and Claude processes of liquefaction of gases. [9 hrs.] **Module – III** Thermodynamic property relations: Maxwell's relations and thermodynamic functions of pure substances. Residual properties, fugacity. [5 hrs.] **Module – IV** Solution thermodynamics and phase equilibrium: Multi-component gaseous systems and solution. Partial molal properties and thermodynamic potential, criteria for equilibrium, thermodynamic properties of solutions, Gibbs-Duhem equation and consistency of thermodynamic data. Activity and activity coefficient, estimation of activity coefficient- Margules and Van laar equations, ASOG and UNIFAC methods. Generation of VLE data. Calculation of bubble and dew points of ideal and non-ideal solutions. Azeotropes. Systems. Phase equilibrium at elevated pressure. [12hrs.] **Module – V** Chemical reaction equilibrium: Estimation of equilibrium constant. Homogeneous reactions. Heterogeneous reactions. [9hrs.] Tutorial on above topics and class tests. [14 hrs.]
Text Books, and/or reference material	Suggested Text Books: 1. Chemical Engineering Thermodynamics – J. M. Smith & H. C. Van Ness and M. M. Abbott (Tata McGraw Hill) 2. Chemical Engineering Thermodynamics – G. N. Halder (Prentice Hall of India) Suggested Reference Book: 1. Chemical & Engineering Thermodynamics – S. I. Sandler (Wiley) 3. Applications of Thermodynamics, V. Kadambi , T. R. Seetharam, K. B. Subramanya Kumar, Wiley (2019)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC303	**FLUID MECHANICS**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods [Continuous (CT) and end assessment (EA)]					
Nil		CT+EA					

Course Outcomes	• CO1: Create a fundamental understanding of fluid statistics kinematics and kinetics • CO2: Apply mass, momentum and energy balance to hydrostatic and fluid flow problems • CO3: Acquire knowledge of Fluid machineries and flow-measuring devices
Topics Covered	**Module - I** Fluids and fluid properties, continuum concept, Fluid statics: Pressure and pressure measuring devices, Fluid kinematics, different flow regimes, equation of continuity. Boundary layer, Skin and form friction. [6 hrs.] **Module - II** Bernoulli's equation, Hagen-Poiseuille equation, Fanning's equation and their applications Pipes, fittings and valves. Pressure losses due to sudden expansion, contraction and fittings Navier-Stoke's equation and total energy balance equation Turbulent flow, Reynold's stress, universal velocity profile [16 hrs.] **Module - III** Flow past solid surface, drag, flow through packed bed, fluidization, pneumatic conveying Flow of compressible fluids, flow through convergent-divergent nozzles Non-Newtonian fluids: Their characteristics and calculation of pressure drop due to their flow through pipes

	Flow measuring devices: Orifice meter, venturi meter, rotameter, weirs, anemometer, pitot tubes, etc. [11hrs.] **Module - IV** Fluid machineries: Pumps, blowers and compressors [10hrs.] Tutorial on above topics and class tests [14 hrs.]
Text Books, and/or reference material	**Suggested Text Books:** 1. Unit Operations – McCabe W L and Smith J L (McGraw Hill) 2. Transport Processes and Unit Operations – Geankoplis J G, Allen A H, Lepek D H (Prentice Hall) **Suggested Reference Books:** 1. Principle of Unit Operations – Foust A S, Wenzel L A, Curtis W, Maus L, Anderson L B (Wiley)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC304	**NUMERICAL METHODS IN CHEMICAL ENGINEERING**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods [Continuous (CT) and end assessment (EA)]					
MAC02		CT + EA					

Course Outcomes	CO1: Apply numerical techniques to solve linear and non-linear algebraic equations commonly encountered in chemical engineering. CO2: Analyze and approximate solutions to differential equations for transient and steady-state problems. CO3: Develop computational algorithms for solving engineering problems using numerical techniques such as finite difference methods.
Topics Covered	**Module 1: Introduction to Numerical Methods (14 Hours)** • Errors in numerical computation: Truncation and round-off errors. • Solution of linear and nonlinear algebraic equations: **Gauss elimination, Gauss-**

	Seidel, and Newton-Raphson methods. • Applications in chemical engineering: Solving equations for material and energy balances. **Module 2: Numerical Differentiation and Integration (14 Hours)** • Numerical differentiation: Finite differences, forward, backward, and central difference methods. • Numerical integration: Trapezoidal and Simpson's rules. • Applications to reactor design and heat exchanger analysis. **Module 3: Solving Differential Equations (14 Hours)** • Initial and boundary value problems: Euler's method, Runge-Kutta method, and finite difference approach. • **Partial differential equations: Heat, mass, and momentum transfer problems.** • Case studies in chemical engineering processes: Reaction engineering and fluid flow.
Text Books, and/or reference material	**Textbooks**: 1. Chapra, S. C., and Canale, R. P., *Numerical Methods for Engineers*, 7th Edition, McGraw Hill, 2015. 2. Gupta, S. K., *Numerical Methods for Engineers and Scientists*, 2nd Edition, New Age International, 1995. **Reference Books**: 1. Jain, M. K., Iyengar, S. R. K., and Jain, R. K., *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, 2012. 2. Smith, G. D., *Numerical Solution of Partial Differential Equations*, 3rd Edition, Oxford University Press, 2004. 3. Hoffmann, J. D., *Numerical Methods for Engineers and Scientists*, 2nd Edition, CRC Press, 2001. 4. Schilling, R. J., and Harris, S. L., *Applied Numerical Methods for Engineers Using MATLAB and C*, 1st Edition, Brooks/Cole, 1999.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemistry							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CYC331	**Industrial Chemistry**	PCR	3	0	0	3	3

Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))
CYC01		CT+MT+EA
Course Outcomes	● CO1: To learn advanced analytical techniques useful for chemical engineering. ● CO2: To learn the few catalytic processes commonly used in industrial applications ● CO3: To learn thermodynamics of solutions and understanding of phase diagrams of single and multicomponent systems and their applications. ● CO4: To learn the principle and application of photochemistry, conductance measurement and electrochemical cells. ● CO5: To apply selected C-C bond forming reactions in industrial set-up following green chemistry approach ● CO6: To understand the basics of carbohydrates, surfactants with their large scale synthesis and application	
Topics Covered	**Module 1:** Application of coordination compound in analytical chemistry: complexometric titration, biological application. (4 Hrs) Analytical methods used to metal ions estimation: Gravimetric, UV-Vis spectrophotometric, atomic absorption spectrometric, solvent extraction etc. (4 Hrs) Catalysis: General principles; Industrial Application of Homogeneous catalysts: hydrogenation of alkenes, hydroformylation, methanol carbonylation, Wacker oxidation of alkenes etc. Industrial Application of Heterogeneous catalysts: hydrogenation catalysts, ammonia synthesis, alkene polymerisation (Ziegler-Natta catalyst). (4 Hrs) **Module 2:** <u>System of Variable compositions:</u> Thermodynamic condition of chemical equilibrium, Molar and Partial Molar Extensive properties, Chemical potential and its significance, Gibbs-Duhem equation, Entropy and Gibb's free energy change of mixing, Concept of Fugacity, Chemical potential of ideal and real gases, Activity. (3 Hrs) <u>Phase-Equilibrium & Colligative Properties</u>*:* Gibb's Phase rule and its derivation, Calusius-Clapeyron Equation, Phase diagram of CO_2, H_2O and Sulphur system, Order of Phase transition. Colligative properties: Raoult's law and Henrys law, Principle and industrial application of Osmosis and Reverse Osmosis, Determination of number average molar mass of macro-molecules, Two component systems: ideal binary solution, liquid-vapour equilibrium, Lever Rule, Industrial process of isobaric fractional distillation, steam distillation, Vacuum distillation in petroleum refining. Duhem-Margules equation, Non-ideal binary solution, Azotropes and industrial methods of Azeotropic distillation: Entrainer and Pressure swing distillation. (4 Hrs) <u>Photochemistry:</u> Principle and Industrial application of Photo-chemical and Photo-physical processes: Jablonsky diagram with Industrial application of Fluorescence and Phosphorescence. (2 Hrs) <u>Electrochemistry:</u> Equivalent and molar conductances, strong and weak	

	electrolytes, transport number, conductometric titration and its application in Industry, Agriculture, Water Treatment and Research; Electrochemical cell with transference: liquid junction potential and applications. (3 Hrs) **Module 3:** Principles of large scale organic synthesis having industrial relevance. Industrial applications of Grignard reagents, Barbier reaction, ethyl acetoacetate and malonic esters in C-C bond formation. Application of green chemistry in industry. (4 Hrs) Introduction to carbohydrate chemistry, classification, structure elucidation. Reactions of glucose and fructose; mutarotation, inversion of cane sugar. Synthetic sweetners, applications of carbohydrates in industry. (4 Hrs) Surfactants: soaps and detergents, critical micelle concentration, synthetic detergents, Friccohesity of surfactants, hydrophilic-lipophilic balance (HLB) values. (4 Hrs)
Text Books, and/or reference material	1. Inorganic Chemistry Part-I & II, R. L. Dutta 2. Fundamentals of Analytical Chemistry By Skoog, West, Holler and Crouch 3. Physical Chemistry by P. C. Rakshit. 4. Physical Chemistry by P. Atkins, Oxford. 5. Organic Chemistry: R.T. Morrison & R.N Boyd, Prentice Hall of India Pvt. Ltd. 6. Engineering Chemistry, 2^{nd} Edition, Wiley.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemistry							
			Total number of contact hours				
Course code	Title of the course	Program Core (PCR)/Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total hours	Credit
CYS381	**Instrumental Analysis Laboratory**	PCR (Practical)	0	0	3	3	2
Pre-requisites		**Course assessment methods**					
CYS51		Continuous assessment (CA) + Viva-voce at the end of the semester					
Course outcomes	CO1: To learn advanced instrumental chemical analysis for chemical engineering. CO2: To estimate concentration of metal ions using advanced spectroscopic techniques. CO3: To synthesize and characterize few compounds of industrial importance						
Topics covered	1. Synthesis of Mohr's salt. 2. Synthesis of paracetamol. 3. Estimation of Fe^{2+} in Mohr's salt by potentiometric titration. 4. Spectroscopic Estimation of metal ion (Cu^{2+}/ Cr^{3+}). 5. Estimation of Na^{+}, K^{+}, Ca^{2+} by Flame photometry. 6. Estimation of base content of commercially available antacid and acid content of vitamin C. 7. Determination of CMC of a surfactant: conductometrically and surface tension measurement. 8. Determination of solubility product of lead iodide. 9. Kinetics of ester hydrolysis. 10. Analysis of pyrolusite ore.						
Text Books, and/or reference materials	Suggested Text Books: 1.Vogel's Quantitative Chemical Analysis (6th Edition) Prentice Hall 2. Practical Chemistry by R.C. Bhattacharya Suggested Reference Books: 1. Selected experiments in Physical Chemistry by N. G. Mukherjee 2. Advanced Physical Chemistry Experiments: by Gurtu & Gurtu 3. Comprehensive Practical Organic Chemistry: Preparative and Qualitative Analysis by V. K. Ahluwalia and S. Dhingra						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	3	2	3	3	2	3
CO2	3	3	3	3	3	2	2	2	3	3	3	3
CO3	3	2	3	3	3	2	2	2	3	3	2	3

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS351	**FUEL LABORATORY**	PCR	0	0	3	3	2
Pre-requisites							
Nil		Viva-Voce					
Course Outcomes	• CO1: Demonstrate and understand the principles of fuel properties testing instruments. • CO2: Conduct the experiments to determine the properties of different fuels. • CO3**:** Analyze the performance of equipment through group tasks.						
Topics Covered	**List of Experiments** 1. Proximate Analysis of Coal determines the moisture ash, volatile matter and fixed carbon of coal in terms of weight percentage. 2. Shattering Index of Coke 3. Caking Index 4. Swelling Index 5. Viscosity of Fuel Oils 6. Determination of Flash point and Fire point of an oil by closed cup Pensky Martin Apparatus 7. Determination of moisture content of fuel oil by Dean and Stark Apparatus 8. Aniline point determination by thin film 9. Determination of vapour pressure of petroleum products using Reid Apparatus. 10. To perform atmospheric distillation of petroleum product and to find out percent recovery, percent total recovery, percent loss, percent residue. 11. Determination of calorific value of solid fuel by Bomb Calorimeter 12. Determination of carbon residue of fuel by Conradson Method [36 hrs.]						
Text Books, and/or reference material	Suggested Text Books: 1. Modern Petroleum Refining: B. K. B. Rao 2. Fuels & Combustion: Samir Sarkar Suggested Reference Books: 1. Petroleum Refining Engineering: W. L. Nelson 2. Petroleum Refining Technology & Economics: J.H. Gary & G.E. Handwerk						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

FOURTH SEMESTER

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHC401	**HEAT TRANSFER**	**PCR**	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
CHC301, CHC303	CT+EA

Course Outcomes	● CO1: Illustrate principles and laws of heat transfer of different heat exchanging phenomena ● CO2**:** Solve heat transfer problems of different difficulty levels ● CO3**:** Design and analyze heat transfer equipment
Topics Covered	**Module - I** Mechanism of heat transmission: Conduction, Convection and Radiation. Conduction: Fourier's law; Steady-state heat transfer through plane wall and composite slabs, cylinders and spheres; Thermal contact resistance, Critical thickness of insulation, Optimum thickness of insulation; Unsteady-state heat transfer - use of Gurnie-Lurie chart, one and two-dimensional conduction in different geometry. [10 hrs.] **Module - II** Convection: Forced convection; Heat transfer coefficients; Overall Heat Transfer Coefficients; Log-mean temperature difference; Dimensional analysis of heat transfer; Equivalent diameter; General equation for forced convection; Thermal boundary layer; Analogy between heat and momentum transfer. [10 hrs.] **Module - III** Natural convection: Empirical equations; Condensation: Film Condensation, Derivation of heat transfer coefficient, Empirical equations; Boiling of liquids: Concept of excess temperature, Pool boiling, Forced convection boiling; Radiation: Black body and Gray body; Laws of radiation; View factor; Radiant heat exchange between surfaces [12hrs.] **Module - IV** Heat exchangers: Type of different heat exchangers and their design - Double pipe, Shell and tube, Finned tube and Compact heat exchangers; Condensers and reboilers. Evaporation: Type of evaporators with accessories; Capacity and Steam economy; Boiling point rise/elevation; Multiple effect evaporators; Design of single and multiple effect evaporators. [10 hrs.] Tutorial on above topics and class Tests [14 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Process Heat Transfer: D. Q. Kern, MGH 2. Heat Transfer Principles and Application, B. K. Dutta, PHI. <u>Suggested Reference Books:</u> 1. Heat Transfer: An Engineering Approach: Cengel and Boles, Tata Mc-Graw Hill

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHC402	**MECHANICAL OPERATIONS**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Fluid Mechanics		CT+MT+EA					
Course Outcomes	● CO1: Identify principles of separation of liquid-solid, gas-solid, and solid-solid ● CO2: Design and analyze mechanical operation equipment ● CO3: Compare performances and select type of size separation, solid-liquid separation and size reduction equipment ● CO4: Learn industrial applications of size separation, solid-liquid separation, size reduction equipment						
Topics Covered	**Module - I** Particle size and shape, particle size distribution: Determination of mean particle size, Sieve analysis, Industrial screens, Effectiveness of screens Size reduction and classification of solid particles: Principles of crushing and grinding, Equipment – selection, Operating principles of Coarse crushing equipment, Intermediate & Grinding equipment, Laws of crushing and grinding – limitation and applicability Size enlargement: Granulation and other size enlargement operations. [18 hrs.] **Module - II** Agitation and mixing: solid-solid mixture, solid-liquid paste and solution preparation, Types of equipment and power requirement, Mixing Index.[8 hrs.] **Module - III** Fluid – particles separation: Terminal settling velocity, free and hindered settling, equal settling velocity and sedimentation; Classifications and clarifications; Settling chambers, thickening, tabling, jigging, floatation, centrifugal separators, centrifuge, cyclone separators, electro-static precipitator, magnetic separator, etc. [8 hrs.]						

	Module - IV Filtration: Introduction; Types of filtration; Filtration equations; batch and continuous filtration equipment – Bed, Plate and Frame, Leaf and Rotary Drum Vacuum Filters; Filter Aid and Filter Medium; Washing Conveying of solids: Bins, silo and hoppers, Conveyors and elevators, Hydraulic and pneumatic transport [10 hrs.] Tutorial on above topics and class tests [14hrs.]
Text Books, and/or reference material	Suggested Text Books: 1. G. G. Brown, Unit Operations, CBS Publishers & Distributors, 2005 2. W. McCabe. J. Smith, ,P. Harriott, Unit Operations of Chemical Engineering McGraw Hill Education, 2017 Suggested Reference Books: 1. W.L. Badger and J. T. Banchero, Introduction to Chemical Engineering, McGraw-Hill book company, 1955 2. C.J. Geankoplis, Transport Processes and Separation Process Principles (Includes Unit Operations), Prentice Hall India Learning Private Limited, 2004 3. Richardson, Coulson and Richardson's Chemical Engineering, Volume 2, 5th Edition: Particle Technology And Separation Processes, Elsevier,2006

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC 403	**MASS TRANSFER- I**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Nil		CT+MT+EA					
Course Outcomes	• CO1 Principles of mass transfer for chemical processes • CO2: Various laws of mass transfer and mass balance of chemical processes • CO3: Design and analyze mass transfer equipment through problem solution						

Topics Covered	**Module - I** Mass transfer operation and principles. General principles of diffusion process, Molecular and eddy diffusion in fluids, Diffusion in solids and measurement of diffusivity, Multi-component diffusion, Diffusion through a variable area, Knudsen diffusion, surface diffusion and self-diffusion [10 hrs.] **Module - II** Convective mass transfer and mass transfer coefficients: Introduction. Dimensionless groups in mass transfer and correlations for the convective mass transfer coefficient. Theories of mass transfer, Analogy between Momentum, Heat and Mass Transfer, Inter-phase mass transfer and Basic laws, Two-film theory, overall mass transfer coefficient, Material balance in contacting equipment – the operating line and Mass transfer in stage-wise contact of two phases. [10 hrs.] **Module III** Gas absorption and stripping: Introduction. Design of a packed tower: Design method based on individual mass transfer coefficients. Design method based on the overall mass transfer coefficient. Determination of the number of stages in a tray tower, HETP, Tray efficiency, Gas-liquid contacting equipment, tray or plate column, operational features of tray column: Hydraulic gradient and multi-pass trays, weeping and dumping, entrainment, flooding, turndown ratio and estimation of diameter of tray. [12 hrs] **Module IV** Elementary idea about multi-component absorption and adsorption with chemical reactions. Extraction: Liquid-liquid extraction, Equilibrium data, Use of triangular diagrams, selectivity and choice of solvent, Single and multi-stage calculation in liquid-liquid extraction. Extraction efficiency, Principles of leaching and stage calculation methods. [10 hrs.] Tutorial on above topics and class Tests [14 hrs]
Text Books, and/or reference material	Suggested Text Books: 1. Mass Transfer Operations: R.E. Treybal 2. Principles of Mass Transfer & Separation Processes: B. K. Dutta Suggested Reference Books: 1. P. Sinha and P. De, Mass Transfer Principles and Operations, PHI 2. Chemical Engineering: 5th Ed., Coulson & Richardson

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	a	b	c	d	e	f	g	h	i	j	k	l
POs COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	1	1		3			2				
CO2	3		3		3					1	3	1
CO3	3		3		3		1		1		3	

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC404	**CHEMICAL REACTION ENGINEERING**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Nil		CE+MT+EA					
Course Outcomes	• CO1: Understand the fundamentals of chemical kinetics • CO2: Design and analyzeideal and non-ideal chemical reactors and bioreactors • CO3: Design and analyze the fluid-solid catalytic &noncatalytic reactors, and fluid-fluid reactors						
Topics Covered	**Module - I** Review of elements of reaction kinetics: The rate expression, mechanism of reactions, Arrhenius' equation. Interpretation of rate data: Constant volume and variable volume batch reactors [6 hrs.] **Module - II** Single homogeneous reaction: Design of isothermal and adiabatic batch, plug flow and back mix reactors Multiple reactions: Independent, parallel and series reactions, autocatalytic reactions. Choice of reactors for single and multiple reactions and multiple reactor systems [12 hrs.] **Module - III** Biochemical reactions: Enzyme-catalyzed and biomass growth reaction kinetics, design of bioreactors Non-ideal flow in reactors:, residence time distribution of fluid in vessels, RTD in ideal and non-ideal reactors, modeling of non-ideal reactors [8 hrs.] **Module - IV** Solid-fluid catalyzed reactions: Catalysis, porous catalyst, steps in catalytic reactions, surface kinetics, pore diffusion resistance, performance equations, interaction of physical and chemical rate processes, effectiveness factor, selectivity, product distribution in multiple reactions, effect of pore distribution, experimental methods. Catalytic reactors Fluid-fluid reactions: Overall rate equations, application to reactor design [9hrs.] **Module - IV** Solid-fluid noncatalytic reactions: Shrinking core model, determination of rate-controlling steps and application to design of reactors [7hrs.] Tutorial on above topics and class tests [14 hrs.]						
Text Books, and/or reference material	Suggested Text Books: 1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall India 2. O. Levenspiel, Chemical Reaction Engineering, Wiley. Suggested Reference Books: 1. J M Smith Chemical Engineering Kinetics, McGraw-Hill Education; 3rd edition						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS451	**REACTION ENGINEERING LABORATORY**	PCR	0	0	3	3	2
Pre-requisites							
Basic Chemistry		Viva-Voce					
Course Outcomes	● CO1: Understand the fundamental principles of reaction kinetics in different reactor through practical experimentation ● CO2: Study the non-catalytic homogeneous saponification reaction in CSTR and residence time distribution in a CSTR. ● CO3: Study the non-catalytic homogeneous saponification reaction in plug flow reactor. ● CO4: Study the non-catalytic homogeneous saponification reaction in isothermal batch reactor.						
Topics Covered	**List of Experiments** 1. Study of Non-catalytic homogeneous reaction in an Isothermal Batch Reactor. 2. Study of non-catalytic homogeneous saponification reaction in a tubular flow reactor and to interpret the kinetic data of the given reaction in the form of a rate equation. 3. Residence distribution (RTD) Studies in CSTR. 4. Study of non-catalytic homogeneous saponification reaction in a continuous stirred tank reactor and to interpret the kinetic data of the given reaction in the form of a rate equation. 5. Removal of dye using Fenton oxidation process and evaluation of its Kinetic data. 6. Study the performance of a cascade of three equal volume CSTRs in series for the saponification of ethyl acetate with NaOH. 7. Study RTD of a packed bed reactor. [36 hrs.]						

Text Books, and/or reference material	Suggested Text Books: 1. Laboratory Manual 2. Chemical Reaction Engineering, Octave Levenspiel, Wiley; Third edition (2006) 3. Elements of Chemical Reaction Engineering 4th Ed - H. Scott Fogler Suggested Reference Books: 1. The engineering of chemical reactions, Lanny D. Schmidt, Oxford University Press Inc; 2nd edition (2004)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHS452	**FLUID MECHANICS LABORATORY**	PCR	0	0	3	3	2
Pre-requisites		Course Assessment methods (Continuous (CT), and end assessment (EA))					
CHC 303 [Fluid Mechanics]		CE+EA					
Course Outcomes	• CO1To prove experimentally laws/equations like Bernoulli's equation, Fanning's equation, etc. • CO2. To determine discharge coefficients of flow meters like orifice and venture meter, and velocity profiles using pitot tube • CO3. To determine K factor of pipe fittings and valves • CO4. To draw characteristic curves of pumps • CO5. To create an experimental understanding of laminar and turbulent flow regimes						
Topics Covered	**List of Experiments** 1. To study different types of flow using Reynold's apparatus. 2. To verify Bernoulli's equation experimentally. 3. To determine point velocity by using Pitot tube. 4. To determine flow velocity by using Venturi meter and Orifice meter. 5. To study the flow characteristic in packed bed. 6. To study the flow characteristic in a helical coil. 7. To study the reciprocating pump characteristics. 8. To determine the losses due to friction in pipes and fittings. 9. Flow measurement by using V-notches [36 hrs]						

Text Books, and/or reference material	Suggested Text Books 1. Transport Processes and Unit Operations - C. J. Geankoplis 2. Principle of Unit Operations – Foust A S, Wenzel L A, Curtis W, Maus L, Anderson L B (Wiley) Suggested Reference Books: 1. W. McCabe. J. Smith, ,P. Harriott *Unit Operations of Chemical Engineering*, McGraw Hill Education, 2017

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Fourth (4^{th}) Semester Department Electives

<table>
<tr><th colspan="9">Department of Chemical Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>CHE410</td><td>FUELS AND COMBUSTION</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Nil</td><td colspan="6">CE+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Understand the properties, types, and characterization of fuels.
CO2: Analyze combustion processes for solid, liquid, and gaseous fuels and their efficiencies.
CO3: Apply air-fuel ratios, thermodynamics, and reaction kinetics concepts in designing combustion systems.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Fuels and Their Properties (14 hrs)
• Classification of fuels: Solid, liquid, and gaseous fuels.
• Characterization of fuels: Calorific value, proximate and ultimate analysis, and fuel standards.
• Liquid fuels: Crude oil processing, gasoline, diesel, and kerosene.
• Gaseous fuels: Natural gas, biogas, and producer gas.
Module 2: Principles of Combustion (14 hrs)
• Combustion stoichiometry: Air-fuel ratio, excess air, and flue gas composition.
• Thermodynamics of combustion: Enthalpy, heat of combustion, and flame temperature.
• Combustion kinetics: Reaction mechanisms, ignition, and flame stability.
Module 3: Combustion Systems and Applications (14 hrs)
• Solid fuel combustion: Fixed bed and fluidized bed combustion.
• Liquid fuel combustion: Burners and spray combustion.
• Gaseous fuel combustion: Gas turbines and internal combustion engines.
• Environmental impact of combustion and pollutant control.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks:
1. Turns, S.R. An Introduction to Combustion: Concepts and Applications. McGraw Hill, 3rd Edition, 2011.
2. Smith, I.W. Combustion and Energy Utilization. Springer, 2nd Edition, 2020.
Reference Books:
1. Sarkar, S. Fuels and Combustion. Universities Press, 2nd Edition, 2009.
2. Glassman, I., Yetter, R.A., & Glumac, N.G. Combustion. Academic Press, 5th Edition, 2014.
3. Kuo, K.K. Principles of Combustion. Wiley, 2nd Edition, 2005.
Mukhopadhyay, A.K. Combustion Engineering and Fuel Technology. McGraw Hill, 2016.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course		Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
				Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE411	**NON-CONVENTIONAL ENERGY ENGINEERING**		PEL	3	0	0	3	3
Pre-requisites			Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Nil			CE+MT+EA					
Course Outcomes	● CO1: Learn about energy technology of different conventional and non-conventional energy resource and Recent worldwide energy market scenario ● CO2: Design & analyze of different renewable energy collectors and renewable energy thermal power plants ● CO3: Learn industrial and domestic applications of different renewable energy sources ● CO4: Solve energy technology problems of different difficulty levels through tutorials							
Topics Covered	**Module I:** Wind Energy: Sources and potentials, Wind energy conversion, General formula -Lift and Drag- Basis of wind energy conversion – Effect of density, frequency variances, angle of attack, and wind speed. Windmill rotors Horizontal axis and vertical axis rotors. Determination of torque coefficient, horizontal and vertical axis windmills, performance characteristics, Betz criteria, Design and analysis of wind turbines. geographical aspects. [10 hrs.] **Module II:** Solar Energy: Energy available form Sun, Solar radiation data, Solar energy conversion into heat, Flat plate and Concentrating collectors, Construction and performance analysis of solar flat plate collectors, Mathematical analysis of Flat plate collectors and collector efficiency, collector efficiency factor, tilt factors, collector heat removal factor, Hottel-Willier-Bliss equation. Principle of Natural and Forced convection, Salt gradient solar ponds: construction, operation, technical problems, Solar drying and dehumidification: Solar cabinet dryers, convective dryers Solar							

	engines-Stirling, Brayton engines, Photovoltaic, p-n junction, solar cells, PV systems, Stand-alone, Grid connected solar power satellite. [10 hrs.] **Module III:** Nuclear Energy: Nuclear fission principles, types of nuclear reactors (BWR, PWR, PHWR, LMCR, GCR, FFR). Nuclear reactor analysis: four factor formula, resonance absorption, reactor buckling, multiplication factor, thermal utilisation coefficient, reflector saving, fast fission factor, optimum moderator to fuel ratio. Radioactive waste disposal Energy from Ocean: Wave, Tidal and OTEC energy- Difference between tidal and wave power generation, Principles of tidal and wave power generation, OTEC power plants (closed cycle, open cycle, hybrid cycle), operation and technical problems, environmental impact, Tidal power, salinity power plants, Geothermal systems: Resources, types of wells, methods of harnessing the energy, Hot water and dry steam systems, energy extraction principles. [10 hrs.] **Module IV:** Energy from biomass: Biomass utilization: pyrolysis, gasification, anaerobic digestion (biogas production). Principles of Bio-Conversion, Anaerobic/aerobic digestion, types of Bio-gas digesters, gas yield, combustion characteristics of bio-gas, Biodiesels: Manufacture and characteristics. Gasohol: Characteristics and manufacture, use of pervaporation technology. Synthetic liquid fuels from coal: F – T Process, Coal hydrogenation, MTOG process. [10 hrs.]
Text Books, and/or reference material	Suggested Text Books: 1.Ashok V Desai, Non-Conventional Energy, Wiley Eastern Ltd, New Delhi, 2003 2.K M, Non-Conventional Energy Systems, Wheeler Publishing Co. Ltd, New Delhi, 2003. Suggested Reference Books: 1. Ramesh R & Kumar K U, Renewable Energy Technologies, Narosa Publishing House, New Delhi, 2004 2. Wakil MM, Power Plant Technology, McGraw Hill Book Co, New Delhi, 2004. 3. G. D. Rai Non – Conventional Energy Sources. Khanna Publication 4. S P Sukhatme and J K Nayak, Solar Energy, McGraw Hill Book Co, New Delhi 4th Edition, 2017

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE412	**COLLOIDS AND INTERFACE ENGINEERING**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
NIL		CT+MT+EA					
Course Outcomes	● CO1: Acquire an idea about the application of colloidal chemistry, fluid-fluid and solid-fluid interface engineering in different industrial fields. ● CO2: To learn the fundamental knowledge of intermolecular forces involved in colloids and interfaces ● CO3: Introduction to surface active agent and learn about the application of surface active agents to enhance the efficiency in the process.						
Topics Covered	**Module I:** Importance and scope of the subject. Overview of colloidal systems, interfaces and surface. Properties and application of the colloids. Colloidal stability factor. Kinetic theory of colloidal systems: sedimentation, centrifugation, diffusion, Domestic and industrial application of colloidal solution. Adsorption at fluid-fluid and fluid-solid interface, Thermodynamics of interfaces, Interfacial rheology and transport process. [10hrs.] **Module II:** Surface active agent: Surfactant, Surface and interfacial tension, surface free energy. Surface tension for curved interfaces, Surface excess and Gibbs equation. Theory of surface tension, contact angle, and wetting. Thermodynamics of micelle and mixed micellar formation. Adsorption of single and mixed surfactants at interfaces, Mixed micellar properties, Rheology of surfactant systems. Preparation, mechanistic details of stabilization and relationship between HLB and solubility parameter, characterization and Application. [10hrs.] **Module III:** Intermolecular forces relevant to colloidal systems: Electrostatic and van der Waals forces. DLVO theory.Measurement techniques of surface tension, contact angle, zeta potential, particle size. [4 hrs.] **Module IV:** Overview of industrial applications of various interfacial phenomena in the industries [Mattress industry (Foam: preparation, characterization, stability), petroleum industry, Mineral processing industry Pesticides, firefighting, personal care formulations], Super hydrophobic surface and self-cleaning surfaces. Case studies related interfacial science. Application of interfacial engineering concept through the surface modification for the synthesis of nanostructured material by using surface active agent. [12hrs.]							

Text Books, and/or reference material	**Suggested Text Books:** 1. P. C. Hiemenz, and R. Rajagopalan, Principle of colloid and surface chemistry, 3rd edition, MercelDekher, N. Y. 1997. 2. Pallab Ghosh, Colloid and Interface Science, 1st Edition, PHI Learning, 2009. 3. M. J. Rosen, Surfactants and Interfacial Phenomena, Wiley-Interscience Publication, New York, 2004. **Suggested Reference Books:** 1. Drew Myers, Surfaces, Interfaces and Colloids, 3rd Edition, Wiley, 2006. 2. Tharwat F. Tadros, Applied Surfactants Principles and Applications, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2005. 3. J. Israelachvili, Intermolecular and Surface Forces, Academic Press, New York, 1992.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE413	**INDUSTRIAL POLLUTION CONTROL AND TREATMENT**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Knowledge of all Unit Operations and Unit processes		CT+MT+EA					
Course Outcomes	• CO1: The fundamental concepts in environmental engineering dealing with water, air, and land pollution. • CO2: Graduates will learn a solid foundation in mathematics, sciences, and technical skills needed to analyze and design environmental engineering systems. • CO3: Graduates will be familiar with current and emerging environmental engineering and global issues, and have an understanding of ethical and societal responsibilities. • CO4: The necessary qualifications for employment in environmental engineering						

	and related professions, for entry into advanced studies, and for assuming eventual leadership roles in their profession.
Topics Covered	**Module I:** Introduction to Water Treatment: National & International Scenario; World-wide Water resources Management; Water quality standards – Drinking water standards; Industrial effluent standards [3 hrs] **Module II:** Physico-Chemical Treatment Technology: Aeration, Ion exchange, Ozone treatment, adsorption. Chemical coagulation-precipitation, settling, flocculation theorems, Chlorination, advanced scheme for municipal water treatment. [6hrs.] **Module III:** Biological Treatment: Basics of biological water treatment, relevant kinetics, biological reactor configurations, Activated sludge process, trickling filtration, lagoon treatment, submerged aerators, upward flow sludge blanket reactor, rotating disc biological contactors, advances in biological treatment. [7hrs.] **Module IV:** Membrane Treatment: Different membranes and modules in water treatment; Transport mechanisms in membrane separation; Principles of Forward and Reverse osmosis; Membrane distillation, Micro and ultrafiltration; Nanofiltration and hybrid processes in water treatment processes. [7 hrs.] **Module V:** Industry-specific advanced water treatment schemes: Petroleum refinery waste treatment, coke-oven waste treatment, pharmaceutical waste treatment, tannery wastewater treatment. [5 hrs.] **Module VI** Air Pollution Environmental threats Role of Atmosphere in dispersion, Plume behavior Dispersion problems and Stack Design (Tutorial): Control devices –Cyclone Separators, ESP, Venturi scrubber, gravity separator, filters Design Problems (Tutorial) Abatement of gaseous pollutants & VOCs [10 hrs.] **Module VII:** Solid and hazardous Waste management [4 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Industrial water treatment Process Technology, P. Pal, Elsevier Science 2. Membrane Technology in Environmental Pollution Control, P.Pal 3. Environmental Pollution Control Engineering – C.S. Rao <u>Suggested Reference Books</u>: 1. Groundwater Arsenic remediation: Treatment Technology and Scale up, P. Pal, Elsevier Science 2. Handbook of Chlorination and Alternative disinfection, Geo. Clifford White, Wiley 3. Water Treatment Plant Design, Stephen J. Randtke, Michael B. Horsley(EDs.), ASCE 4.Water Technology, N.F. Gray, Elsevier Science

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

FIFTH SEMESTER

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				**Credit**
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHC501	**INSTRUMENTATION AND PROCESS CONTROL**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Knowledge of applied mathematics, Unit operations		CE+MT+EA					
Course Outcomes	• CO1: Understand the principles of industrial instrumentation and measurement techniques. • CO2: Develop mathematical models of dynamic systems and analyze their transient responses. • CO3: Design controllers for process control applications and evaluate their performance. • CO4: Integrate control systems with instrumentation for automated process industries.						
Topics Covered	**Module 1: Introduction to Process Control and Instrumentation (14 Hours)** • Overview of process control systems: Components and objectives. • Types of instruments: Sensors, transducers, and actuators. • Measure process variables: Temperature, pressure, flow, and level. **Module 2: Dynamic Modeling and System Behavior (14 Hours)** • First-order and second-order dynamic systems. • Linearization of nonlinear systems. • Transient response analysis for dynamic systems. **Module 3: Control Systems and Design (14 Hours)** • Feedback control: P, PI, PID controllers, and tuning methods. • Stability analysis using Routh-Hurwitz and Root Locus. • Frequency response methods: Bode plot and Nyquist criteria. **Module 4: Advanced Control Strategies and Applications (14 Hours)** • Cascade, feedforward, and ratio control. • Distributed control systems (DCS), supervisory control, and data acquisition (SCADA). • Applications in chemical process industries.						
Text Books, and/or reference material	<u>Suggested Text Book:</u> 1. Process Systems Analysis and Control, Donald Coughanowr McGraw-Hill Science/Engineering/Math; 2 edition (March 1, 1991) 2. Chemical Process control, G. Stephanopoulos, PHI, 2008 3. Essentials of Process Control, Luyben et al. McGraw-Hill Companies (August 1, 1996) <u>Suggested Reference Books:</u> 1. Process control, Thomas Marlin, McGraw-Hill Education; 2nd International edition (July 1, 2000)						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHC502	**MASS TRANSFER-II**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
CHC 403, CHC301		CT+MT+EA					
Course Outcomes	• CO1: Understanding fundamentals of some major Mass transfer operations • CO2: Application of design principles for mass transfer devices • CO3: Learning operations of various mass transfer systems • CO4: Building foundation for process intensification • CO5:Motivation towards innovations for novel systems of mass transfer						
Topics Covered	**Module-I** Humidification & Dehumidification Operations: Principles of Humidification & Dehumidification Wet & dry bulb thermometry, Construction and use of humidity charts, characteristics of saturated and unsaturated vapor- gas mixtures, design & operation of cooling tower, Design problems [10 hrs.] **Module-II** Drying: Theory and mechanism of drying, steady and unsteady state drying, classification and selection of industrial dryers, estimation of drying rates, drying characteristics of materials, performance and design of batch and continuous dryers [10 hrs.] **Module-III** Distillation processes: Vapor- liquid equilibrium, relative volatility, azeotropism, Equilibrium and flash distillation, types of distillation columns and construction,						

	Rectification of binary systems, enthalpy-composition diagram and construction. [6 hrs.] **Module-IV** Rectification column design methods: Lewis-Sorel &Ponchon–Savarit, McCabe-Thiele method, Design problems [6 hrs.] **Module-V** Special distillation processes: Membrane, molecular, extractive, catalytic Distillation, multi-component Distillation & introduction to ASPEN PLUS [9 hrs.] **Module-VI** Theory of crystallization, Nucleation and crystal growth, Batch and continuous crystallizers, Design calculations for crystallizers [3 hrs.] **Module- VII** Membrane separation basics, classification, transport & exclusion mechanisms, Membrane modules and design problems on micro, ultra, nano& reverse osmosis [3hrs.] Tutorial on above topics and class Tests [14 hrs.]
Text Books, and/or reference material	Suggested Text Books: 2. Unit Operations of Chemical Engineering: W.L. McCabe & J.C. Smith 3. Principles of Mass Transfer & Separation Processes: B. K. Dutta 4. Mass Transfer Operations: R.E. Treybal Suggested Reference Books: 1. Introduction to chemical engineering: W.L.Badger&J.T.Banchero 2. Membrane Science & Technology, Osada& Nakagawa 3. Industrial Water Treatment Process Technology, P. Pal, Elsevier Science 4. Chemical Engineering: Coulson & Richardson 5. Principles of Unit Operation: C. J. Geankoplis

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><th colspan="9">Department of Chemical Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>CHC503</td><td>CHEMICAL PROCESS TECHNOLOGY</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Knowledge of Unit operations and Unit processes</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: Ability to understand the manufacturing of various inorganic and organic chemicals.
● CO2: Ability to understand the process flow diagram and various process parameters.
● CO3: Ability to identify and solve engineering problems during production.
● CO4: Knows current scenario of chemical & allied process industries.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Introduction to Process Industries and Development (14 Hours)
• Overview of chemical process industries and their economic significance.
• Process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs).
• Sustainability and raw material selection.
• Case studies: Cement and glass production processes.
Module 2: Inorganic Chemical Industries (14 Hours)
• Manufacturing processes for ammonia (Haber-Bosch), nitric acid (Ostwald), and sulfuric acid (contact process).
• Chlor-alkali industry: Chlorine and caustic soda production.
• Fertilizers: Urea and NPK compounds.
Module 3: Organic Chemical Industries (14 Hours)
• Production of ethanol, methanol, and acetic acid.
• Ethylene and propylene derivatives.
• Introduction to bioprocess technologies.
Module 4: Advanced Processes and Trends (14 Hours)
• Hydrogen production: Steam reforming and electrolysis.
• Green chemistry and catalysis in chemical industries.
• Carbon capture, utilization, and storage (CCUS).
• Emerging bio-based processes: Bioplastics and biofuels.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u>
1. Dryden, C. E., and Rao, M.G. (Ed.), Outlines of Chemical Technology Affiliated East West Press.
2. Shreve, R.N., & Brink, J.A. Chemical Process Industries. McGraw Hill.
<u>Suggested Reference Books:</u>
1. Austins, G.T., Sherve's Chemical Process Industries, MGH 5thEdn.
2. Rao, M.G. Outlines of Chemical Technology. East-West Press.
3. S. K. Ghoshal, S. K. Sanyal and S. Datta, Introduction to Chemical Technology, Tata McGraw Hill, New Delhi.
4. Moulijn, J.A., Makkee, M., & Diepen, A.E.V. Chemical Process Technology. Wiley.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC504	**INDUSTRIAL SAFETY AND RISK MANAGEMENT**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
None		CT+MT+EA					

Course Outcomes

CO1: Understand the principles of industrial safety and risk assessment techniques to prevent hazards in chemical industries.

CO2: Analyze and apply safety management systems, regulatory frameworks, and standards to mitigate industrial risks.

CO3: Design safe processes and implement emergency response strategies for risk reduction in industrial operations.

Topics Covered

Module 1: Fundamentals of Industrial Safety and Risk (14 Hours)

- Overview of industrial safety and importance in chemical industries.
- Types of industrial accidents and preventive strategies.
- Concepts of hazard and risk: Hazard triangle and risk matrix.
- Hazard identification methods: HAZOP, HAZAN, FMEA.
- Case studies of major industrial accidents.

Module 2: Risk Management and Safety Standards (14 Hours)

- Risk assessment techniques: HIRA, QRA, and FTA.
- Safety standards and regulations: OSHA, BIS, PSM principles.
- Process safety in chemical handling, storage, and transportation.
- Emergency response planning and mitigation strategies.
- Safety auditing and compliance in industrial processes.

Module 3: Safety in Design and Operation (14 Hours)

- Inherently safer design principles.
- Fire and explosion prevention and control.

	• Personal protective equipment (PPE) and safety training. • Safety in plant layout, equipment design, and automation. • Role of digital tools in safety monitoring and emergency response.
Text Books, and/or reference material	**Textbooks:** 1. Heinrich, H.W., *Industrial Accident Prevention: A Scientific Approach*, McGraw Hill, 1980. 2. Crowl, D.A., & Louvar, J.F., *Chemical Process Safety: Fundamentals with Applications*, Prentice Hall, 3rd Edition, 2011. **Reference Books:** 1. Lees, F.P., *Loss Prevention in the Process Industries*, Butterworth-Heinemann, 4th Edition, 2012. 2. Goetsch, D.L., *Occupational Safety and Health for Technologists, Engineers, and Managers*, Pearson, 8th Edition, 2015. 3. Gupta, R.C., *Industrial Safety and Environment*, Laxmi Publications, 2006. 4. Mannan, S., *Lees' Process Safety Essentials*, Butterworth-Heinemann, 1st Edition, 2013.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS551	**HEAT TRANSFER LABORATORY**	PCR	0	0	3	3	2
Pre-requisites		Course Assessment methods: Continuous (CT) and Viva-Voce					
Basic knowledge of heat transfer		CT + Viva-Voce					
Course Outcomes	CO1: Demonstrate practical applications of heat transfer principles in conduction, convection, and radiation. CO2: Perform experiments on heat transfer equipment and interpret results to validate theoretical models. CO3: Design and analyze the performance of heat exchangers, evaporators, and other industrial systems. CO4: Develop skills to troubleshoot and optimize heat transfer processes in laboratory-scale equipment.						

Topics Covered	**List of Experiments:** 1. Determination of thermal conductivity of a metal rod. 2. Study of heat transfer in a composite wall. 3. Measurement of thermal conductivity of an insulating material. 4. Experiment on free convection heat transfer from a vertical cylinder. 5. Forced convection heat transfer in a circular pipe. 6. Study of boiling heat transfer characteristics. 7. Performance evaluation of a shell-and-tube heat exchanger. 8. Determination of emissivity of a gray surface using an emissivity apparatus. 9. Heat transfer by radiation: Stefan-Boltzmann law verification. 10. Study of multiple-effect evaporators for concentration processes.
Text Books, and/or reference material	**Textbooks:** 1. Holman, J.P., *Heat Transfer Laboratory Manual*, McGraw Hill, 2010. 2. Kern, D.Q., *Process Heat Transfer*, McGraw Hill, 1950. **Reference Books:** 1. Incropera, F.P., & DeWitt, D.P., *Fundamentals of Heat and Mass Transfer*, Wiley, 2011. 2. Gupta, C.P., & Prakash, R., *Engineering Heat Transfer*, Nem Chand & Bros, 2014. 3. Rohsenow, W.M., Hartnett, J.P., & Cho, Y.I., *Handbook of Heat Transfer*, McGraw Hill, 2018. 4. Özisik, M.N., *Heat Transfer: A Basic Approach*, McGraw Hill, 1985.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS552	**MECHANICAL OPERATION LABORATORY**	PCR	0	0	3	3	2
Pre-requisites							
	Viva-Voce						
Course Outcomes	• CO1: Understand of the fundamental principles underlying mechanical operation through practical experimentation.						

	● CO2: Know the principles of different mechanical operation equipment. ● CO3: Design and analyse mechanical operation equipment. ● CO4: Compare performances and select type of mechanical operation equipment. ● CO4: Learn industrial applications of size reduction equipment (k)
Topics Covered	1. To verify Rittinger's Law in a Jaw Crusher 2. To Study comminution through a Ball Mill and calculate its theoretical Efficiency 3. Studies on the performance of the Cyclone Separator-(I. To study the characteristics of a cyclone separator. II. To measure the fractional collection efficiency of different particle size ratio) 4. To determine overall effectiveness of a vibrating screen for a given solid sample of unknown size 5. To determine the mixing index of flour and pulses in kneader mixer 6. To determine the power consumption in a propeller mixer and compare it with the actual power requirements in agitated vessel 7. To run the operation of Plate and Frame Filter Press For filtration of calcium carbonate slurry. (I. To determine the lost quantity of calcium carbonate after filtration process.) 8. To study the influence of different flow rates of water on separation efficiency of an Elutriator 9. To determine average size of a group of particles in a mixture based on volume and surface and graphical representation of screen analysis data for size distribution of the mixture. 10. To study the working of continuous type thickener [36 hrs]
Text Books, and/or reference material	Suggested Text Books: Lab Manual 1. Unit Operations- G. G Brown (CBS Publishers & Distribution) 2. Introduction to Chemical Engineering-Badger and Banchero (McGraw-Hill) 3. Transport Processes and Unit Operation-C. J. Geankoplis (Prentice-Hall India) Suggested Reference Books: 1. Mechanical Operations for Chemical Engineers-C.M. Narayanan, B.C. Bhattacharyya (Khanna Publishers) 2. Unit Operations Of Chemical Engineering-Mc. Cabe Smith &Harriot (TMH) 3. Unit Operation-C.J. King 4. Coulson & Richardson's Chemical Engineering Volume.2

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Fifth (5th) Semester Department Electives

Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE510	**PROCESS INTENSIFICATION AND MEMBRANE TECHNOLOGY**	PCR	3	0	0	3	3
Pre-requisites		CHC302: Chemical Engineering Thermodynamics CHC301: Process Calculations					

Course Outcomes	CO1: Understand and apply process intensification regime for sustainable Industrialization CO2: Ability to develop innovative engineering solutions to the global problems on energy, environment and sustainability CO3: Ability to techno-economically analyse, design and operate sustainable systems
Topics Covered	**Module 1:** Basics of Process Intensification, definitions, approaches, benefits, role of process intensification in sustainable development. Twelve principles of green chemistry. Matrices for chemistry: Effective mass yield, carbon efficiency, atom economy, reaction mass efficiency, Environmental factor (E). **Module 2:** Process Intensification by Multifunctional equipment, Reactive distillation system, Catalytic distillation: principles, design, operation and case studies. Process Intensification through cavitation reactors, monolith reactors, oscillatory baffled reactors, sonochemical, hydrodynamic cavitation reactors. **Module 3:** Membrane Technology fundamentals and Process Intensification through Membrane-based technology. Process intensification in Biochemical production sectors, Chlor-alkali sector, industrial waste treatment through Membrane-based technology adoption.
Text Books and/or reference material	**Suggested Text Book:** 1. Membrane based technologies for environmental pollution control, P.Pal, Elsevier Sci., Amsterdam, 2020. **Suggested References Book:** 1. Intensification of bio-based processes, A. Gorak, Andrzej Stankiewicz edited. RSC publication, A.Stankiewicz, J.A. Moulijin, Re-engineering the Chemical Processing Plant, Process intensification, Marcel Dekker, New York (2004) 2.Industrial Water Treatment Process Technology, P.Pal, Elsevier Science, Amsterdam, 2017.

Mapping of CO (Course outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE511	**MATERIAL SCIENCE AND ENGINEERING**	PCR	3	0	0	3	3
Pre-requisites		CHC301: Process Calculations					
Course Outcomes	CO1: Understand the structure, properties, and processing of engineering materials. CO2: Analyze material behavior under mechanical, thermal, and chemical stresses. CO3: Evaluate and select materials for specific engineering applications.						
Topics Covered	**Module 1: Fundamentals of Material Science (14 Hours)** • Atomic structure, bonding, and crystalline structures. • Defects in materials: point, line, and surface defects. • Phase diagrams and phase transformations. • Mechanical properties: elasticity, plasticity, and toughness. **Module 2: Advanced Materials and Properties (14 Hours)** • Composite materials: types, properties, and applications. • Polymers and ceramics: properties and processing techniques. • Corrosion and degradation of materials. • Thermal and electrical properties of materials. **Module 3: Materials in Engineering Applications (14 Hours)** • Material selection criteria for chemical process equipment. • High-performance materials: superalloys, ceramics, and composites. • Case studies: materials used in heat exchangers, reactors, and pipelines. • Sustainability in material selection.						
Text Books and/or reference material	**Textbooks:** 1. Callister, W. D., & Rethwisch, D. G. *Materials Science and Engineering: An Introduction*. Wiley, 10th Edition, 2020. 2. Smith, W. F., & Hashemi, J. *Foundations of Materials Science and Engineering*. McGraw-Hill, 5th Edition, 2010. **Reference Books:** 1. Van Vlack, L. H. *Elements of Materials Science and Engineering*. Pearson, 6th Edition, 1989. 2. Askeland, D. R., & Wright, W. J. *Essentials of Materials Science and Engineering*. Cengage, 3rd Edition, 2013. 3. Shackelford, J. F. *Introduction to Materials Science for Engineers*. Pearson, 8th Edition, 2015. 4. Budinski, K. G., & Budinski, M. K. *Engineering Materials: Properties and Selection*. Pearson, 9th Edition, 2010.						

Mapping of CO (Course outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE512	**ENERGY MANAGEMENT AND PROCESS OPTIMIZATION**	PCR	3	0	0	3	3
Pre-requisites		CHC302: Chemical Engineering Thermodynamics					
Course Outcomes	CO1: Acquire an idea about the energy intensity in industry context and benchmarking energy intensity CO2: To learn the step by step methodology for energy assessment in industry, finding optimization opportunities and how to exploit them in industry. CO3: To learn the fundamental knowledge of different Process optimization techniques to increase profit						
Topics Covered	**Module I:** Basic concept and introduction Challenges faces by process industries, Paradigm shift of chemical business, Background of energy and process optimization in industry, Five ways to improve energy efficiency, Four key elements for continuous improvement, Theory of energy intensity, Definition of process energy intensity, Concept of fuel equivalent, Energy intensity for a total site, Benchmarking energy intensity, Data extraction from historian, Convert all energy usage to fuel equivalent, Energy balance, Energy performance index method, Key indicators and targets, Define key indicators, Set up targets for key indicators, Economic evaluation of key indicators, Implementing key indicators into energy dashboard. [10hrs.] **Module II:** Pinch Technology for heat exchanger network, Basic concept of pinch, Hot and cold composite curve, Pinch temperature, Golden rules of pinch, cross pinch heat transfer, Minimum hot and cold utility target, Optimum delta T min. [12hrs.] **Module III:** Heat exchanger Distillation system performance assessment, Basic concept and calculations, understanding performance criteria –U values, understanding pressure drop, Improving heat exchanger performance, Heat exchanger fouling assessment, Fouling mechanism, Fouling mitigation, Fouling resistance calculations, A cost based model for clean cycle optimization, Energy loss assessment, Energy loss audit, Energy loss evaluations, Brainstorming, Energy audit report, Distillation system assessment Distillation operating window, Distillation efficiency, Understanding operating window, Typical capacity limit, Distillation system optimization, Define a base case, Building process simulation, Tower efficiency assessment, Tower optimization basis, Energy optimization for distillation system, Overall process optimization. [10hrs.] **Module IV**: Process optimization in industryCollect online data for the whole operation cycle, Determine the true benefit from process variation, Map the whole process in cost term, How to detect opportunities for optimization, Common tools available to exploit those opportunities. [12hrs.]						

Text Books and/or reference material	Suggested Text Books: 1. Energy and process optimization for the process industries By Frank (Xin X) Zhu (Wiley, ISBN 978-1-118-10116-2) 2. Profit Maximization Techniques for operating Chemical Plants, Sandip Kumar Lahiri, Wiley, ISBN 978-1-119-53215-6 Suggested Reference books: 1. Process Heat Transfer – D.Q.Kern (McGraw-Hill)

Mapping of CO (Course outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13
CO1	2	2	2	1	2	1	1	2	1	2	2	1	2
CO2	3	3	3	2	3	2	1	3	1	3	3	1	3
CO3	3	3	3	2	3	2	1	3	1	3	3	1	3

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td colspan="9">Department of Chemical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CHE513</td><td>BIOPROCESS & BIOREACTOR ENGINEERING</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">CHC 301, CHC 403, CHC501</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: Apply kinetics of biochemical reactions for design of bioreactor.
● CO2: Analyze performance of ideal and non-ideal bioreactors.
● CO3: Integrate different type of reactor and reactor assembly.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I:
Introduction to the kinetics of Bioprocess; Free enzyme kinetics; Inhibition in enzymatic reactions. Kinetics of immobilized enzymes. Bioreactors for enzymatic reactions. [15 hrs.]
Module II:
Cell growth kinetics; Growth models, Inhibition in cell growth kinetics, Immobilized cell growth system. Reactors for cell growth system. Combination of bioreactors for cell growth. [15 hrs.]
Module III:
Multiplicity in Biosystems, Global and local stability analyses of Bioreactors. Bioreactor controlling probes, Characteristics of bioreactor sensors, Temperature measurement and control, DO measurement and control, pH/redox measurement and control, Detection and prevention of the foam. [10 hrs.]
Module IV:
Downstream processing in bioprocesses; Intra and extracellular product extraction and separation. Industrial application of bioprocesses. [10 hrs.]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u>
1. J. E. Bailey, D. F. Ollis, Biochemical Engineering Fundamentals, Second Edition, Mc. Graw Hill Inc., Singapore, 1986.
2. H. W. Blanch, D. S. Clark, Biochemical Engineering, Special Indian Edition, Marcel Dekker Inc. New York, 2007.
3. M. L. Shuler, F. Kargi, Bioprocess Engineering - Basic Concepts, Second Edition, Prentice Hall of India Private Ltd., New Delhi, 2002.
<u>Suggested Reference Books:</u>
1. P. M. Doran, Bioprocess Engineering Principles, Academic Press, California, 2009.
2. J. Nielsen, J. Villadsen, G. Liden, Bioreaction Engineering, Second Edition, Springer, 2007.
3. D. G. Rao, Introduction to Biochemical Engineering, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2008.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

SIXTH SEMESTER

Department of Humanities and Social Sciences								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
HSC631	**ECONOMICS AND ACCOUNTANCY**	PCR	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))
NIL	CT+MT+EA

Course Outcomes	• CO1: To review basic economic principles with students; • CO2: To introduce students basic capital appraisal methods used for carrying out economic analysis of different alternatives of engineering projects or works; • CO3: To educate the students on how to evaluate systematically the various cost elements of a typical manufactured product, an engineering project or service, with a view to determining the price offer.
Topics Covered	**Module I:** PART 1: Economics Group A: Microeconomics Economics: Basic Concepts Theory of Production, Cost and Firms, Analyses of Market Structures: Perfect Competition, Monopoly Market, General Equilibrium & Welfare Economics [14 hrs.] **Module II:** Group B: Macroeconomics Introduction to Macroeconomic Theory, National Income Accounting, Determination of Equilibrium Level of Income, Money, Interest and Income, Inflation and Unemployment, Output, Price and Employment. [14 hrs.] **Module III:** PART 2: Accountancy Introduction to Accounting, Financial Statement Preparation and Analysis. Financial Ratio Analysis. [14 hrs.]
Text Books, and/or reference material	Suggested Text Books 1. Koutsoyiannis: Modern Microeconomics 2. Maddala and Miller: Microeconomics 3. Gupta, R. L. and Radhaswamy, M: Financial Accounting; S. Chand & Sons 4. Ashoke Banerjee: Financial Accounting; Excel Books 5. W. H. Branson: Macroeconomics – Theory and Policy (2nd ed) 6. N. G. Mankiw: Macroeconomics, Worth Publishers Suggested Reference book 1. Dornbush and Fisher: Macroeconomic Theory 2. SoumyenSikder: Principles of Macroeconomics

	3. Anindya Sen: Microeconomics: Theory and Applications 4. Pindyck & Rubenfeld: Microeconomics 5. Maheshwari: Introduction to Accounting; Vikas Publishing 6. Shukla, MC, Grewal TS and Gupta, SC: Advanced Accounts; S. Chand & Co.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC601	**CHEMICAL PLANT DESIGN AND ECONOMICS**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT)and end assessment (EA))					
Unit operations and Chemical reactor, Chemical Process Technology, Optimal design methods		**CT+MT+EA**					
Course Outcomes (CO)	CO1: Managing various process design projects CO2: Understanding process design concept based on mass-energy balance and optimization CO3: Determining design-project feasibility and implementation time						
Topics Covered	**Module I:** Plant Design life cycle: Various stages of a plant design project – managing the various stages of plant design project – various approaches. Various scheduling methods for plant design [10hrs.] **Module II:** Plant Design Projects: Process design principles; process selection-DOF-design variable; -mass balance and energy balance; flow sheeting; sizing of equipment; P&ID-basic engineering package (BEP); Principles of equipment layout in and site selection for chemical plants; Types and selection of materials of construction for process equipment. [12 hrs.] **Module III:** Feasibility of Plant Design**:** Estimation of cost and profit - taxes & depreciation-rate of						

	return (ROI)-case studies; Screening of Process Alternatives; Concepts of investment, interest and time value of money; Profitability analysis. Analysis of alternative investments and replacements. [10hrs.] **Module IV:** Case studies: Design of Reactors; Design of Separation Processes; Energy Integration and Design of Heat Exchanger Network (Pinch Technology);[13 hrs.]
TextBooks, and/or reference material	Suggested Text Books: 1. Peters, M S, Timmerhaus, KD, Plant Design and Economics, McGraw Hill, 1991 2. Towler G, Sinnott, Ray, Chemical Engineering Design, Elsevier, 2008 Suggested Reference Books: 1. Rudd DF, Watson, CC. Strategies of process engineering, John Wiley, 1968 2. Seader WD, Seader, JD, Lewin, DR. Product & process design principles, John Wiley, 2004.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC602	**PETROLEUM REFINING & PETROCHEMICALS**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
None		CT+MT+EA					
Course Outcomes	• CO1: Understanding technical, economic, environmental and international market issues in petroleum refining business • CO2: Understanding correlation of petroleum properties with system design and operation • CO3: Understanding design and safe operation of complex refinery units for various petroleum products • CO4: Knowledge of application of Chemical Engineering Principles in one of most relevant industrial sectors of the economy						

	• CO5: Ignited minds with passion for innovation and sustainable development
Topics Covered	**Module I:** Petroleum - Origin and Occurrence, Exploration, Estimation and recovery [3 hrs.] **Module II:** Evaluation of crude, Properties, testing and specifications of petroleum products [6hrs.] **Module III:** Technical, Economic, environmental and societal issuesinPetroleum Refining and marketing business. [4 hrs.] **Module IV:** Processing of Crude Petroleum: crude pre-treatment, Atmospheric and Vacuum distillation, column control schemes. [6 hrs.] **Module V:** Cracking, Reforming, Vis-breaking, Delayed Coking processes to cater to the market demand of various petroproducts, Environmental pollution associated with such processing and abatement strategies [10 hrs.] **Module VI**: Rebuilding possibilities with small molecules**:** Alkylation, Isomerization. [3 hrs.] **Module VII:** Production of finished petroleum goods like, LPG, Kerosene, Petrol, Diesel, Lubricating Oil, Bitumen, Hydro processing; Innovations and novel approaches in Hydrogen production as green fuel. [10 hrs.] **Module VIII:** Petrochemical- feedstocks, classification of petrochemicals, Cracking of raw feed stock for intermediate feed stock production, manufacture of important petrochemical products [8 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Petroleum Refining Engineering: W.L. Nelson 2. Advanced Petroleum Refining: G.M. Sarkar 3. Modern Petroleum Refining: B.K.B. Rao 4. Petroleum Refining: J.P. Fauquier 5. Petroleum Refining Technology: Ram Das <u>Suggested Reference Books:</u> 1. Catalytic Naphtha Reforming: Sc. & Technology: G.M. Antos, A.M. Aitani, J.M. Pereira 2. Environmental Control in Petroleum Refining: J.C. Reis 3. Petroleum Refining Technology & Economics: J.H. Gary & G.E. Handwerk 4. Petrochemicals Technology: B.K.B. Rao 5. Lubricant base oil and wax processing: Avilino Sequeira Jr. 6. Hydrocarbon Technology Journal (Center for High Technology, Delhi)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS 651	**PROCESS CONTROL LABORATORY**	PCR	0	0	3	3	2

Pre-requisites	Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))
Process Control and Instrumentation	CT and Viva-Voce

Course Outcomes	• CO1: Understand the fundamental principles of process control through practical experimentation • CO2: Handling various instruments and solve various difficulty levels
Topics Covered	**List of Experiments** 1. Study the control valve flow coefficient (C_v) and its inherent characteristics. 2. Study the temperature control trainer and to find out steady state process gain. 3. Study the level control trainer and to find out steady state process gain. 4. Compare the observed transient response with the theoretical transient response for the interacting – non-interacting system. 5. Study the step response of mercury manometer and water manometer. 6. Plot Bode diagram of manometer systems and design the controller using Z-N tuning method. 7. Study the root locus of a manometer and hence to determine the region of stability. [36 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Process Systems Analysis and Control, Donald Coughanowr McGraw-Hill Science/Engineering/Math; 2 Edition (1991) 2. Chemical Process Control, G. Stephanopoulos, PHI, (2008) <u>Suggested Reference Books:</u> 1. Essentials of Process Control, Luyben et al. McGraw-Hill Companies (1996)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td colspan="9">Department of Chemical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CHS652</td><td>MASS TRANSFER LABORATORY</td><td>PCR</td><td>0</td><td>0</td><td>3</td><td>3</td><td>2</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Mass Transfer-I and Mass Transfer-II</td><td colspan="6">CT and Viva-Voce</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To demonstrate an understanding of mass transfer modes and models
• CO2: To formulate the idea of the different types of setup
• CO3: To apply principles of mass transfer phenomena to chemical process industries
• CO4: To enable solving the problems on process and materials related to mass transfer phenomena</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1. Study the characteristics of simple batch distillation
2. Determination of diffusivity of a hydrocarbon liquid through air
3. Study the performance of drying in atmospheric tray drier
4. Find out the heat transfer co-efficient for drop wise & film wise condensation
5. Study characteristics of bubble cap column
6. Determination of overall heat transfer coefficient of an open pan evaporator
7. Calculate hold up in a rotary drier
8. Experiment on flooding & loading phenomena in a packed absorption tower
[36 hrs.]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u>
1. Mass Transfer: R.E.Treybal
2. Unit operations of chemical engineering: W.L. McCabe &J.C.Smith
3. Laboratory manual
<u>Suggested Reference Books:</u>
1. Principles of Mass Transfer & Separation Processes: B. K. Dutta</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS653	**PROCESS EQUIPMENT DESIGNS**	PCR	0	0	3	3	3
Pre-requisites		Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))					
Heat Transfer		Viva-Voce					
Course Outcomes	CO1: Ability to design Evaporator and techno-economic evaluation CO2: Ability to design Shell and Tube Heat Exchanger and selection of materials						
Topics Covered	1. Design of Multiple Effects Evaporator and techno-economic evaluation. 2. Selection of material Design of Shell and tube heat exchanger [36 hrs]						
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Process Heat Transfer by Kern 2. Coulson & Richardson's Chemical Engineering Design (Vol 6) 3. Process Equipment Design by Lloyd E. Brownell & Edwin H. Young 4. Process Equipment Design by M. V. Joshi <u>Suggested Reference Books:</u> 2. Introduction to Chemical Equipment Design: Mechanical Aspects by B. C. Bhattacharya 3. Plant Design and Economics for Chemical Engineers by M.S. Peters and K.D. Timmerhaus 4. Chemical Process Equipment: Selection and Design by James R. Couper.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Sixth (6th) Semester Department Electives

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE610	**CFD APPLICATIONS IN CHEMICAL ENGINEERING**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Fluid Mechanics, Transport Phenomena, Numerical Methods		CT+MT+EA					
Course Outcomes	● CO1: To learn basics of continuum based modelling and simulations; its area of applications and limitations. ● CO2: To learn different discretization methods of continuum based governing equations. ● CO3: To learn different steps of CFD simulations. ● CO4: To learn the use of CFD techniques in realistic problems.						
Topics Covered	**Module I:** Introduction: Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modelling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools. [5 hrs] **Module II:** Principles of Solution of the Governing Equations: Finite difference, Finite volume and Finite Element Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation. [8 hrs] **Module III:** Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation. [4 hrs] **Module IV:** Solution Algorithms: Discretization schemes for pressure, momentum and energy equations - Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations. [15 hrs] **Module V:** CFD Solution Procedure: Problem setup – creation of geometry, mesh generation,						

	selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization. [5 hrs] **Module VI:** Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem. [5 hrs]
Text Books, and/or reference material	Suggested Text Books: 1. Numerical heat transfer and fluid flow by S.V. Patankar, Hemisphere Publishing Corporation, 1980. 2.Introduction to Computational Fluid Dynamics by Anil W. Date, Cambridge University Press, 1st Edition, 2005. 3. P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw-Hill (1998). Suggested Reference Books: **1.** Muralidhar, K.,and Sundararajan, T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House (1995). **2.** Computational Fluid Dynamics and Heat Transfer by P S Ghosdastidar (Publisher: Cengage Learning India) **3.** Ranade, V.V., Computational flow modeling for chemical reactor engineering, Academic Press (2002).

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CHE 611	**COMBUSTION ENGINEERING**	PEL	3	0	0	3	3

Pre-requisites:	Course Assessment methods (Continuous (CT), Midterm (MT) and end assessment (EA))
Process calculation, Material and energy balance, Engg. Mathematics, ODE, PDE, Numerical techniques, modelling simulation with computing	CT+MT+EA

skill using c and Matlab program	
Course Outcomes	• CO1: Clean coal technologies, coal bed methane blending of biomass with coal. • CO2: Mass and energy balance during combustion of solid, liquid and gaseous fuel. • CO3: Reaction kinetics and mechanism of Pyrolysis, Combustion and gasification. • CO4: Burner design for different industrial application.
Topics Covered	**Module I:** Properties of solid liquid and gaseous fuels Classification, Composition, Calorific Values, Lower and higher heating values, ASTM test techniques of solid, liquid and gaseous fuels. Gasification of coal –Coal gasification technologies, chemical reactions, process conditions, design of gasification equipment. Underground coal gasification technology, process route. Clean coal Technologies: What is clean coal technology? Principle and objectives.Oxyfuel combustion, Biochar, Carbon capture and storage, Carbon sequestration, Kyoto Protocol, Mitigation of global warming, Refined coal, Coal bed methane deposits, CBM recovery through microporous network, Primary method-Dewatering process, Secondary method (Carbon dioxide injection technique). [24 hrs.] Module II: Stoichiometry of combustion - Chemical equations, Mass and energy balance of solid liquid and gaseous fuel combustion, concept of mixture fraction and equivalence ratio, problems on Fuel efficiency, excess air ratio and draft.Gas analyzers- Orsat and modern gas analyzers [7 hrs.] **Module III:** Combustion of liquid and gaseous fuels, Theory of diffusion flame, development diffusion flame equations and its solution technique, length of diffusion flame, chemical properties of diffusion flame & Premixed flame and its nature. Burner design for liquid and gaseous fuel, Types of Burners, design parameters and problems.[7 hrs.] **Module IV:** **12h** Combustion of solid fuels, Stages of combustion- drying, devolatilization, volatile combustion, combustion of residual char, Pulverized coal combustion, Combustion in fluidized bed system, burning rate in fluidized bed, factors affecting combustion efficiency. Combustion in bubbling fluidized bed boilers Combustion mechanism dense phase and lean phase concept and mass and energy balance, Recirculation of fly ash, effect of design parameters on combustion efficiency. Single particle combustion modelling- Single particle combustion modelling using volume reaction model, reaction mechanism and role of pore surface area. Heat and species transport equation in porous medium.Excremental technique in TG/DTA and drop tube furnace. [24 hrs.] Tutorial and class test [5 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Combustion and Fuel Technology, A.K.Saha 2. Combustion and gasification in Fluidized bed, PrabirBasu, Taylor & Francis <u>Suggested Reference Books:</u> 1. Fundamentals of Combustion Engineering by Achintya Mukhopadhyay and Swarnendu Sen

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHE612	**PROCESS MODELLING AND SIMULATION**	PEL	3	0	0	3	3
Pre-requisites: Process calculation, Engg. Math I-III			Course Assessment methods (Continuous (CT), Midterm (MT) and end assessment (EA))				
			CT+MT+EA				

Course Outcome	● CO1: Understanding the principle ofmass, energy and momentum conservation equations. ● CO2: Concept of steady state and unsteady state model equations ● CO3: Numerical techniques to solve Algebraic, ODE and PDE ● CO4: Solution of various model equationsand graphical presentation
Topics Covered	**Module I:** Introduction to Mathematical Model and its Necessity: Empirical relationship, experimentation, data interpretation, correlation and mathematical modelling using example Model Development Principles and Classification of Models: Dimensional Analysis, Synthesis of sub-models, Experimental facts, Hypothesis, Scale up concept, Steady state, unsteady state model, dynamic response, Constitutive relationships, Deterministic and Stochastic – Macroscopic diffusion equation, Lumped and Distributed Parameter - Stirred tank and plug flow models, Linear and non-linear models Conservation principles of mass and energy and momentum balance equations and Modelling of few simple systems, Gravity flow tank, Flash drum, Distillation column, Double pipe heat exchanger, Gas-liquid absorption column, CSTR, Batch reactor, Plug flow reactor. **[**18 hrs.] **Module II:** Development of dynamic model, Input output model vs. state model, system

	parameters, numerical integration,Linear models and deviation variables, linearization of non-linear models, System with one state variables, one input. State space model,Heated mixing tank, Isothermal CSTR, Non-isothermal CSTR with 2nd order chemical reaction, linearized model for the system and state space representation, Stability analysis and Eigen values. Model development ofPyrolysis, Combustion, Gasification process of coal and biomass and comprehensive modellingin TGDA, Isothermal mass loss Apparatus. [12 hrs.] **Module III:** Specialized Modeling for distributed parameter system: Distributed parameter system and model equations,the general conservation equation and interpretation of individual terms, Detail derivation of Finite Volume Method (FVM) and its application to steady state diffusive, convective and convective-diffusive problem. Extensions of the same for unsteady state operation, Presence of non-linear reaction terms, radiation term and linearization technique. Solution ofmodel equations. [14hrs.] Tutorial and class test [14 hrs.]
Text Books, and/or reference material	Suggested Text Books: 1.*Lyuben*, W.L, *Process Modelling*, Simulation and Control, McGraw-Hill, N.Y. 1990. Suggested Reference books: 1. Patankar, S. V., 'Numerical fluid flow and heat transfer', 1980, Hemisphere

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td colspan="9">Department of Chemical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CHE613</td><td colspan="2">TREATMENT AND MANAGEMENT OF WATER RESOURCES</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="4">Pre-requisites:</td><td colspan="5">Course Assessment methods (Continuous (CT), Midterm (MT) and end assessment (EA))</td></tr>
<tr><td colspan="4"></td><td colspan="5">CT+MT+EA</td></tr>
<tr><td colspan="2">Course Outcome</td><td colspan="7">CO1: Ability to assess issues of water quality, quantity, access and management
CO2: Ability to understand, design and operate water treatment facilities
CO3: Enhancing capability of critical thinking and analysis</td></tr>
<tr><td colspan="2">Topics Covered</td><td colspan="7">Module-1
World-wide temporal and spatial variation of water resources; WHO standards for safe potable water; Access to safe potable water; Standards for Industrial effluents; Water Act (India); Degradation water resources (Groundwater, surface water): sources and major classes of contaminants; Water resources management approaches; Water Footprint in Agriculture; Climate changes and challenges. Ethics and compliance of regulations.
14Hr
Module-2
Chemical, Biological, Physico-Chemical and Membrane technology in water treatment. Membrane-based Hybrid Treatment technologies and Nanotechnology in Water Treatment. Principles, design, operation, case studies and Techno-economic feasibility analysis of the technologies.
14 Hr
Module-3
Industry-specific treatment of wastewater: Pulp and paper industry; Leather industry; Dairy industry; Petroleum industry; Textile Industry; Steel industry. Wastewater treatment with circular economy approach, closed loop treatment and recovery of metal value from various industries.
14Hr</td></tr>
<tr><td colspan="2">Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u>
1. Industrial Water Treatment Process Technology, Parimal Pal, Butter-Worth Heinemann an Imprint of Elsevier Science, Cambridge, MA, USA 2017
<u>Suggested Reference books:</u>
1. Groundwater Arsenic Remediation: Treatment Technology and Scale Up, Parimal Pal, Elsevier Science
2. Membrane-based Technologies for Environmental Pollution Control, Parimal Pal, Elsevier Science
3. Metal Value Recovery from Industrial Waste Using Advanced Physicochemical Treatment Technologies, Edited by DA Giannakoudakis, P. Das, P. Pal, J. Nayak and S.</td></tr>
</table>

	Chakrabortty. Elsevier Science 2024. 4. Waste Treatment and Disposal, Eddy & Metcalf

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

SEVENTH SEMESTER

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MSC731	**PRINCIPLES OF MANAGEMENT**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous assessment (CA) and end assessment (EA))					
		CA+MT+EA					

Course Outcomes	• CO1: To make budding engineers aware of various management functions required for any organization • CO2: To impart knowledge on various tools and techniques applied by the executives of an organization • CO3: To make potential engineers aware of managerial function so that it would help for their professional career • CO4: To impart knowledge on organizational activities operational and strategic both in nature • CO5: To impart knowledge on each functional area of management like Marketing, Finance, Behavioral Science, Quantitative Techniques and Decision Science
Topics Covered	**Module I:** Management Functions and Business Environment: Business environment- macro, Business environment -micro; Porter's five forces, Management functions –overview, Different levels and roles of management, Planning- Steps, Planning and environmental analysis with SWOT, Application of BCG matrix in organization [8 hrs.] **Module II:** Quantitative tools and techniques used in management: Forecasting techniques, Decision analysis, PERT & CPM as controlling technique [7 hrs.] **Module III:** Creating and delivering superior customer value: Basic understanding of marketing, Consumer behavior-fundamentals, Segmentation, Targeting & Positioning, Product Life cycle. [8 hrs.] **Module IV:** Behavioral management of individual: Motivation, Leadership, Perception, Learning. [8 hrs.] **Module V:** Finance and Accounting: Basics of Financial management of an organization, Preparation of Final Accounts, Analysis of Financial statements, Cost Volume Profit (CVP) Analysis, An overview of financial market with special reference to India. [12 hrs.]

Text Books, and/or reference material	Suggested Text Books: 1. Financial Management, 11th Edition, I M Pandey, Vikas Publishing House. 2. Marketing Management 15th Edition, Philip Kotler and Kelvin Keller, Pearson India 3. Management Principles, Processes and practice, first edition, Anil Bhat and Arya Kumar, Oxford Higher education Suggested Reference Books: 1. Organizational Behavior,13 th edition, Stephen P Robbins, Pearson Prentice hall India 2. Operations Management, 7th edition (Quality control, Forecasting), Buffa & Sarin, Willey

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHC701	**TRANSPORT PHENOMENA**	PCR	3	1	0	4	4
Pre-requisites CHC301, CHC303, CHC401, CHC403, CHC501, CHC502		Course Assessment methods (Continuous (CT)and end assessment (EA))					
		CT+MT+EA					
Course Outcomes (CO)	• CO1: To create an understanding on universal approach of transport Phenomena and fundamental transport processes like mass, momentum and energy. • CO2: To give an understanding on shell balance technique, setting of boundary conditions etc. for different geometry of a system • CO3: To develop NSE, equation of continuity, equation of energy etc. from the fundamental concept of conservation • CO4: To solve problems on mass, momentum and energy transport using shell balance techniques and basic transport equations						

Topics Covered	**Module I** Transport Phenomena: Basic concepts, fundamental transport Processes and the irrelation, transport properties, measurement of properties, boundary conditions etc. [6hrs.] **Module II:** Momentum transport phenomena: Shell balance technique, Derivation momentum, velocity, shear force. in rectangular, cylindrical and spherical coordinate systems by using shell balance, Equation of continuity and change (mass, momentum & energy), Navier stokes equation (NSE), Euler equation, application of NSE in rectangular, cylindrical and spherical coordinate systems. [10 hrs.] **Module III :** Flow of fluids in thin films, parallel plates, circular tubes and annulus, adjacent flow of two immiscible fluids, couette flow, rotating surface flow and radial flow, flow near a wall suddenly set in motion.[10 hrs.] **Module IV:** Energy transport: Basic energy transport equations, derivation using elementary volume concept and conservation theorems in different coordinate system, analysis of energy transport using hell balance techniques and basic transport equations. [8 hrs.] **Module V:** Conduction with energy sources in fixed bed catalytic reactors and in cooling fins, forced convection circular tubes, natural convection from a heated plate and unsteady state conduction of in the slab [10 hrs.] **Module VI:** Mass transport: Types of fluxes and their relation, continuity equation for a binary mixture, boundary conditions , analysis of mass transport using shell balance techniques and equation of continuity for different coordinate systems, steady and unsteady state systems, diffusion in porous catalyst with and without chemical reaction, diffusion in falling liquid film, turbulent mass flux, interphasemass transport [12hrs.]
TextBooks, and/or reference material	<u>Suggested Text Books:</u> 1. Transport Phenomena by Bird, Stewart & Lightfoot, Wiley, 2ndEdition,2010. 2. Introduction to Transport Phenomena: Momentum, Heat and Mass by Bodh Raj, PHI Learning, 2012 <u>Suggested Reference Books:</u> 1.TransportPhenomena: A Unified Approach by Brodkey & Hershey, McGraw- Hill Chemical Engineering Series, Brodkey Publishing, 2003

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH1001	**ADVANCED PROCESS DYNAMICS AND CONTROL**	PCR	3	0	2	4	4
Pre-requisites		Course Assessment methods (Continuous (CT)and end assessment (EA))					
		CT+MT+EA					
Course Outcomes (CO)	● Develop advanced mathematical models for dynamic systems, including multi-variable, nonlinear, and distributed parameter systems. ● Apply optimization and real-time control techniques for improving chemical process efficiency and performance. ● Design and implement robust and intelligent control strategies for solving complex industrial problems. ● Analyze and integrate advanced control systems with existing instrumentation for automated chemical industries.						
Topics Covered	**Module 1: Advanced Process Dynamics and Modeling (14 Hours)** • Dynamics of multi-variable systems: Interaction and decoupling. • Modeling of distributed parameter systems (DPS). • State-space representation and solutions to state equations. • Nonlinear dynamics: Phase plane analysis, limit cycles, bifurcation, and chaos theory. • System identification techniques: Linear and nonlinear model identification. **Module 2: Optimization in Process Control (14 Hours)** • Optimal control theory: Principle of optimality, dynamic programming, and calculus of variations. • Linear Quadratic Regulators (LQR) and Linear Quadratic Gaussian (LQG) control. • Model Predictive Control (MPC): Concept, formulation, constraints handling, and industrial case studies. • Real-time optimization and applications in chemical processes. • Introduction to process data analytics and optimization integration. **Module 3: Nonlinear and Robust Control Strategies (14 Hours)** • Nonlinear control systems: Feedback linearization, sliding mode control, and Lyapunov stability. • Adaptive control: Self-tuning regulators and model-reference adaptive control. • Robust control: H-infinity control, structured singular value analysis, and applications in uncertain systems. • Process fault detection and diagnosis using advanced control systems. **Module 4: Intelligent Control Systems and Applications (14 Hours)** • Artificial intelligence in process control: Neural networks, fuzzy logic, and hybrid systems. • Reinforcement learning and control.						

	• Integration of advanced control systems with SCADA and distributed control systems (DCS). • Applications in chemical processes such as reactors, distillation columns, energy systems, and bioprocess control.
TextBooks, and/or reference material	**Text Books** 1. Seborg, D. E., Edgar, T. F., Mellichamp, D. A., & Doyle, F. J. **Process Dynamics and Control**. Wiley, 4th Edition, 2023. 2. Ogunnaike, B. A., & Ray, W. H. **Process Dynamics, Modeling, and Control**. Oxford University Press, 1st Edition, 1994. **Reference Books** 1. Skogestad, S., & Postlethwaite, I. **Multivariable Feedback Control: Analysis and Design**. Wiley, 2nd Edition, 2005. 2. Bequette, B. W. **Process Dynamics: Modeling, Analysis, and Simulation**. Prentice Hall, 1st Edition, 1998. 3. Maciejowski, J. M. **Predictive Control with Constraints**. Pearson Education, 2002. 4. Khalil, H. K. **Nonlinear Systems**. Prentice Hall, 3rd Edition, 2002.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

COs	PO1	PO2	PO3
CO1	3	2	3
CO2	3	3	3
CO3	3	2	3
CO4	3	2	3

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR)/ Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS751	**PROCESS MODELLING AND SIMULATION LABORATORY**	PCR	3	0	2	4	4
Pre-requisites		Course Assessment methods (Continuous (CT)and end assessment (EA))					
		CT+MT+EA					
Course Outcomes (CO)	• CO1: To improve the skill of programming with numerical methods • CO2: To solve Chemical Engg problems using computers (using Matlab/Aspen/Ansys)						
Topics Covered	**Module I** 1. Arrays Operations, Loops in Matlab 2. Script and Functions in Matlab						

	3. Plotting in Matlab 4. Truncation Error and Numerical error in Matlab 5. Numerical Differentiation and Integration using Matlab **Module II** Solving Linera/non-linear equations using Matlab Solving set of linear equation Solving ODEs in Matlab (RK/ODE45) **Module III** Intruduction to Matlab-Simulink Tuning of PID controller using Simulink Example cases using Simulink **Module IV** Introduction to Aspen-Plus Property analysis using Aspen-Plus Process Modelling and simulation using Aspen-Plus [36 hrs.]
Text Books, and/or Reference material	Suggested Text Books: 1. Computational Techniques for Process Simulation and Analysis Using MATLAB, Niket S. Kaisare, CRC Press 2. Teach Yourself the Basics of Aspen Plus, Ralph Schefflan, 2nd Edition, AIChE, Willey Suggested Reference Books: 1. Introduction to Simulink: With Engineering Applications,by Steven T. Karris, Orchard Pubns; 3rd edition

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CHS752	**INDUSTRIAL TRAINING / INTERNSHIP and SEMINAR**		0	0	3	3	2
Course Outcomes		• CO1: Ability to understand all the Unit Operations and Unit Processes in real-life problem. • CO2: Knowledge sharing					
Topics Covered		Industrial Training, Internship etc. 6 -8 weeks					
Text Books, and/or reference material		NA					

Seventh (7th) Semester Department Electives

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CHE710</td><td>MULTIPHASE FLOW</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Fluid mechanics, heat transfer, transport phenomena, mathematical methods</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To learn the fundamental concepts and applications of multiphase flow
• CO2: To learn the numerical models and methods for transport mechanisms and design strategy for multiphase flow
• CO3: To learn the dynamics of bubble, drop and solid particle
• CO4: To learn the measurement methods for multiphase flow</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I:
Fundamental concepts and applications of multiphase flow
Two-phase flow; three-phase flow; components; fields; space and time-averaging; volume/void fraction; flow quality; superficial velocities; phase velocities; volumetric flux; velocity ratio; slip; volume and mass-centered velocity; homogeneous flow; drift flux; separated flow; Martinelli parameters; two-phase multiplier and correlations; two-phase pressure drop; isothermal and non-isothermal flows; applications of nuclear, thermal, petroleum, chemical industries and in nature. [6 hrs]
Module II:
Flow patterns and transitions
Flow patterns; identification and classification; flow pattern maps and transition in gas-liquid, solid-gas, solid-liquid, gas-solid-liquid flows; boiling channel; bubble column, fluid bed; trickle beds; prediction of holdup and pressure drop in different flow regimes.[6 hrs]
Module III:
Numerical models and methods
Conservation equations for mass, momentum and energy for heat transfer and flow field in multiphase flow; homogeneous and separated flow model; drift flux model; two-fluid models; Eulerian and Lagrangian methods; numerical methods for solutions; closure equations for fluid-wall and interfacial transports of heat and momentum; drift flux and slip correlations for bubbly, slug, annular and stratified flows. [12 hrs]
Module IV:
Dynamics of bubble, drop and solid particle
Growth of bubble and drop; terminal velocity of bubble, drop and particle; pinch-off; contact line and triple contact lines; coalescence; breakup and collapse; deformation of bubbles and particles; flow around a spherical particle; flow through porous medium. [8 hrs]</td></tr>
</table>

	Module V: Measurement methods in multiphase flow: Two-phase pressure drop, void fraction, phase indication; phase distributions; phase velocities; anemometry; velocimetry; densitometry; optical methods; electrical methods. [10 hrs]
Text Books, and/or reference material	Suggested Text Books: 1. Yadigraoglu, G., Hewitt, G. F., Introduction to Multiphase flow – Basic Concepts, Applications and Modeling. Springer, 2018. 2. Wallis, G. B., “One Dimensional Two Phase Flow”, McGraw Hill Book Co., 1969. 3. Collier, J. G. and Thome, J. R., Convective Boiling and Condensation, 3rd ed., Oxford University Press 4. Ghiaasiaan, S. M., Two-Phase flow, Boiling, and Condensation, Cambridge University Press, 2007. 5. Crowe, C. T., Sommerfeld, M. and Tsuji, Y., Multiphase Flows with Droplets and Particles, CRC Press, 1998. 6. Govier, G. W. and Aziz. K., “The Flow of Complex Mixture in Pipes”, Van Nostrand Reinhold, New York, 1972. 7. Prosperetti, A., Tryggvason, G., Computational Methods for Multiphase Flow, Cambridge University Press, 2007 Suggested Reference Books: 1. G. Hetsroni, Handbook of Multiphase Systems, Mcgraw-Hill Book Company, 1982.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE711	**PINCH TECHNOLOGY FOR PROCESS HEAT INTEGRATION**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Heat Transfer		CT+MT+EA					

Course Outcomes	● CO1: Acquire an idea to optimize the process heat recovery and reducing the external utility loads. ● CO2: To achieve financial saving by constructing the best process heat integration.
Topics Covered	**Module I:** Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram. Overview of Pinch Technology: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔT_{min}, Data Extraction, Targeting, Designing, Optimization-Supertargeting Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve. Targeting of Heat Exchanger Network: Energy Targeting, Area Targeting, Number of units targeting, Shell Targeting and Cost targeting. [12 hrs] **Module II:** Designing of HEN: Pinch Design Methods, Heuristic rules, stream splitting, and design of maximum energy recovery (MER). Use of multiple utilities and concept of utility pinches, Design for multiple utilities pinches, Concept of threshold problems and design strategy.Network evolution and evaluation-identification of loops and paths, loop breaking and path relaxation. [12 hrs] **Module III:** Design tools to achieve targets, Driving force plot, remaining problem analysis, diverse pinch concepts, MCp ratio heuristics. Targeting and designing of HENs with different ΔT_{min} values, Variation of cost of utility, fixed cost, TAC, number of shells and total area with ΔT_{min} Capital-Energy trade-offs. Process modifications-Plus/Minus principles, Heat Engines and appropriate placement of heat engines relative to pinch. Heat pumps, Appropriate placement of heat pumps relative to pinch. Steam Rankin Cycle design, Gas turbine cycle design, Integration of Steam and Gas turbine with process. Refrigeration systems, Stand alone and integrated evaporators. Heat integrations and proper placement of Reactors for batch Processes as well as continuous processes. [12 hrs] **Module IV:** Case studies on heat integration by pinch technology [6 hrs]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. Ian C. Kemp, Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy, 2nd Edition, ISBN: 9780750682602, Butterworth-Heinemann, 2016. 2. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B. E. A., Guy A. R., and Marsland R. H.; "A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers. <u>Suggested Reference Books:</u> 1. Shenoy U. V.; "Heat Exchanger Network Synthesis", Gulf Publishing Co. 2. Smith R.; "Chemical Process Design", McGraw-Hill.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3:Substantial(High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE712	**NANOTECHNOLOGY**	PEL	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic knowledge of Chemistry, Physics and Mathematics	CE+EA

Course Outcomes	• CO1: Acquire the concept of nanoscience and nanotechnology at the basic level to apply for different application. • CO2: Acquire the concept of synthesis and characterization of nanomaterials. • CO3: Acquire the idea how to apply nanotechnology in different fields (catalysis, energy and environment) for better efficiency.
Topics Covered	**Module I:** Introduction, History of Nanomaterials synthesis approach of nanomaterials, various kind of nanostructures. [10 hrs] **Module II:** Synthesis of nanomaterials: Physical Methods, Chemical Methods and Biological Methods. Properties of Nanomaterials: Mechanical, Structural, Thermal, Electrical and Optical properties. [11 hrs] **Module III:** Characterization techniques of nanomaterials: Spectroscopy, XRD, BET, TGA, SEM, TEM and XPS. [11 hrs] **Module IV:** Application of the nanomaterials in different fields. Nanolithography, Nanocomposites. Nanoparticles as catalyst Nanoparticles in energy and environment application. Nanoparticles in biomedical application. [10 hrs]

Text Books, and/or reference material	Suggested Text Books: 1. Dieter Vollath, Nanomaterials: An introduction to synthesis, properties and application, Wiley-VCH Verlag GmbH & Co. Weinheim, Germany, 2008. 2. CNR Rao, PJ Thomas, GU Kulkarni, Nanocrystals: Synthesis, Properties and Applications, Springer-Verlag Berlin Heidelberg 2007. 3. T. Pradeep, Nano: The Essentials, Understanding Nanoscience and Nano Technology, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2007. Suggested Reference Books: 1. Goddard III, WA, Brenner, DW, Lyshevski, SE, Iafrate, GJ. Handbook of nanoscience, Engineering and Technology, 2nd Edition, CRC Press. 2. Nanotechnology: Principles & Practices; Sulabh K. Kulkarni, Capital Publishing Company, Kolkata 3. In some cases research articles.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE713	**POLYMER TECHNOLOGY**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Organic Chemistry, Chemical Reaction Engineering		CE+MT+EA					
Course Outcomes	● Understand the fundamentals of polymer science, including structure, properties, and molecular weight determination. ● Analyze polymerization techniques and processing methods for industrial applications. ● Evaluate the applications and advancements in polymers, including sustainable and biodegradable options.						
Topics Covered	**Module 1: Fundamentals of Polymer Science (14 Hours)** • Introduction to polymers: Classification, structure, and properties. • Molecular weight and its determination: Number-average, weight-average, and viscosity-average molecular weights.						

	• Thermal properties: Glass transition temperature (Tg) and melting point (Tm). • Polymer rheology and viscoelastic behavior. **Module 2: Polymerization Techniques and Processing (14 Hours)** • Mechanisms of polymerization: Addition (chain-growth) and condensation (step-growth) polymerization. • Polymerization methods: Bulk, solution, suspension, and emulsion. • Polymer processing techniques: Extrusion, injection molding, blow molding, and thermoforming. • Role of catalysts in polymerization: Ziegler-Natta and metallocene catalysts. **Module 3: Industrial Applications and Advances in Polymers (14 Hours)** • Commodity polymers (e.g., polyethylene, polypropylene) and engineering polymers (e.g., nylon, polycarbonate). • Biodegradable and biopolymers: PLA, PHA, and applications in sustainable industries. • Polymers in advanced applications: Conducting polymers, polymer composites, and smart polymers. • Environmental aspects: Recycling and sustainability of polymer materials.
Text Books, and/or reference material	**Textbooks** 1. Fried, J. R. **Polymer Science and Technology**. Prentice Hall, 3rd Edition, 2014. 2. Billmeyer, F. W. **Textbook of Polymer Science**. Wiley, 3rd Edition, 1984. **Reference Books** 1. Odian, G. **Principles of Polymerization**. Wiley, 4th Edition, 2004. 2. Sperling, L. H. **Introduction to Physical Polymer Science**. Wiley, 4th Edition, 2005. 3. Gowariker, V. R., Viswanathan, N. V., & Jayadev Sreedhar. **Polymer Science**. New Age International, 2015. 4. Stevens, M. P. **Polymer Chemistry: An Introduction**. Oxford University Press, 3rd Edition, 1999.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE720	**APPLIED MICROFLUIDICS IN CHEMICAL ENGINEERING**	PEL	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of Fluid Mechanics, Transport Phenomena, and Thermodynamics	CE+MT+EA

Course Outcomes	• Understand the fundamental principles and scaling laws governing microfluidic systems. • Analyze transport phenomena and design microfluidic devices for various chemical engineering applications. • Evaluate the applications of microfluidics in chemical, biological, and energy-related processes.
Topics Covered	**Module 1: Fundamentals of Microfluidics (14 Hours)** • Introduction to microfluidics: Concepts, applications, and importance in chemical engineering. • Scaling laws and governing equations at microscale: Navier-Stokes equations, surface tension, and capillary forces. • Fluid flow regimes in microchannels: Laminar flow, slip flow, and rarefied gas dynamics. • Pressure-driven and electrokinetic flows (e.g., electroosmosis, electrophoresis). **Module 2: Microfluidic Transport Phenomena (14 Hours)** • Heat and mass transfer in microchannels. • Diffusion-dominated processes and mixing strategies in microfluidics. • Microfluidic multiphase flows: Droplets, bubbles, and emulsions. • Design and operation of microreactors for chemical processes. **Module 3: Applications of Microfluidics in Chemical Engineering (14 Hours)** • Microfluidic-based separation processes (e.g., Lab-on-a-Chip for chemical analysis). • Applications in chemical synthesis, catalysis, and energy systems. • Microfluidics in biotechnology: Cell sorting, diagnostics, and drug delivery. • Advances in microfluidic fabrication techniques: Lithography, soft lithography, and 3D printing.
Text Books, and/or reference material	**Textbooks** 1. Tabeling, P. **Introduction to Microfluidics**. Oxford University Press, 2005. 2. Nguyen, N. T., & Wereley, S. T. **Fundamentals and Applications of Microfluidics**. Artech House, 3rd Edition, 2019. **Reference Books** 1. Stone, H. A., & Kim, S. **Microfluidics and Nanofluidics: Theory and Selected**

	Applications. Cambridge University Press, 2010. 2. Whitesides, G. M., & Stroock, A. D. **Applications of Microfluidics in Chemistry and Biology**. Annual Reviews in Chemical and Biomolecular Engineering, 2001. 3. Kirby, B. J. **Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices**. Cambridge University Press, 2010. 4. Chakraborty, S. **Microfluidics and Microscale Transport Processes**. CRC Press, 2009.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CHE721	**WASTE MANAGEMENT AND RESOURCE RECOVERY**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Environmental Engineering, Chemical Process Principles		CE+MT+EA					
Course Outcomes	• Understand waste management principles, policies, and technologies. • Analyze and select appropriate treatment methods for different types of waste. • Develop strategies for resource recovery and implement circular economy concepts.						
Topics Covered	**Module 1: Fundamentals of Waste Management (14 Hours)** • Introduction to waste management: Types of waste (industrial, municipal, hazardous, e-waste, etc.). • Waste characterization: Physical, chemical, and biological properties. • Legislative framework and policies on waste management: Global and Indian perspectives. • Hierarchy of waste management: Reduce, Reuse, Recycle (3Rs), treatment, and disposal.						

	Module 2: Waste Treatment Technologies (14 Hours) • Thermal treatment: Incineration, pyrolysis, and gasification. • Biological treatment: Composting, anaerobic digestion, and bioremediation. • Physical and chemical treatment: Sedimentation, filtration, coagulation, and advanced oxidation processes. • Landfill design and leachate management. **Module 3: Resource Recovery and Circular Economy (14 Hours)** • Principles of resource recovery and circular economy. • Recovery of energy from waste: Bioenergy, waste-to-energy processes, and RDF (Refuse-Derived Fuel). • Material recovery: Metals, plastics, and critical minerals. • Industrial symbiosis and integrated waste management for sustainable development. • Case studies: Successful resource recovery projects worldwide.
Text Books, and/or reference material	**Textbooks** 1. Kreith, F., & Tchobanoglous, G. **Handbook of Solid Waste Management**. McGraw-Hill, 2nd Edition, 2002. 2. Agarwal, S. K. **Waste Management: Pollution and Recovery**. APH Publishing, 2005. **Reference Books** 1. Bhatia, S. C. **Solid and Hazardous Waste Management**. Atlantic Publishers, 2021. 2. Christensen, T. H. **Solid Waste Technology and Management**. Wiley-Blackwell, 2011. 3. Velma, I., & Velmurugan, P. **Bioenergy Recovery from Waste**. CRC Press, 2020. 4. Matsuura, T. **Progress in Waste Management Research**. Nova Science Publishers, 2008.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

<table>
<tr><th rowspan="2">Course Code</th><th rowspan="2">Title of the course</th><th rowspan="2">Program Core (PCR) / Electives (PEL)</th><th colspan="4">Total Number of contact hours</th><th rowspan="2">Credit</th></tr>
<tr><th>Lecture (L)</th><th>Tutorial (T)</th><th>Practical (P)</th><th>Total Hours (H)</th></tr>
<tr><td>CHE722</td><td>INNOVATION AND ENTREPRENEURSHIP IN CHEMICAL PROCESSES</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basic Knowledge of Chemical Engineering Principles</td><td colspan="6">CE+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Develop innovative solutions for chemical process challenges and assess their feasibility.
• Design business strategies to commercialize chemical engineering innovations.
• Demonstrate entrepreneurial skills by formulating sustainable and impactful business models for chemical processes.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Fundamentals of Innovation and Entrepreneurship (14 Hours)
• Basics of innovation: Types of innovation (product, process, and disruptive innovation).
• Role of creativity and problem-solving in innovation.
• Principles of entrepreneurship: Characteristics of entrepreneurs, entrepreneurial mindset, and types of ventures.
• Identifying and evaluating opportunities in chemical processes.
• Technology readiness levels (TRLs) and pathways for innovation commercialization.
Module 2: Developing and Managing Innovative Chemical Processes (14 Hours)
• Process development lifecycle: From concept to pilot plant and scale-up.
• Case studies of successful innovations in chemical engineering (e.g., green chemistry, process intensification).
• Protection of intellectual property: Patents, trademarks, and copyrights in chemical engineering.
• Business models for chemical process technologies: Licensing, joint ventures, and start-ups.
• Sustainable and socially responsible innovation practices.
Module 3: Entrepreneurship in Chemical Engineering (14 Hours)
• Building a business plan: Market research, customer discovery, and value propositions.
• Financial planning: Estimation of capital costs, funding mechanisms, and risk management.
• Pitching innovative ideas to investors and stakeholders.
• Challenges and opportunities for entrepreneurs in chemical industries.
• Government policies, schemes, and incubation centers supporting entrepreneurship.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks
1. Hisrich, R. D., Peters, M. P., & Shepherd, D. A. Entrepreneurship. McGraw Hill, 11th Edition, 2020.
2. Clark, J., & Deswarte, F. Introduction to Chemicals from Biomass. Wiley, 2nd Edition, 2015.</td></tr>
</table>

	Reference Books 1. Drucker, P. F. **Innovation and Entrepreneurship**. HarperBusiness, 2006. 2. Osterwalder, A., & Pigneur, Y. **Business Model Generation**. Wiley, 2010. 3. Marr, B. **Data-Driven Business Models for Chemical Processes**. CRC Press, 2021. 4. Byers, T. H., Dorf, R. C., & Nelson, A. J. **Technology Ventures: From Idea to Enterprise**. McGraw Hill, 5th Edition, 2020.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
CHC723	**Fuel Cell Technology**	**PCL**	**3**	**0**	**0**	**3**	**3**
Pre-requisites		Physics, Chemistry, Mathematics, Process calculation, Material and energy balance					
Chemistry		CT+EA+ MT					
Course Outcomes	CO1: Explain types of fuel cells and their applications CO2: Demonstrate the working principle of fuel cells and its process design CO3: Classify materials for electrodes and testing of different cells CO4: Demonstrate the processing of fuels for the fuel cell						
Topics Covered	**Module – I** [10 hrs.] **Introduction to Fuel Cells:** Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells. **Module - II** [10 hrs.] **Fuels for Fuel Cells:** Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others, liquid hydrogen and compressed hydrogen-metal hydrides, alkaline fuel cell. **Module – III** [14 hrs.] **Fuel cell electrochemistry:** electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents, current density, power density, potential and thermodynamics of fuel cell, Introduction to direct						

	methanol fuel cell. **Fuel cell process design:** Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, Fuel cell operating conditions: pressure, temperature, flow rates, humidity. **Module – IV** [12 hrs.] **Fuel processing:** Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal, Using renewable fuels for solid oxide fuel cell.
Text Books, and/or reference material	Suggested Text Books: 1. Hoogers G., Fuel Cell Technology Hand Book, CRC Press, 2003. 2. Karl Kordesch & Gunter R. Simader., Fuel Cells and Their Applications, 1st ed., VCH Publishers, NY, 2001. Suggested Reference Books: **1.** Barbir F., PEM Fuel Cells: Theory and Practice, 2nd edition, Elsevier/Academic Press, 2013. **2.** Subhash C., Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications, Elsevier Advanced Technology, 2003.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

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

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Seventh (7th) Semester Department Electives

MTech Basket

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9010</td><td>BIOCHEMICAL AND BIO ENGINEERING</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Basic knowledge of Chemical Reaction Engineering, Thermodynamics, and Biology</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Understand the principles of biochemical engineering and their industrial applications.
• Analyze bioreactor performance and optimize bioprocess parameters.
• Design bioprocess systems for the production of biochemicals and bioproducts.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Fundamentals of Biochemical Engineering (14 Hours)
• Overview of bioprocessing and biotechnology.
• Kinetics of enzyme-catalyzed reactions: Michaelis-Menten equation and inhibition models.
• Cell growth kinetics: Monod model, batch and continuous cultures, yield coefficients.
Module 2: Bioreactors and Process Design (14 Hours)
• Types of bioreactors: Stirred tank, airlift, packed bed, and membrane bioreactors.
• Mass transfer in bioreactors: Oxygen transfer, diffusion, and scale-up strategies.
• Downstream processing: Separation, purification, and recovery of bioproducts.
Module 3: Applications and Case Studies (14 Hours)
• Applications in pharmaceuticals, food, and biofuels.
• Bio-remediation and environmental applications of bioprocesses.
• Case studies: Production of antibiotics, bioethanol, and biosensors.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks
1. Shuler, M. L., & Kargi, F. Bioprocess Engineering: Basic Concepts. Pearson, 2nd Edition, 2001.
2. Bailey, J. E., & Ollis, D. F. Biochemical Engineering Fundamentals. McGraw Hill, 2nd Edition, 1986.
Reference Books
1. Doran, P. M. Bioprocess Engineering Principles. Academic Press, 2nd Edition, 2012.
2. Blanch, H. W., & Clark, D. S. Biochemical Engineering. CRC Press, 1st Edition, 1997.</td></tr>
</table>

	3. Najafpour, G. D. **Biochemical Engineering and Biotechnology**. Elsevier, 2nd Edition, 2015. 4. Stanbury, P. F., Whitaker, A., & Hall, S. J. **Principles of Fermentation Technology**. Butterworth-Heinemann, 3rd Edition, 2016.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9011	**REACTIVE MULTIPHASE SYSTEM**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Chemical Reaction Engineering, Mass Transfer Operations		CT+EA					
Course Outcomes	• Understand the fundamental principles governing multiphase systems and their interactions. • Design and analyze multiphase reactors for specific industrial applications. • Evaluate the performance of multiphase systems using advanced modeling techniques.						
Topics Covered	**Module 1: Fundamentals of Multiphase Systems (14 Hours)** • Characteristics of gas-liquid, liquid-liquid, and gas-solid systems. • Transport phenomena in multiphase systems: Mass, momentum, and energy transfer. • Hydrodynamics of multiphase systems: Flow regimes and bubble/droplet dynamics. **Module 2: Reactor Design and Modeling (14 Hours)** • Design of packed bed, fluidized bed, slurry, and trickle bed reactors. • Modeling multiphase reactors: Eulerian and Lagrangian approaches. • Reaction and diffusion in porous catalysts. **Module 3: Applications and Advanced Topics (14 Hours)** • Industrial applications: Fischer-Tropsch synthesis, hydrocracking, and oxidation processes. • Non-idealities in multiphase reactors: Backmixing, channelling, and bypassing. • Emerging technologies: Microreactors and membrane reactors for multiphase systems.						

Text Books, and/or reference material	**Textbooks** 1. Levenspiel, O. **Chemical Reaction Engineering**. Wiley, 3rd Edition, 1999. 2. Fan, L.-S., & Zhu, C. **Principles of Gas-Solid Flows**. Cambridge University Press, 1st Edition, 1998. **Reference Books** 1. Ranade, V. V. **Computational Flow Modeling for Chemical Reactor Engineering**. Academic Press, 1st Edition, 2002. 2. Shah, Y. T. **Gas-Liquid-Solid Reactor Design**. McGraw Hill, 1st Edition, 1979. 3. Froment, G. F., Bischoff, K. B., & De Wilde, J. **Chemical Reactor Analysis and Design**. Wiley, 3rd Edition, 2010. 4. Krishna, R., & Sie, S. T. **Design and Scale-up of Multiphase Reactors**. Elsevier, 1st Edition, 1994.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9012	**ADVANCED PROCESS INTEGRATION AND OPTIMIZATION**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Process Design and Optimization		CT+EA					
Course Outcomes	• Understand the principles of process integration and its role in sustainable design. • Apply advanced optimization techniques to solve chemical engineering problems. • Analyze and improve process performance through integration and optimization strategies.						
Topics Covered	**Module 1: Fundamentals of Process Integration (14 Hours)** • Overview of process integration and its significance in sustainable chemical industries. • Heat integration: Pinch analysis, energy targeting, and heat exchanger network design. • Water integration: Water pinch and reuse/recycle strategies.						

	Module 2: Optimization Techniques (14 Hours) • Linear and nonlinear programming: Basics and applications. • Advanced optimization methods: Genetic algorithms, simulated annealing, and neural networks. • Multi-objective optimization for sustainability and cost-effectiveness. **Module 3: Applications and Case Studies (14 Hours)** • Applications in petrochemical, pharmaceutical, and agrochemical industries. • Life cycle assessment (LCA) and techno-economic analysis of integrated processes. • Case studies: CO_2 capture and sequestration, waste-to-energy systems, and process retrofitting.
Text Books, and/or reference material	**Textbooks** 1. Smith, R. **Chemical Process Design and Integration**. Wiley, 2nd Edition, 2016. 2. Biegler, L. T., Grossmann, I. E., & Westerberg, A. W. **Systematic Methods of Chemical Process Design**. Prentice Hall, 1997. **Reference Books** 1. Seider, W. D., Seader, J. D., & Lewin, D. R. **Product and Process Design Principles**. Wiley, 3rd Edition, 2016. 2. Douglas, J. M. **Conceptual Design of Chemical Processes**. McGraw Hill, 1988. 3. Floudas, C. A. **Nonlinear and Mixed-Integer Optimization**. Oxford University Press, 1995. **4.** Klemes, J. J. **Sustainability in the Process Industry: Integration and Optimization**. McGraw Hill, 1st Edition, 2010.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

EIGHT (8th) SEMESTER

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH2001	**Computer-aided Design**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
CHC601: Chemical Plant Design and Economics or equivalent undergraduate-level course	CT+EA

Course Outcomes	• Utilize computer-aided tools for process modeling, simulation, and optimization. • Design chemical process equipment and systems using computational software. • Apply advanced computational techniques for solving complex chemical engineering problems. • Integrate process simulation with plant design and economic analysis.
Topics Covered	**Module 1: Introduction to Computer-Aided Design (14 Hours)** • Fundamentals of computer-aided design in chemical engineering. • Introduction to process simulators: Aspen Plus, HYSYS, and DWSIM. • Development of flow sheets for chemical process systems. • Introduction to numerical methods: Solving algebraic and differential equations in chemical engineering applications. **Module 2: Process Modeling and Simulation (14 Hours)** • Modeling of steady-state and dynamic systems: Principles and approaches. • Process simulation of unit operations: Distillation, heat exchangers, reactors, and separators. • Optimization of chemical processes using simulators. • Case studies on chemical process design and troubleshooting using simulation software. **Module 3: Computer-Aided Equipment Design (14 Hours)** • Design of heat exchangers, distillation columns, and chemical reactors using software tools. • Piping and instrumentation diagram (P&ID) development. • Equipment costing and economic analysis using computational tools. • Plant layout design and optimization. **Module 4: Advanced Computational Techniques (14 Hours)** • Artificial intelligence (AI) and machine learning (ML) applications in chemical engineering design. • Computational fluid dynamics (CFD) for chemical process analysis. • Optimization algorithms and their applications in process design. • Integration of process simulation and control in chemical plant operations.

Text Books, and/or reference material	**Textbooks** 1. Biegler, L. T., Grossmann, I. E., & Westerberg, A. W. **Systematic Methods of Chemical Process Design**. Prentice Hall, 1997. 2. Seider, W. D., Seader, J. D., & Lewin, D. R. **Product and Process Design Principles: Synthesis, Analysis, and Evaluation**. Wiley, 3rd Edition, 2017. **Reference Books** 1. Towler, G., & Sinnott, R. **Chemical Engineering Design: Principles, Practice, and Economics of Plant and Process Design**. Elsevier, 2nd Edition, 2013. 2. Himmelblau, D. M., & Riggs, J. B. **Basic Principles and Calculations in Chemical Engineering**. Pearson, 8th Edition, 2012. 3. Bhattacharyya, D., & Reklaitis, G. V. **Introduction to Chemical Engineering Computing**. CRC Press, 2nd Edition, 2014. 4. Versteeg, H. K., & Malalasekera, W. **An Introduction to Computational Fluid Dynamics: The Finite Volume Method**. Pearson Education, 2nd Edition, 2007.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			
CO4			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH2002	**ADVANCED MATERIALS FOR CHEMICAL ENGINEERING APPLICATIONS**	PEL	4	0	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic courses in materials science and chemical engineering thermodynamics	CT+EA

Course Outcomes	• Understand the properties, synthesis, and characterization of advanced materials. • Analyze the applications of advanced materials in chemical engineering processes. • Explore emerging trends and innovations in advanced materials for industrial use.

	• Evaluate material performance for sustainable and efficient chemical processes.
Topics Covered	**Module 1: Properties and Synthesis of Advanced Materials (14 Hours)** • Introduction to advanced materials: Polymers, composites, ceramics, and nanomaterials. • Structure-property relationships in advanced materials. • Synthesis of advanced materials: Sol-gel, chemical vapor deposition (CVD), physical vapor deposition (PVD), and hydrothermal methods. • Advanced polymeric and composite materials for chemical engineering applications. **Module 2: Characterization of Advanced Materials (14 Hours)** • Techniques for material characterization: X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and atomic force microscopy (AFM). • Thermal analysis techniques: Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). • Spectroscopic techniques: FTIR, UV-Vis, and Raman spectroscopy. • Mechanical testing of materials: Tensile, compressive, and impact tests. **Module 3: Applications of Advanced Materials in Chemical Engineering (14 Hours)** • Membranes for separation and filtration processes. • Catalysts and catalytic materials in chemical reactions. • Materials for energy storage and conversion: Batteries, fuel cells, and supercapacitors. • Corrosion-resistant materials for chemical industries. **Module 4: Emerging Trends in Advanced Materials (14 Hours)** • Biomaterials and their applications in chemical and biomedical industries. • Functional materials: Smart materials, self-healing materials, and shape-memory alloys. • Advanced carbon-based materials: Graphene, carbon nanotubes, and fullerenes. • Sustainability and recyclability of advanced materials.
Text Books, and/or reference material	**Textbooks** 1. Ashby, M. F., & Jones, D. R. H. **Engineering Materials: An Introduction to Properties, Applications, and Design**. Elsevier, 4th Edition, 2012. 2. Callister, W. D., & Rethwisch, D. G. **Materials Science and Engineering: An Introduction**. Wiley, 10th Edition, 2020. **Reference Books** 1. Schwartz, M. M. **Composite Materials: Properties, Nondestructive Testing, and Repair**. Prentice Hall, 1997. 2. Hull, D., & Clyne, T. W. **An Introduction to Composite Materials**. Cambridge University Press, 2nd Edition, 2006. 3. Ratner, B. D., & Hoffman, A. S. **Biomaterials Science: An Introduction to Materials in Medicine**. Academic Press, 3rd Edition, 2013. 4. Li, J., & Kaner, R. B. **Graphene-Based Materials: Science and Technology**. Wiley, 2016.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			
CO4			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH2051	**Environment and Membrane Laboratory**	PEL	4	0	0	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fundamental knowledge of environmental chemistry and process analysis.		CT+EA					
Course Outcomes	• Ability to perform environmental pollutant analysis in air and water • Ability to apply analytical skill in abatement technology • Ability to synthesize and apply indigenously developed membranes • Ability to investigate performance of membrane systems in purification						
Topics Covered	**List of Experiments** **1. Water Quality Analysis** o Determination of pH, turbidity, and alkalinity of water samples. o Estimating total dissolved solids (TDS) and total suspended solids (TSS). **2. Measurement of Key Pollutants** o Determining biochemical oxygen demand (BOD) and chemical oxygen demand (COD). o Analysis of heavy metals (e.g., lead, chromium, arsenic) using atomic absorption spectroscopy (AAS). **3. Air Quality Monitoring** o Measurement of particulate matter (PM10 and PM2.5) using air samplers. o Determination of gaseous pollutants such as SO_2, NO_x, and CO using portable gas analyzers. **4. Advanced Wastewater Treatment Processes** o Study of Membrane-based systems o Study of advanced oxidation processes (AOPs).						

	5. Microbiological Analysis o Total coliform and fecal coliform count in water samples using the MPN method. **6. Membrane-Based Treatment Systems** o Demonstration and analysis of reverse osmosis (RO) and ultrafiltration (UF) systems. o Evaluation of membrane performance for desalination and wastewater treatment.
Text Books, and/or reference material	**Textbooks** 1. Sawyer, C. N., McCarty, P. L., & Parkin, G. F. **Chemistry for Environmental Engineering and Science**. McGraw Hill, 5th Edition, 2003. 2. Manahan, S. E. **Environmental Chemistry**. CRC Press, 10th Edition, 2017. **Reference Books** **1. P.Pal, Industrial Water Treatment Process Technology, Elsevier, 2017** **2. P.Pal, Membrane-based Technologies for Environmental Pollution Control, Elsevier Science 2020** 3. AWWA. **Standard Methods for the Examination of Water and Wastewater**. American Public Health Association, 23rd Edition, 2017.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1	3	2	1
CO2	3	2	1
CO3	3	2	1
CO4	3	2	1

Correlation levels1,2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

EIGHT (8th) Semester Department Electives
MTech Basket

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9020	**BUBBLE AND DROPLET DYNAMICS**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
	CT+EA

Course Outcomes	• Understand the fundamental principles governing bubble and droplet dynamics. • Analyze transport phenomena and dynamics in industrial systems. • Apply the principles of bubble and droplet dynamics to process optimization and emerging technologies.
Topics Covered	**Module 1: Fundamentals of Bubble and Droplet Dynamics (12 Hours)** • Physical characteristics of bubbles and droplets: Shape, size, and interfacial phenomena. • Surface tension, capillary pressure, and Young-Laplace equation. • Dynamics of bubble and droplet formation: Nucleation, growth, and detachment. • Coalescence, breakup, and stability. **Module 2: Transport Phenomena in Bubbles and Droplets (14 Hours)** • Momentum, heat, and mass transfer in single and multiphase systems. • Drag force, terminal velocity, and bubble rise in stagnant and flowing fluids. • Interaction between bubbles/droplets and solid surfaces: Wetting and spreading. • Applications in boiling, condensation, and spray systems. **Module 3: Applications in Industrial Systems (16 Hours)** • Bubbles in reactors: Fluidized beds, bubble column reactors, and fermenters. • Droplets in spray drying, coating, atomization, and emulsification. • Emerging applications in microfluidics, inkjet printing, and drug delivery systems. • Case studies: Bubble dynamics in wastewater treatment, droplet-based microreactors.
Text Books, and/or reference material	**Textbooks** 1. Clift, R., Grace, J. R., & Weber, M. E. **Bubbles, Drops, and Particles**. Dover Publications, 2005. 2. Levich, V. G. **Physicochemical Hydrodynamics**. Prentice Hall, 2nd Edition, 1962. **Reference Books** 1. Batchelor, G. K. **An Introduction to Fluid Dynamics**. Cambridge University Press, 2000.

	2. Crowe, C. T., Sommerfeld, M., & Tsuji, Y. **Multiphase Flows with Droplets and Particles**. CRC Press, 2nd Edition, 2011. 3. Brennen, C. E. **Fundamentals of Multiphase Flow**. Cambridge University Press, 2005.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3
CO1	3	2	1
CO2	3	2	1
CO3	3	2	1

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9021	**ENVIRONMENTAL ENGINEERING**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic subjects of Chemical Engineering and Mathematics		CT+EA					
Course Outcomes	● Understand the fundamentals of environmental pollution and regulatory frameworks. ● Design and evaluate pollution control technologies for air, water, and soil. ● Develop sustainable practices for minimizing environmental impact in industrial processes.						
Topics Covered	**Module 1: Fundamentals of Environmental Pollution (12 Hours)** • Overview of air, water, and soil pollution: Sources and effects. • Environmental regulations and standards: National and international frameworks. • Environmental impact assessment (EIA) and life cycle analysis (LCA). **Module 2: Pollution Control Technologies (14 Hours)** • Air pollution control: Cyclones, scrubbers, electrostatic precipitators, and bag filters. • Water and wastewater treatment: Physical, chemical, and biological processes. • Soil remediation techniques: Bioremediation, phytoremediation, and thermal treatment. **Module 3: Sustainable Practices in Environmental Engineering (16 Hours)** • Waste management: Reduction, reuse, recycling, and energy recovery. • Carbon capture and sequestration (CCS) technologies. • Green process engineering: Resource efficiency, circular economy, and						

	sustainable manufacturing. • Case studies: Sustainable solutions in the chemical industry and environmental restoration projects.
Text Books, and/or reference material	**Textbooks** 1. Peavy, H. S., Rowe, D. R., & Tchobanoglous, G. **Environmental Engineering**. McGraw Hill, 1985. 2. Metcalf & Eddy. **Wastewater Engineering: Treatment and Reuse**. McGraw Hill, 5th Edition, 2013. **Reference Books** 1. Rao, C. S. **Environmental Pollution Control Engineering**. Wiley, 2nd Edition, 2006. 2. Tchobanoglous, G., & Kreith, F. **Handbook of Solid Waste Management**. McGraw Hill, 2nd Edition, 2002. 3. Kumar, R., & Singh, S. N. **Air Pollution Control**. The Energy and Resources Institute (TERI), 2010.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1	3	2	1
CO2	3	2	1
CO3	3	2	1

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9022	**CHEMICAL PROCESSES FOR MICRO-ELECTRONIC FABRICATION**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• Understand the chemical processes involved in microelectronics fabrication. • Analyze and optimize deposition, etching, and polishing techniques. • Apply microfabrication principles to emerging technologies in electronics and nanotechnology.
Topics Covered	**Module 1: Introduction to Microelectronics Fabrication (12 Hours)** • Overview of semiconductor industry and fabrication processes. • Materials for microelectronics: Silicon, III-V semiconductors, and thin films.

	• Cleanroom protocols and contamination control. **Module 2: Chemical Processes in Fabrication (16 Hours)** • Deposition processes: Chemical vapor deposition (CVD), physical vapor deposition (PVD), and atomic layer deposition (ALD). • Etching processes: Wet and dry etching techniques, anisotropic and isotropic etching. • Chemical mechanical polishing (CMP): Principles and applications. **Module 3: Emerging Technologies and Case Studies (14 Hours)** • Advanced lithography: Photolithography, EUV lithography, and nanoimprint lithography. • Applications of microelectronics in MEMS and nanoelectronics. • Case studies: Fabrication of transistors, sensors, and photovoltaic devices.
Text Books, and/or reference material	**Textbooks** 1. Campbell, S. A. **The Science and Engineering of Microelectronic Fabrication**. Oxford University Press, 2nd Edition, 2001. 2. Madou, M. J. **Fundamentals of Microfabrication and Nanotechnology**. CRC Press, 3rd Edition, 2011. **Reference Books** 1. Plummer, J. D., Deal, M. D., & Griffin, P. B. **Silicon VLSI Technology: Fundamentals, Practice, and Modeling**. Pearson, 2000. 2. Jaeger, R. C. **Introduction to Microelectronic Fabrication**. Prentice Hall, 2nd Edition, 2002. 3. Wolf, S., & Tauber, R. N. **Silicon Processing for the VLSI Era, Vol. 1: Process Technology**. Lattice Press, 2000.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1	3	2	1
CO2	3	2	1
CO3	3	2	1

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9030	**ADVANCED FLUID DYNAMICS**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic Fluid Mechanics and Transport Phenomena	CT+EA

Course Outcomes	• Understand the principles and mathematical modeling of complex fluid flows. • Apply advanced techniques to analyze turbulent, multiphase, and non-Newtonian flows. • Develop numerical solutions for fluid flow problems in chemical engineering applications.
Topics Covered	**Module 1: Fundamentals and Governing Equations (12 Hours)** • Review of Navier-Stokes equations and boundary conditions. • Dimensional analysis and similarity principles in complex flows. • Non-Newtonian fluids: Rheological models and flow behavior. **Module 2: Advanced Flow Phenomena (14 Hours)** • Turbulent flow: Transition to turbulence, Reynolds-averaged Navier-Stokes (RANS), and turbulence models. • Multiphase flow: Bubbly flow, particle-laden flow, and liquid-liquid systems. • Compressible flows and shockwave phenomena. **Module 3: Numerical Techniques and Applications (16 Hours)** • Introduction to computational fluid dynamics (CFD): Finite volume and finite element methods. • Applications in process industries: Reactors, pipelines, and heat exchangers. • Case studies: Flow modeling in microchannels and porous media.
Text Books, and/or reference material	**Textbooks** 1. White, F. M. **Viscous Fluid Flow**. McGraw Hill, 3rd Edition, 2005. 2. Bird, R. B., Stewart, W. E., & Lightfoot, E. N. **Transport Phenomena**. Wiley, 2nd Edition, 2006. **Reference Books** 1. Anderson, J. D. **Computational Fluid Dynamics: The Basics with Applications**. McGraw Hill, 1995. 2. Fox, R. W., McDonald, A. T., & Pritchard, P. J. **Introduction to Fluid Mechanics**. Wiley, 8th Edition, 2011.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1	3	2	1
CO2	3	2	1
CO3	3	2	1

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9031</td><td>CIRCULAR ECONOMY AND WASTE VALORIZATION</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Environmental Engineering and Industrial Waste Management</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Understand the principles and strategies of circular economy in industrial processes.
• Analyze and implement waste valorization methods for resource recovery.
• Evaluate case studies and propose innovative solutions for achieving sustainability goals.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Introduction to Circular Economy (12 Hours)
• Fundamentals of circular economy: Concepts, strategies, and global practices.
• Linear vs. circular economy: Challenges and opportunities in transitioning.
• Policies, regulations, and sustainability goals.
Module 2: Waste Valorization Technologies (14 Hours)
• Physical, chemical, and biological methods of waste conversion.
• Biomass valorization: Biofuels, bioplastics, and bio-based chemicals.
• Industrial symbiosis and resource recovery from industrial waste streams.
Module 3: Applications and Case Studies (16 Hours)
• Circular economy in chemical industries: Zero-waste manufacturing and closed-loop processes.
• Case studies: Waste valorization in agro-industries, petrochemicals, and construction.
• Emerging trends: Waste-to-energy, carbon capture, and life cycle thinking.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks
1. Stahel, W. R. The Circular Economy: A User's Guide. Routledge, 2019.
2. Letcher, T. M., & Vallero, D. A. Waste: A Handbook for Management. Academic Press, 2nd Edition, 2019.
Reference Books
1. Clark, J. H., & Farmer, T. J. Green and Sustainable Medicinal Chemistry. Royal Society of Chemistry, 2017.
2. Lange, J.-P. Sustainable Development in the Chemical Industry. Wiley-VCH, 2021.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9032</td><td>CATALYSIS IN CHEMICAL INDUSTRY</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3"></td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Understand the principles of catalysis and its role in chemical reactions.
• Develop and optimize catalysts for specific industrial applications.
• Apply advanced catalytic methods to address sustainability challenges.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Fundamentals of Catalysis (12 Hours)
• Principles of homogeneous and heterogeneous catalysis.
• Catalyst properties: Surface area, porosity, and active sites.
• Mechanisms and kinetics of catalytic reactions.
Module 2: Catalyst Design and Synthesis (14 Hours)
• Methods of catalyst preparation: Impregnation, sol-gel, and hydrothermal methods.
• Nanocatalysis and structured catalysts: Design and characterization techniques (XRD, SEM, BET, etc.).
• Catalyst deactivation: Fouling, sintering, and poisoning.
Module 3: Industrial Catalytic Processes (16 Hours)
• Catalysis in refining: Hydrocracking, reforming, and desulfurization.
• Applications in petrochemical, pharmaceutical, and polymer industries.
• Green catalysis: Enzymatic catalysis, photocatalysis, and CO2 utilization.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks
1. Thomas, J. M., & Thomas, W. J. Principles and Practice of Heterogeneous Catalysis. Wiley-VCH, 2nd Edition, 2014.
2. Levenspiel, O. Chemical Reaction Engineering. Wiley, 3rd Edition, 1999.
Reference Books
1. Somorjai, G. A., & Li, Y. Introduction to Surface Chemistry and Catalysis. Wiley, 2nd Edition, 2010.
2. Gates, B. C. Catalytic Chemistry. Wiley, 2nd Edition, 2005.
3. Ertl, G., Knozinger, H., & Weitkamp, J. Handbook of Heterogeneous Catalysis. Wiley-VCH, 2nd Edition, 2008.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

NINE (9th) SEMESTER

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH3001	**MULTI-SCALE SIMULATION OF CHEMICAL PROCESSES**	PEL	4	0	0	4	4
Pre-requisites			Course Assessment methods (Continuous (CT) and end assessment (EA))				
Process Control and Instrumentation, Transport Phenomena			CT+EA				
Course Outcomes	• Understand the fundamentals of multi-scale modeling and its relevance to chemical processes. • Apply molecular and mesoscale simulation techniques to study process behaviors. • Develop models for process systems using advanced simulation tools. • Solve practical problems in chemical engineering using multi-scale approaches.						
Topics Covered	**Module 1: Introduction to Multi-Scale Modeling (14 Hours)** • Fundamentals of multi-scale modeling: Molecular, mesoscopic, and continuum scales. • Integration of models across scales: Bridging molecular and macroscopic behaviors. • Applications in chemical processes: Reaction kinetics, transport phenomena, and material properties. **Module 2: Molecular and Mesoscale Simulations (14 Hours)** • Molecular Dynamics (MD) simulations: Interatomic potentials, force fields, and statistical mechanics. • Monte Carlo methods: Random sampling, Markov chains, and thermodynamic property prediction. • Mesoscale modeling: Lattice Boltzmann Method (LBM) and Dissipative Particle Dynamics (DPD). **Module 3: Process Systems Modeling and Optimization (14 Hours)** • Continuum scale modeling using Partial Differential Equations (PDEs). • Process simulation tools: ASPEN Plus, MATLAB, and COMSOL Multiphysics. • Process optimization techniques: Linear and nonlinear programming, Genetic Algorithms (GA), and Artificial Neural Networks (ANN). **Module 4: Applications and Case Studies (14 Hours)** • Multi-scale modeling in catalysis, crystallization, and polymerization. • Application of simulation tools in reactor design and scale-up processes. • Environmental applications: Modeling pollution dispersion and CO_2 capture.						
Text Books, and/or	**Textbooks** 1. Logtenberg, J., & Krestenitis, M. **Multi-Scale Simulation Methods for**						

reference material	**Chemical Engineering**. Springer, 2017. 2. Li, J., Zhang, H., & Xu, W. **Multi-Scale Modeling and Simulation in Chemical Engineering**. Elsevier, 2020. **Reference Books** 1. Bird, R. B., Stewart, W. E., & Lightfoot, E. N. **Transport Phenomena**. Wiley, 2nd Edition, 2002. 2. AspenTech. **Aspen Plus User Guide**. Aspen Technology Inc., Latest Edition. 3. Fletcher, R. **Practical Methods of Optimization**. Wiley, 2nd Edition, 2000. 4. Frenkel, D., & Smit, B. **Understanding Molecular Simulation: From Algorithms to Applications**. Academic Press, 2nd Edition, 2001.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3
CO1			
CO2			
CO3			
CO4			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH3002	**ADVANCE SEPARATION PROCESSES**	PEL	4	0	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
CHC502 Mass Transfer Operations, CHC506 Chemical Reaction Engineering	CT+EA

Course Outcomes	• Understand the principles and thermodynamics of advanced separation processes. • Apply modeling techniques to simulate separation systems using computational tools. • Evaluate and optimize advanced separation processes for industrial applications. • Analyze emerging separation technologies and their applicability to specific processes.
Topics Covered	**Module 1: Fundamentals of Advanced Separation Processes (14 Hours)** • Overview of separation technologies: Conventional vs. advanced.

	• Thermodynamic basis of separations: Phase equilibria and selectivity. • Mathematical modeling and simulation of separation processes. **Module 2: Emerging Separation Technologies (14 Hours)** • Membrane-based separation processes: Microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. • Adsorptive separations: Pressure Swing Adsorption (PSA) and Temperature Swing Adsorption (TSA). • Hybrid separations: Pervaporation, membrane distillation, and reactive distillation. **Module 3: Advanced Topics and Case Studies (14 Hours)** • Supercritical fluid extraction and ionic liquid separations. • Separation in bioprocessing: Chromatography and affinity-based separations. • Industrial applications: CO_2 capture, desalination, and petrochemical processing. **Module 4: Simulation and Optimization of Separation Systems (14 Hours)** • Process design and optimization using ASPEN Plus and HYSYS. • Economic evaluation and sustainability in separation processes. • Case studies on advanced separation systems in chemical industries.
Text Books, and/or reference material	**Textbooks** 1. Seader, J. D., Henley, E. J., & Roper, D. K. **Separation Process Principles**. Wiley, 4th Edition, 2016. 2. King, C. J. **Separation Processes**. McGraw Hill, 2nd Edition, 1980. **Reference Books** 1. Wankat, P. C. **Separation Process Engineering**. Pearson, 4th Edition, 2021. 2. Geankoplis, C. J. **Transport Processes and Unit Operations**. Prentice Hall, 4th Edition, 2003. 3. Noble, R. D., & Stern, S. A. **Membrane Separations Technology: Principles and Applications**. Elsevier, 1st Edition, 1995. 4. Humphrey, J. L., & Keller, G. E. **Separation Process Technology**. McGraw Hill, 1997.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			
CO4			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

NINTH (9th) Semester Department Electives
MTech Basket

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9040	**BIOFUEL TECHNOLOGY**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of Energy Engineering, Chemical Reaction Engineering	CT+EA

Course Outcomes	• Understand the fundamentals of biofuels and their significance in sustainable energy systems. • Analyze and evaluate various feedstocks and conversion technologies. • Assess the economic and environmental impacts of biofuel production.
Topics Covered	**Module 1: Introduction to Biofuels (12 Hours)** • Overview of energy resources: Fossil fuels vs. renewable energy. • Classification of biofuels: First, second, and third generations. • Feedstocks: Agricultural residues, lignocellulosic biomass, algae, and waste streams. **Module 2: Biofuel Production Technologies (14 Hours)** • Biochemical conversion: Fermentation, anaerobic digestion, and enzymatic hydrolysis. • Thermochemical conversion: Gasification, pyrolysis, and transesterification for biodiesel. • Microbial and algal biofuel technologies: Bioethanol, biobutanol, and biohydrogen. **Module 3: Sustainability and Applications (16 Hours)** • Lifecycle analysis of biofuels: Carbon footprint and energy balance. • Economic and policy aspects of biofuel production. • Applications in transportation, power generation, and industrial heating.
Text Books, and/or reference material	**Textbooks** 1. Demirbas, A. **Biofuels: Securing the Planet's Future Energy Needs**. Springer, 2009. 2. Lee, J. W. **Advanced Biofuels and Bioproducts**. Springer, 2012. **Reference Books** 1. Pandey, A., et al. **Biofuels: Alternative Feedstocks and Conversion Processes**. Academic Press, 2nd Edition, 2019. 2. Chandra, R., et al. **Advances in Biofuel Production**. Springer, 2019.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9041	**ARTIFICIAL INTELLIGENCE AND OPTIMIZATION FOR CHEMICAL PROCESSES**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Process Modeling and Simulation, Numerical Methods	CT+EA

Course Outcomes	• Apply AI techniques to model and analyze chemical process systems. • Solve optimization problems using advanced algorithms. • Integrate AI and optimization strategies for improving process efficiency and sustainability.
Topics Covered	**Module 1: Introduction to Artificial Intelligence (12 Hours)** • Fundamentals of AI: Machine learning, deep learning, and neural networks. • Overview of AI tools and software for chemical engineering. • Data-driven modeling in chemical processes: Regression, classification, and clustering. **Module 2: Optimization Techniques (14 Hours)** • Optimization principles: Linear and nonlinear programming, dynamic programming. • Metaheuristic algorithms: Genetic algorithms, particle swarm optimization, simulated annealing. • Multi-objective optimization in chemical process systems. **Module 3: Applications of AI and Optimization (16 Hours)** • Process monitoring and fault diagnosis using AI techniques. • Optimization in reactor design, energy efficiency, and supply chain management. • Case studies: AI in process control and advanced process automation.

Text Books, and/or reference material	**Textbooks** 1. Babu, B. V. **Process Plant Simulation and Optimization**. CRC Press, 2020. 2. Hastie, T., Tibshirani, R., & Friedman, J. **The Elements of Statistical Learning**. Springer, 2nd Edition, 2009. **Reference Books** 1. Rao, S. S. **Engineering Optimization: Theory and Practice**. Wiley, 4th Edition, 2009. 2. Sutton, R. S., & Barto, A. G. **Reinforcement Learning: An Introduction**. MIT Press, 2nd Edition, 2018.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9042	**SUSTAINABLE PROCESS TECHNOLOGY**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of Chemical Process Design, Environmental Engineering	CT+EA
Course Outcomes	• Understand and apply sustainability principles in process technology. • Design energy-efficient and environmentally friendly chemical processes. • Analyze case studies to identify best practices for sustainable chemical production.
Topics Covered	**Module 1: Principles of Sustainable Process Design (12 Hours)** • Fundamentals of sustainability in chemical engineering. • Green chemistry principles and atom economy. • Process intensification and eco-friendly process designs. **Module 2: Cleaner Production and Energy Efficiency (14 Hours)** • Cleaner production strategies and assessment techniques. • Energy efficiency in process industries: Pinch analysis and heat integration. • Renewable energy integration into chemical processes. **Module 3: Emerging Sustainable Technologies (16 Hours)**

	• Carbon capture, utilization, and storage (CCUS). • Circular economy in chemical industries: Waste minimization and valorization. • Case studies: Sustainable technologies in petrochemicals, polymers, and pharmaceuticals.
Text Books, and/or reference material	**Textbooks** 1. Dunn, J. B., & Posen, I. D. **Sustainable Process Engineering**. McGraw Hill, 2019. 2. Manahan, S. E. **Green Chemistry and the Ten Commandments of Sustainability**. ChemChar Research, 2nd Edition, 2011. **Reference Books** 1. Anastas, P. T., & Warner, J. C. **Green Chemistry: Theory and Practice**. Oxford University Press, 1998. 2. Smith, R. **Chemical Process Design and Integration**. Wiley, 2nd Edition, 2016.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs COs	PO1	PO2	PO3
CO1			
CO2			
CO3			

Correlation levels1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)