B. Tech.

IN

CHEMICAL ENGINEERING

FLEXIBLE CURRICULUM
(Students Admitted in 2016-17)

DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015TAMIL NADU, INDIA

Vision of the Department

- To be a world class chemical engineering department

Mission of the Department

- To produce globally competent professional chemical engineers.
- To faster process engineering knowledge through research and innovation.
- To serve organization and society as adaptable engineers, entrepreneurs or leaders.

Programme Educational Objectives (PEOs)

After 4-5 years of graduation our graduates will:

- Choose their careers as practicing chemical engineers in traditional chemical industries aswell as in expanding areas of materials, environmental and energy-related industries.
- Engage in post-baccalaureate study and are making timely progress toward an advanced degree in chemical engineering or a related technical discipline or business
- Function effectively in the complex modern work environment with the ability to assume professional leadership roles.

Programme Outcomes: Chemical Engineering

1) The Chemical Engineering graduates are capable to apply knowledge of mathematics, science and engineering.
2) The Chemical Engineering graduates are capable to design and conduct experiments, as well as to analyze and interpret data.
3) The Chemical Engineering graduates are capable to design a system, a component, or a process to meet desired needs within realistic constraints such as economic, environmental, social, ethical, health and safety, manufacturability, and sustainability.
4) The Chemical Engineering graduates are capable to function on multi-disciplinary teams.
5) The Chemical Engineering graduates are capable to identify, formulate and solve engineeringproblems.
6) The Chemical Engineering graduates have the understanding of professional and ethical responsibility.
7) The Chemical Engineering graduates are capable to communicate effectively.
8) The Chemical Engineering graduates have the broad education necessary to understand the impact of engineering solutions in a global, economic and societal context.
9) The Chemical Engineering graduates are capable to engage themselves in life-long learning.
10) The Chemical Engineering graduates have knowledge of contemporary /current issues.
11) The Chemical Engineering graduates are capable to use the techniques, skills, and modern engineering tools necessary for engineering practice.
12) Chemical engineering graduates are capable to apply fundamental and practical knowledge of unit operations and processes, principles of management and economics for providing better services to chemical process industries.

CURRICULUM

The total minimum credits for completing the B.Tech. programme in **Chemical Engineering** is **180 [68 + 112)].**

MINIMUM CREDIT REQUIREMENT FOR THE VARIOUS COURSE CATEGORIES

The structure of B.Tech. programmes shall have General Institute Requirements (GIR), Programme Core (PC), Elective Courses (PE, OE and MI) and Essential Programme Laboratory Requirements (ELR) are as follows:

Sl.No.	COURSE CATEGORY	Number of Courses	Number of Credits
1.	General Institute Requirement (GIR)	17	68
2.	Programme Core (PC)	20	63
3.	Essential Programme Laboratory Requirement (ELR)	2 per session	16
4.	**Elective courses** (a) Programme Electives (PE)+ (b) Open Electives (OE) (c) Minor (MI)# A student should be allowed a minimum of 50% of the total electives of a programme from (b) and (c) if so desired by the student.	11	33
TOTAL			**180**
+ At least 3 courses # 5 Courses			

(I) GENERAL INSTITUTE REQUIREMENTS

Sl.No.	Name of the course	Number of Courses	Maximum Credits
1.	Mathematics	4	14
2.	**Physics***	**2**	**7**
3.	**Chemistry***	**2**	**7**
4.	Humanities	1	3
5.	Communication	2	6
6.	Energy and Environmental Engineering	1	2
7.	Professional Ethics	1	3
8.	***Engineering Graphics***	***1***	***3***
9.	***Engineering Practice***	***1***	***2***
10.	Basic Engineering	2	4
11.	Introduction to Computer Programming	1	3
12.	**Branch Specific Course** (Introduction to Branch of Study)**	**1**	**2**
13.	***Summer Internship***	***1***	***2***
14.	***Project work***	***1***	***6***
15.	***Comprehensive Viva***	***1***	***3***
16.	Industrial lecture	-	1
17.	NSS / NCC / NSC	-	0
	TOTAL	**17 (Excluding Italics)**	**68**

***including Lab**

**** Commence during Orientation Programme**

I. GENERAL INSTITUTE REQUIREMENTS

1. MATHEMATICS

Sl.No.	Course Code	Course Title	Credits
1.	MAIR11	Mathematics - I	**4**
2.	MAIR21	Mathematics - II	**4**
3.	MAIR31	Transforms, Special Functions and Partial Differential Equations	**3**
4.	MAIR41	Numerical Techniques	**3**
		Total	**14**

2. PHYSICS

Sl.No.	Course Code	Course Title	Credits
1	PHIR11	Physics - I	**3**
2	PHIR12	Physics - II	**4**
		Total	**7**

3. CHEMISTRY

Sl.No.	Course Code	Course Title	Credits
1.	CHIR11	Chemistry - I	**3**
2.	CHIR14	Chemistry - II	**4**
		Total	**7**

4. COMMUNICATION

Sl.No.	Course Code	Course Title	Credits
1	HSIR11	English for Communication	**3**
2	HSIR12	Professional Communication	**3**
		Total	**6**

5. HUMANITIES

Sl.No.	Course Code	Course Title	Credits
1.	HSIR13	Industrial Economics & Foreign Trade	**3**
		Total	**3**

6. ENERGY AND ENVIRONMENTAL ENGINEERING

Sl.No.	Course Code	Course Title	Credits
1.	ENIR11	Energy and Environmental Engineering	**2**
		Total	**2**

7. PROFESSIONAL ETHICS

Sl.No.	Course Code	Course Title	Credits
1	HSIR14	Professional Ethics	**3**
		Total	**3**

8. ENGINEERING GRAPHICS

Sl.No.	Course Code	Course Title	Credits
1	MEIR12	Engineering Graphics	**3**
		Total	**3**

9. ENGINEERING PRACTICE

Sl.No.	Course Code	Course Title	Credits
1	PRIR11	Engineering Practice	2
		Total	**2**

10. BASIC ENGINEERING

Sl.No.	Course Code	Course Title	Credits
1.	CEIR11	Basics of Civil Engineering	**2**
2.	EEIR11	Basics of Electrical and Electronic Engineering	**2**
		Total	**4**

11. INTRODUCTION TO COMPUTER PROGRAMMING

Sl.No.	Course Code	Course Title	Credits
1	CSIR11	Introduction to Computer Programming	**3**
		Total	**3**

12. BRANCH SPECIFIC COURSE

Sl.No.	Course Code	Course Title	Credits
1	CLIR15	Introduction to Chemical Engineering	**2**
		Total	**2**

13. SUMMER INTERNSHIP

Sl.No.	Course Code	Course Title	Credits
1.	CLIR16	INTERNSHIP / INDUSTRIAL TRAINING / ACADEMIC ATTACHMENT (2 to 3 months duration during summer vacation)	**2**
		Total	**2**

The student should undergo industrial training/internship for a minimum period of two months during the summer vacation of 3rd year. Attachment with an academic institution within the country (IISc/IITs/NITs/IIITs and CFTIs) or university abroad is also permitted instead ofindustrial training.

 # To be evaluated at the beginning of VII semester by assessing the report and seminar presentations.

14. PROJECT WORK

Sl.No.	Course Code	Course Title	Credits
1.	CLIR17	Project Work	**6**
		Total	**6**

15. COMPREHENSIVE VIVA

Sl.No.	Course Code	Course Title	Credits
1.	CLIR18	Comprehensive Viva-Voce	**3**
		Total	**3**

16. INDUSTRIAL LECTURE

Sl.No.	Course Code	Course Title	Credits
1.	CLIR19	Industrial Lectures	**1**
		Total	**1**

17. NSS/NCC/NSO

Sl.No.	Course Code	Course Title	Credits
1.	SWIR11	NSS/NCC/NSO	**0**
		Total	**0**

A course based on industrial lectures shall be offered for 1 credit. A minimum of five lectures of two hours duration by industry experts will be arranged by the Department. The evaluation methodology, will in general, be based on quizzes at the end of each lecture.

(II) PROGRAMME CORE (PC)

Note: (1) Number of programme core: 16 to 20 (2) Credits: 56 - 65

Sl.No.	Course Code	Course Title	Prerequisites	Credits
1.	CLPC10	Strength of Materials	NONE	3
2.	CLPC11	Chemistry-III	NONE	3
3.	CLPC12	Applied Electrical and Electronics Engineering	NONE	3
4.	CLPC13	Introduction to Mechanical Engineering	NONE	3
5.	CLPC14	Momentum Transfer	NONE	3

6.	CLPC15	Process Calculations	NONE	4
7.	CLPC16	Chemical Technology	NONE	3
8.	CLPC17	Chemical Engineering Thermodynamics	CLPC15	3
9.	CLPC18	Particulate Science and Technology	NONE	3
10.	CLPC19	Chemical Reaction Engineering– I	CLPC17	3
11.	CLPC20	Mass Transfer	CLPC15	3
12.	CLPC21	Heat Transfer	NONE	3
13.	CLPC22	Safety in Chemical Industries	CLPC16	3
14.	CLPC23	Chemical Reaction Engineering– II	CLPC19	3
15.	CLPC24	Equilibrium staged Operations	CLPC20	4
16.	CLPC25	Process Dynamics and Control	CLIR10	3
17.	CLPC26	Biochemical Engineering	CLPC19	3
18.	CLPC27	Chemical Process Equipment Design	CLPC10, CLPC19, CLPC20, CLPC21	4
19.	CLPC28	Project Engineering and Economics	CLPC16	3
20.	CLPC29	Transport Phenomena	CLPC14, CLPC20, CLPC21	3
Total				**63**

(III) PROGRAMME ELECTIVES (PE)

[Note: Number of programme elective: at least 3 courses]

Students pursuing B.Tech. in Chemical Engineering should take at least three courses fromthe Programme Electives listed below.

Sl.No.	Course Code	Course Title	Prerequisites	Credits
1.	CLPE10	Petroleum and Petrochemical Engineering	NONE	3
2.	CLPE11	Fertilizer Technology	NONE	3
3.	CLPE12	Industrial Process Biotechnology	NONE	3
4.	CLPE13	Polymer science and Technology	NONE	3
5.	CLPE14	New Separation Process	CLPC20	3
6.	CLPE15	Nano Technology	NONE	3
7.	CLPE16	Fluidization Engineering	CLPC14, CLPC18	3
8.	CLPE17	Pharmaceutical Technology	NONE	3
9.	CLPE18	Process Intensification	CLPC21	3
10.	CLPE19	Electrochemical Reaction Engineering	CLPC19, CLPC20	3
11.	CLPE20	Food Processing Technology	NONE	3

(IV) ESSENTIAL PROGRAMME LABORATORY REQUIREMENT (ELR)

Sl.No.	Course Code	Course Title	Co requisites	Credits
1.	CLLR10	Applied Electrical and Electronics Engineering Lab	CLPC12	2
2.	CLLR11	Momentum Transfer Lab	CLPC14	2
3.	CLLR12	Instrumental Analysis and Thermodynamics Lab	CLPC17	2
4.	CLLR13	Particulate Science and Technology Lab	CLPC18	2
5.	CLLR14	Heat Transfer Lab	CLPC21	2
6.	CLLR15	Chemical Reaction Engineering Lab	CLPC19	2
7.	CLLR16	Mass Transfer Lab	CLPC20, CLPC24	2
8.	CLLR17	Process Dynamics and Control Lab	CLPC25	2
Total				**16**

NOTE: Students can register for 2 laboratory courses during one session along withregular courses (PC / PE / OE / MI).

(V) OPEN ELECTIVES (OE)

Sl.No.	Course Code	Course Title	Prerequisites	Credits
1.	CLOE10	Environmental Engineering	NONE	3
2.	CLOE11	Nuclear Engineering	NONE	3
3.	CLOE12	Renewable Energy	NONE	3
4.	CLOE13	Pipe line Corrosion and Cathodic Protection	NONE	3
5.	CLOE14	Electrochemical Engineering	NONE	3
6.	CLOE15	Energy Engineering	NONE	3
7.	CLOE16	Process Instrumentation	NONE	3
8.	CLOE17	Design and Analysis of Experiments	NONE	3
9.	CLOE18	Nano Technology	NONE	3
10.	CLOE19	Optimization Techniques	NONE	3
11.	CLOE20	Material Science and Technology	NONE	3
12.	CLOE21	Bioenergy	NONE	3

(VI) MINORS (MI)

Students who have registered for B.Tech. Minor in Chemical Engineering

[Note: Number of Minor courses: 5 courses (Minimum)]

Sl.No.	Course Code	Course Title	Prerequisites	Credits
1.	CLMR10	Chemical Process Calculations	NONE	3
2.	CLMR11	Transfer Operations - I	NONE	3
3.	CLMR12	Transfer Operations - II	CLMR11	3
4.	CLMR13	Chemical Reaction Engineering	CLMR10,CLMR11, CLMR12	3
5.	CLMR14	Chemical Technology	NONE	3
		Total		**15**

Note : Student should be allowed a minimum of 50% of the total electives of a programme from Open electives and Minor, if so desired by the student.

VII. HONOURS

A student can obtain B.Tech. (Honours) degree provided the student has to

i. register at least for 12 theory courses and 2 ELRs in the second year.
ii. consistently obtain a minimum GPA of 8.5 in the first four sessions and continue tomaintain the same GPA of 8.5 in the subsequent sessions (including the Honours courses)
iii. complete 3 additional theory courses specified for the Honors degree of the programme.
iv. complete all the courses registered, in the first attempt and in four years of study.

Sl.No.	Course Code	Course Title	Co requisites	Credits
1.	CLHO10	Advanced Process control	CLPC25	3
2.	CLHO11	Advances in Fluidization Engineering	CLPC14, CLPC18	3
3.	CLHO12	Process Modelling and Simulation	CLPC14, CLPC20, CLPC21	3
4.	CLHO13	Pinch Analysis and Heat Exchange Network Design	CLPC17, CLPC21,	3
5.	CLHO14	Applied Mathematics in Chemical Engineering	CLPC19, CLPC20, CLPC21	3
6.	CLHO15	Advances in Heat Transfer	CLPC21	3

The following table should be prepared before the commencement of the programme

Sl. No.	Course Code	Course Title	Year of Study	Session
1.	HSIR11	English for Communication	I	July
2.	MAIR11	Mathematics – I	I	July
3.	PHIR11	Physics – I	I	July
4.	CHIR11	Chemistry – I	I	July
5.	CSIR11	Basics of Programming	I	July
6.	CLIR15	Branch Specific Course	I	July
7.	CEIR11	Basics of Civil Engineering	I	July
8.	EEIR11	Basics of Electrical and Electronic Engg.,	I	July
9.	MEIR12/ PRIR11	Engineering Graphics/ Engineering Practice	I	July
10.	HSIR12	Professional Communication	I	January
11.	MAIR21	Mathematics - II	I	January
12.	PHIR12	Physics - II	I	January
13.	CHIR14	Chemistry - II	I	January
14.	ENIR11	Energy and Environmental Engineering	I	January
15.	CLPC10	Strength of Materials	I	January
16.	MEIR12/ PRIR11	Engineering Graphics/ Engineering Practice	I	January
17.	MAIR31	Transforms, Special Functions and Partial Differential Equations	II	July
18.	CLPC11	Chemistry-III	II	July
19.	CLPC12	Applied Electrical and Electronics Engineering	II	July
20.	CLPC13	Introduction to Mechanical Engineering	II	July
21.	CLPC14	Momentum Transfer	II	July
22.	CLPC15	Process Calculations	II	July
23.	CLLR10	Applied Electrical and Electronics Engineering Lab.	II	July
24.	MAIR41	Numerical Techniques	II	January
25.	HSIR14	Professional Ethics	II	January
26.	CLPC16	Chemical Technology	II	January
27.	CLPC17	Chemical Engineering Thermodynamics	II	January
28.	CLPC18	Particulate Science and Technology	II	January
29.		Elective - I	II	January
30.	CLLR11	Momentum Transfer Lab.	II	January
31.	CLPC19	Chemical Reaction Engineering– I	III	July
32.	CLPC20	Mass Transfer	III	July
33.	CLPC21	Heat Transfer	III	July
34.	CLPC22	Safety in Chemical Industries	III	July
35.		Elective – II	III	July
36.		Elective – III	III	July
37.	CLLR12	Instrumental Analysis and Thermodynamics Lab.	II	July
38.	CLLR13	Particulate Science and Technology Lab.	III	July
39.	HSIR13	Industrial Economics and Foreign Trade	III	January
40.	CLPC23	Chemical Reaction Engineering– II	III	January

41.	CLPC24	Equilibrium Staged Operations	III	January
42.	CLPC25	Process Dynamics and Control	III	January
43.		Elective - IV	III	January
44.		Elective - V	III	January
45.	CLIR19	Industrial Lecture	III	January
46.	CLIR16	Internship / Industrial Training / Academic Attachment (2 to 3 months duration during summer vacation)	III	January
47.	CLLR14	Heat Transfer Lab.	III	January
48.	CLLR15	Chemical Reaction Engineering Lab.	III	January
49.	CLPC26	Biochemical Engineering	IV	July
50.	CLPC27	Chemical Process Equipment Design	IV	July
51.	CLPC28	Project Engineering and Economics	IV	July
52.	CLPC29	Transport Phenomena	IV	July
53.	CLIR18	Comprehensive Viva-Voce	IV	July
54.		Elective - VI	IV	July
55.		Elective - VII	IV	July
56.	CLLR16	Mass Transfer Lab.	IV	July
57.	CLLR17	Process Dynamics and Control Lab.	IV	July
58.		Elective - VIII	IV	January
59.		Elective - IX	IV	January
60.		Elective - X	IV	January
61.		Elective - XI	IV	January
62.	CLIR17	Project Work	IV	January

Course Code	**:**	**CLPC11**
Course Title	**:**	**CHEMISTRY-III**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To learn the principles of photochemical reactions and catalyzed reactions in order to apply them in organic synthesis.
2. To acquire knowledge on the advanced characterization techniques in identification of compounds.
3. To understand the principles of reaction kinetics, phase equilibrium and solution chemistry.
4. To gain insight into fundamentals and applications of electrochemical systems.

COURSE CONTENT

Photochemistry and catalytic reactions: Fundamentals of Photochemistry, Norrish type I and II reactions, photo reduction of ketones, photochemistry of arenes. Pericyclic reactions, Classification, Woodward-Hoffmann rules, and FMO theory. Hydroformylation, Wacker-smidt Synthesis, Eastman-Halcon Carbonylation process, Alkene Metathesis, Pd catalyzed coupling reactions- Heck, Suzuki coupling & Ene Reaction. The Pauson- Khand Reaction

Identification of organic compounds: By using combined Mass, IR and NMR spectral analysis. Index of hydrogen deficiency. Mass spectroscopy: Methods of desorption and ionization (EI, CI, MALDI, ESI), study of fragmentation pattern. Basics of IR spectroscopy, applications. Basic Principles of ^{1}H & ^{13}C NMR, Applications of ^{1}H and ^{13}C NMR (DEPT) to organic chemistry, Case studies and combined problems.

Reaction Kinetics**:** Rate order and molecularity of simple chemical reactions. Consecutive - Parallel and opposing reactions. Chain reactions. Energy of activation - Theories on reaction rates. Catalysis- Homogeneous & heterogeneous catalysis, Langmuir – Hinshelwood mechanism of a bimolecular surface reaction, Elay – Rideal mechanism of a surface reaction, Enzyme catalysis, zeolites as catalysts, Self-assembled monolayers and Langmuir-Blodgett films. Adsorption isotherm: Langmuir and B.E.T adsorption isotherm, Determination of surface area of solids by B.E.T. method.

Phase Equilibria**:** Phase rule: Application - to one components system (water, sulphur and carbondioxide), Two component systems (Eutetic, Intermediate compound formation and solid solutions) and simple three component systems. Solutions: Ideal and non-ideal solutions, solubility of gases in liquids. Henry's law. Completely miscible liquids - Rauolt's law - vapour pressure and boiling point diagrams. Partially miscible liquids - Critical solution temperature - completely immiscible liquids - Nernst: distribution law - Dilute solution and their colligative properties. Molecular weight determination using these properties

Electrical Conductance**:** Debye - Huckell Onsager theory; Ostwald's dilution law - solubility of electrolytes and solubility product – Applications, common ion action - acids, bases - definitions based on proton transference, dissociation constant, amphoteric electrolyte - pH - Buffer solutions. Hydrolysis of salts. Decomposition potential, over voltage, definitions of current density, current efficiency, energy consumption; oxidation - reduction redox couple; e.m.f. and energy relations. Conductometry, Potentiometry, Voltammetry, their applications. Fuel cells.

REFERENCE BOOKS

1. *Morisson and Boyd- A Text book of Organic Chemistry, 7th Edn, Pearson Education Singapore Pte Ltd, 2010*
2. *K. Jagadamba Singh, Jaya Singh, Photochemistry and Pericyclic Reactions, 3rd Edn, NewAge International publications, 2009*
3. *B. R. Puri and SL. R. Sharma, "Principles of Physical Chemistry", Shoban Lal Nagin Chand & Co.*
4. *R. M. Silverstein and F. X. Webster: Spectrometric Identification of Organic Compounds, 7thEdn, 2007*
5. *R.H. Crabtree, The Organometallic Chemistry of Transition Metals, 6 th Edn, Wiley, 2014*
6. *I. L. Finar. Organic Chemistry, Vol 1 &2, 5th Edn, ELBS, London, 1975*
7. *K.J. Laidler, "Chemical Kinetics", 3rd Edn., PHI Publishers,1987.*
8. *Atkins, P and Julio De Paula, 'Physical Chemistry', 9th Edn., W. H. Freeman, 2009.*

COURSE OUTCOMES

At the end of the course, student will be able to

CO1	apply the concepts of photochemistry and catalysts in optimizing the conditions of organic synthesis.
CO2	use advanced spectroscopic tools in characterization of the reaction products to assess purity and yield.
CO3	determine the best reaction conditions to maximize the products by applying the principles of homogeneous and heterogeneous catalysis.
CO4	adopt phase equilibrium principles to achieve fractional distillation, steam distillation and solvent extraction.
CO5	become familiar with the properties of electrolytes and electrodes and their use in electroanalytical techniques and electrochemical power sources.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC12**
Course Title	**:**	**APPLIED ELECTRICAL AND ELECTRONICS ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To provide the key concepts about Transformers, DC and AC motors and thereby able to choose the appropriate drives for various applications.
2. To equip students to understand and apply the basic concepts of Combinational logic circuits and INTEL 8085 Microprocessor.

COURSE CONTENT

DC motors - Characteristics - Starting and speed control – Testing - Applications. Transformers:(Single phase only) - equivalent circuit and regulation - losses and efficiency - Testing.

Three-phase induction motor - Cage and slip ring motors -torque slip characteristics –starting and speed control of induction motors - single phase induction motors and universal motors. Synchronous motors - starting and applications.

Electric drive for general factory, textile mill, cement mill - pump, blowers, hoists, traction etc. - group and individual drives

Combinational logic - representation of logic functions – SOP and POS forms K-map representations – minimization using K maps - simplification and implementation of combinational logic – multiplexers and demultiplexers – code converters, adders, subtractors, memory and its types.

Microprocessor – Architecture of INTEL 8085 – Instruction set – addressing modes - Basic assembly language programming

REFERENCE BOOKS

1. *Mehta V K and Rohit Mehta, 'Principles of Electrical Machines', S Chand and company Ltd., 2006.*
2. *Dubey G K, 'Fundamentals of Electric drives', Narosa book distributors pvt. ltd, 2nd edition, 2012*
3. *Ramesh S. Gaonkar, 'Microprocessor Architecture Programming and Applications with 8085', Penram Intl. Publishing, 6th edition, 2013.*
4. *Morris Mano, Michael D Ciletti, 'Digital Design', Pearson Education, 4th edition, 2008.*
5. *Theraja B L,'A TextBook of Electrical Technology', vol 2,S Chand,23rd edition,2007.*
6. *Vincent Del Toro, 'Electrical Engineering Fundamentals', PHI, 2nd edition, 2009*
7. *Subrahmanyan V, 'Thyristor control of Electric Drives', Tata McGraw Hill, 1st edition.*

COURSE OUTCOMES

Upon completion of the course, the student will be able to

CO1	analyze the performance of DC Motors and Transformers under various operating conditions using their various characteristics models.
CO2	describe different types AC motors and their characteristics.
CO3	select appropriate drive for any industrial application.
CO4	design and analyze combinational logic circuits.
CO5	understand the architecture and instruction set of 8085.

Mapping of Course Outcomes with Programme Outcome

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

Course Code	**:**	**CLPC13**
Course Title	**:**	**INTRODUCTION TO MECHANICAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To understand the basic knowledge of thermodynamic systems used in Chemical Engineering operations.
2. To understand basic working principles of boilers.
3. To understand the Energy conservation opportunities in steam systems

COURSE CONTENT

Laws of Thermodynamics: Thermodynamic systems -closed, open and isolated. Property, state, path and process, quasi-static process, work, Energy. Zeroth, First and Second laws of Thermodynamics (Basic concepts only), Internal energy, Specific heat capacity and Enthalpy.

Thermodynamic Cycles: Air standard Cycles: Carnot, Otto, Diesel and Combined cycle; Brayton and Rankine cycles – determination of cycle efficiency.

Boilers: Types and classification of boilers: water tube, fire tube, coal, oil and gas fired boilers; Stoker fired, pulverized and fluidized bed boilers. Mountings and accessories. Performance and efficiency calculation of boilers.

Properties of Steam: Properties of steam, Mollier chart, determination of dryness fraction of steam- Different types of calorimeters. Concept of Steam distribution systems. steam traps-typesand their characteristics. Energy conservation opportunities in steam systems.

Turbines and Vacuum Systems: Steam turbines- types and principles: Reaction and impulse turbines; Application of co-generation principles in process industries. Gas turbines- principle and working. Production of Vacuum: Systems and Equipment - Vacuum Pumps, Steam Ejectors;Instrumental methods of Vacuum measurement.

REFERENCE BOOKS

1. *Rajput R.K., "Thermal Engineering", 9th Edition, Laxmi Publications, 2010.*
2. *Rudramoorthy R., "Thermal Engineering", 4th Edition, Tata McGraw Hill Publishing Company, New Delhi, 2006.*
3. *Kothandaraman, C.P., "Course in Thermodynamics and Heat Engines: Thermal Engineeringwith Introduction to Solar Energy ", 3rd Edition, Dhanpat Rai Publisher, New Delhi, 1985.*
4. *Ballaney P.L., "Thermal Engineering", Khanna Publishers, New Delhi, 2005.*

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1	understand the conceptual laws of thermodynamics for application in thermodynamic cycles.
CO2	understand and analyze different thermodynamic cycles and calculate their thermal efficiencies.
CO3	understand the basics of boilers and perform simple calculations of boiler efficiencies.
CO4	understand the steam distribution and utilization systems to identify the energy conservation opportunities.
CO5	comprehend principles of steam turbines and calculation of turbine efficiencies; understand the basics of vacuum pumps and instruments for measurement of vacuum.

Mapping of Course Outcomes with Programme Outcome

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

Course Code	**:**	**CLPC14**
Course Title	**:**	**MOMENTUM TRANSFER**
Number of Credits	**:**	**4**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To impart the fundamental concepts of fluid statics, pressure distribution and dimensionalanalysis
2. To nurture the students to solve fluid dynamics problems using Newton's laws of motion.
3. To enable students to compute velocity profile, friction factor and head loss in pipes andfittings
4. To impart the knowledge of metering and transportation of fluids and fluid moving machinery performance

COURSE CONTENT

Properties of fluids and concept of pressure: Introduction - Nature of fluids - physical properties of fluids - types of fluids. Fluid statics: Pressure - density - height relationships. Pressure Measurement. Units and Dimensions - Dimensional analysis. Similarity - forces arising out of physical similarity - dimensionless numbers.

Momentum Balance and their Applications: Kinematics of fluid flow: Stream line -stream tube - velocity potential. Newtonian and non-Newtonian fluids - Time dependent fluids - Reynolds number - experiment and significance - Momentum balance - Forces acting on stream tubes - Potential flow - Bernoulli’s equation - Correction for fluid friction - Correction for pump work.

Flow of Incompressible Fluids Through Ducts: Flow of incompressible fluids in pipes - laminar and turbulent flow through closed conduits - velocity profile & friction factor for smooth and rough pipes - Head loss due to friction in pipes, fitting etc. Introduction to compressible flow. Isentropic flow through convergent and divergent nozzles and sonic velocity

Flow of Fluids through Solids: Form drag - skin drag - Drag co-efficient. Flow around solids andpacked beds. Friction factor for packed beds. Ergun's Equation - Motion of particles through fluids - Motion under gravitational and centrifugal fields - Terminal settling velocity. Fluidisation - Mechanism, types, general properties – applications

Transportation and Metering: Measurement of fluid flow: Orifice meter, venturi meter, pitot tube, rotameter, weirs and notches Wet gas meter and dry gas meter. Hot wire and hot film anemometers. Transportation of fluids: Fluid moving machinery performance. Selection and specification. Air lift and diaphragm pump. Positive displacement pumps: Rotary and Reciprocating pumps. Centrifugal pumps and characteristics.

REFERENCE BOOKS

1) *Noel. D.Nevers, "Fluid Mechanics for Chemical Engineers", McGraw Hill, 3rd International Edition, 2005.*
2) *W. L. McCabe, J.C. Smith and P. Harriott, "Unit operations of Chemical Engineering”, 7th Edn., McGraw Hill, International Edn., 2004.*
3) *J. M. Coulson and J. F. Richardson, "Chemical Engineering", Vol 1, 6th Edn. Butterworth-Heinemann, 1999.*

COURSE OUTCOMES

On completion of the course, the students would have

CO1	the knowledge of fundamental concepts in fluids statics and to use dimensional analysis for scaling experimental results.
CO2	the ability to solve hydrostatic and fluid flow problems using Newton's laws of motion.
CO3	the ability to analyze frictional flow in pipes and piping networks and to computethe head loss and power requirements for chemical process equipments.
CO4	the ability to select the metering equipments and fluid moving machinery for an appropriate chemical engineering operations.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC15**
Course Title	**:**	**PROCESS CALCULATIONS**
Number of Credits	**:**	**4**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To give students fundamental knowledge in Units and conversions and also the basic lawsgoverning chemical operations.
2. To impart knowledgeable on material and energy balance with and without reactions

COURSE CONTENT

Stoichiometry: Introduction - Units and Dimensions - Stoichiometric principles –composition relations, density and specific gravity.

Ideal Gases and Vapor Pressure: Behaviour of Ideal gases - kinetic theory of gases - application of ideal gas law - gaseous mixtures - volume changes with change in composition. Vapour pressure - effect of Temperature on vapour pressure - vapour pressure plots - vapour pressure of immiscible liquids - solutions.

Humidity and Solubility: Humidity - saturation - vaporization - condensation - wet and dry bulb thermometry Solubility and Crystallisation - Dissolution - solubility of gases.

Material Balance: Material Balance - Processes involving chemical reaction - Combustion of coal, fuel gases and sulphur - Recycling operations - bypassing streams - Degree of conversion – excess reactant - limiting reactant. Unsteady state problems

Energy Balance: Thermo chemistry - Hess's law of summation - heat of formation, reaction, combustion and mixing - mean specific heat - Theoretical flame Temperature

REFERENCE BOOKS

1. *O. A .Hougen, K. M. Watson and R. A. Ragatz, "Chemical Process Principles", Vol- I, CBSPublishers and Distributors, New Delhi, 1995.*
2. *V.Venkataramani, N.Anantharaman and K.M. Meera Sheriffa Begum*, *2nd Edn., 'Process Calculations' Prentice Hall of India Ltd, New Delhi. 2013*
3. *B. I. Bhatt, "Stoichiometry", 5th Edn., Tata McGraw Hill Publishers Ltd., New Delhi, 2010.*
4. *Himmelblau, "Basic Principles and Calculations in Chemical Engineering", 8th Edn., Prentice Hall of India Ltd, India 2012.*

COURSE OUTCOMES

At the end of the course, student will have

CO1	the capability to convert units and dimensions and also modify equations from system to another.
CO2	the capability apply the laws of physics and chemistry in solving process industry related applications.
CO3	the proficiency to integrate the data and formulate the mass and energy balance problems.
CO4	the capability to use mathematical knowledge for solving mass and energy balance problems with and without chemical reactions.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC16**
Course Title	**:**	**CHEMICAL TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of chemical technology.
2. To develop understanding about unit process and unit operations in various industries.
3. To learn manufacturing processes of organic and Inorganic Chemicals and its applications and major engineering problems encountered in the process
4. To learn the process flow sheet drawing for the manufacturing chemical processes.

COURSE CONTENT

Natural Products Processing: Production of pulp, paper and rayon, Manufacture of sugar, starch and starch derivatives, Gasification of coal and chemicals from coal.

Industrial Microbial Processes and Edible Oils: Fermentation processes for the production of ethyl alcohol, citric acid and antibiotics, Refining of edible oils and fats, fatty acids, Soaps and detergents.

Alkalies and Acids: Chlor - alkali Industries: Manufacture of Soda ash, Manufacture of caustic soda and chlorine - common salt. Sulphur and Sulphuric acid: Mining of sulphur and manufacture of sulphuric acid. Manufacture of hydrochloric acid.

Cement Gases, Water and Paints: Types and Manufacture of Portland cement, Glass: Industrial gases: Carbon dioxide, Nitrogen, Hydrogen, Oxygen and Acetylene - Manufacture of paints - Pigments

Fertilizers: Nitrogen Fertilizers; Synthetic ammonia, nitric acid, Urea, Phosphorous Fertilizers: Phosphate rock, phosphoric acid, super phosphate and Triple Super phosphate

REFERENCE BOOKS

1. *G.T. Austin, N. Shreve's Chemical Process Industries", 5th Edn., McGraw Hill, New York,1984.*
2. *W.V.Mark, S.C. Bhatia "Chemical Process Industries volume I and II", 2nd Edition 2007*
3. *R. Gopal and M. Sittig " Dryden's Outlines of Chemical Technology: For The 21st Century" Third Edition, Affiliated East-West Publishers, 1997.*
4. *S. D. Shukla and G. N. Pandey, "Text book of Chemical Technology" Vol 2, Vikash Publishing Company, 1984*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	understand the various unit operations and processes with their symbols
CO2	understand the manufacturing process of natural products processing and industrial Microbial Processes and Edible Oils.
CO3	understand the various chemical reactions involved in the process
CO4	understand the manufacturing process of inorganic chemicals
CO5	draw the process Flowsheet and understand the major engineering problems encountered in the processes.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC17**
Course Title	**:**	**CHEMICAL ENGINEERING THERMODYNAMICS**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC15**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

To understand and appreciate thermodynamics as applied to various Chemical Engineering Processes.

COURSE CONTENT

Introduction to Basic laws and Terminologies in Thermodynamics- Statement of First law, P-V- T behavior of pure fluids - Heat effects accompanying chemical Reactions - Statements of second law- Clausius Inequality-Mathematical Statement of Second law-Third Law of Thermodynamics.

Applications to Laws of Thermodynamics - Flow processes: Flow in pipes, Flow through nozzles, Compression- Refrigeration

Thermodynamic Properties of Pure Fluids- Classification of Thermodynamic properties -Work function and Gibb's Free energy-Fundamental Property relations-Maxwell's equations-Clapyeron equation- Entropy Heat capacity relationship-Differential equations of Entropy-Relationship between Cp and Cv-Effect of pressure and volume on Cp and Cv- Gibb's Helmholtz Equation-Properties of Jacobians-Thermodynamic Relations through method of jacobians

Thermodynamic Properties of Solutions - Introduction to fugacity and activity, Activity coefficients-Partial molar properties-Chemical potential as a partial molar property-Lewis randall rule-Roults and henry's law-Gibbs Duhem Equation

Phase Equilibria and Chemical Reaction Equilibria - Criteria for phase equilibrium, Criterion of stability, Phase equilibria in single and multiple component systems, Duhem's theorem, VLE for Ideal solutions, Calculation of activity coefficients- Reaction stoichiometry-Equilibrium constant- Feasibility of reaction- Effect of temperature, pressure, volume and other factors-Simultaneous Reactions

REFERENCE BOOKS

1. *J.M. Smith, Hendrick Van Ness, Michael M. Abbott, Introduction to Engineering Thermodynamics, McGraw Hill, New York, 2005.*
2. *S. Sundaram, Chemical Engineering Thermodynamics, Ahuja Publishers, New Delhi, 2001*
3. *K.V.Narayanan, A Textbook of Chemical Engineering Thermodynamics, PHI Learning, 2004.*
4. *B.F. Dodge, Chemical Engineering Thermodynamics, McGraw Hill, New York, 1971.*

COURSE OUTCOMES

On completion of the course, the students will be familiar with

CO1	fundamentals of thermodynamics as applied to various processes
CO2	properties as applied to ideal and real gases
CO3	determination of equilibrium states for mixture of gases, phases and chemical reaction

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC18**
Course Title	**:**	**PARTICULATE SCIENCE AND TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. Understand many basic principles in various Chemical Engineering operations such as Size Reduction, Filtration, Sedimentation, Mixing and Agitation etc. and their mathematical relationships
2. Understand basic principles of particle preparation and their characterization
3. Study various methods for storage of solids and conveyors available for their transportation
4. Understand the performance of different equipments for separation of solids and size reduction

COURSE CONTENT

Characteristics of Particulate Material: Properties and characterization of particulate solids, analysis and technical methods for size and surface area distribution of powder; Flow properties of particulates.

Synthesis Methods: Introduction to synthesis of composite material by spray technique, aerosol generation, Introduction to size reduction equipment, energy and power requirement in milling operations, computer simulation techniques for mill performance.

Particulate Processes: Gas-liquid separation methods, Classification by size, agitation of liquids and mixing of solids, Fluidization, encapsulation etc., process performance simulations

Handling of Particulate Material: Conveying methods, Storage methods and design of silo, selection of feeders and elevators

REFERENCE BOOKS

1. *McCabe and J.C.Smith," Unit Operation of Chemical Engineering", 7thEdn., McGraw Hill., New York, 2004.*
2. *M. Coulson and J.F .Richardson, "Chemical Engineering", Vol.II, 5thEdn., Butterworth - Heinemann, 2002*
3. *Raymond A. Kulweic, "Materials Handling Handbook", 2ndEdn, Wiley- Interscience Publications, 1985.*
4. *Badger and Banchero, "Introduction to Chemical Engineering", 1stEdn., McGraw Hill, New York, 1955.*

COURSE OUTCOMES

On completion of the course

CO1	students are expected to understand the basic principles of particles preparation and their characterization.
CO2	students are expected to have an understanding of solid storage and their conveying in chemical process industries.
CO3	students are expected to have an understanding of design of sedimentation tanks andother solid fluid separation equipment.
CO4	students are expected to have knowledge about different size reducing equipment and power requirements during size reduction.
CO5	students should have an ability to design chemical engineering processes while including economic safety, environment and ethical consideration.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR11**
Course Title	**:**	**MOMENTUM TRANSFER LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC14**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

Understand and application of the principles & concepts of learned in momentum transfer theorycourse

List of Experiments

1. Flow Through Straight Pipe
2. Flow Through Pipe Fittings
3. Flow Through Helical Coil
4. Flow Through Spiral Coil
5. Flow Through Packed Bed
6. Flow Through Fluidized Bed
7. Flow Through Flow Meters (Orifice & Venturi)
8. Centrifugal Pump
9. Flow of Non-Newtonian Fluid

REFERENCE BOOKS

1. Lab Manual
2. *W. L. McCabe, J.C. Smith and P. Harriott, "Unit operations of Chemical Engineering", 7thEdn., McGraw Hill, International Edn.., 2005.*

COURSE OUTCOMES

After completion of the course, students are able to

CO1	understand and analyze the laminar and turbulent flow
CO2	understand, apply and analyze the friction factor
CO3	understand the flow regime and pump performance

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC19**
Course Title	**:**	**CHEMICAL REACTION ENGINEERING – I**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC17**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. Introduce basic concepts of chemical kinetics like homogeneous and heterogeneous reactions, rate of reaction, order and molecularity of reaction, concentration and temperature dependency of rate of reaction
2. Build up the concepts to analyze kinetic data and determine the rate expression for a reaction
3. This course will guide students to make use of key concepts and techniques of chemicalkinetics to design single reactor and multiple reactors
4. Analyze multiple reactions to determine selectivity and yield
5. Work together in same-discipline teams to solve engineering problems

COURSE CONTENT

Basics of Kinetics: Introduction - kinetics of homogeneous reactions: Concentration dependent& Temperature dependent term of rate equation, Searching for a mechanism. Interpretation of Batch Reactor data

Reactor Design: Introduction to Reactor Design. Single Ideal Reactors.

Design of Reactor for Multiple Reaction: Design for single and multiple Reactions. Size comparison of single reactors for single reactions. Multiple Reactor system for single reactions. Reactions in parallel, reactions in series and series - parallel reactions of first order. Recycle reactor, auto catalytic reactions.

Heat Effects: Temperature and pressure effects on single and multiple reactions.

Flow Behaviour of Reactors: Non - ideal flow: Residence time distribution studies: C, E, F and I curves, conversion calculations directly from tracer studies. Models for non-ideal flow - dispersion and tanks in series multi-parameter models

REFERENCE BOOKS

1. *O. Levenspiel, "Chemical Reaction Engineering", 3rd Edn., Wiley Easter Ltd., New York,1999.*
2. *K. A. Gavhane Chemical Reaction Engineering -I, Nirali Prakashan Publications, Pune, 2013*
3. *J.M. Smith, "Chemical Engineering Kinetics", 3rd Edn., McGraw Hill, New York, 1981.*
4. *Fogler.H.S., "Elements of Chemical Reaction Engineering", Prentice Hall of India Ltd., III rd Edition, 2000*

COURSE OUTCOMES

On completion of the course, the student

CO1	will understand the classification of chemical reactions, factors affecting the rate of reaction, and the effect of temperature on rate of reaction.
CO2	will gain the knowledge on Analyzing the laboratory data for determining the order of reaction and reaction rate constant Ability to relate rate of reaction with design equation for reactor sizing.

CO3	familiar with the comparisons of ideal reactor types (batch, plug flow, mixed flow, etc.) and select the most suitable one. Also familiar with the determining optimal ideal reactor design for multiple reactions for particular yield or selectivity.
CO4	will have knowledge on non-ideal reactors and troubleshooting the existing non-ideal reactors to improve its performance.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC20**
Course Title	**:**	**MASS TRANSFER**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC15**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To learn the concept of diffusion in gas, liquid & solid.
2. To understand the basics of interphase mass transfer.
3. To learn application of gas-liquid operation and simultaneous heat and mass transfer operations.

COURSE CONTENT

Definition, Ficks law, Molecular and eddy diffusion, Diffusion in gaseous mixtures, liquid mixtures and solids, Types of solid diffusion, Pseudo steady state diffusion, measurement and calculation of diffusivities. Ordinary diffusion in multicomponent gaseous mixtures. Unsteady state Diffusion.

Equilibria, Mass transfer coefficients - Individual and overall with relations, Theories of mass transfer, Analogies between momentum, heat and mass transfer to predict mass transfer coefficients.

Absorption – Solubility, theory of gas absorption, Design of absorption towers, Concept of Equilibrium and operating lines. Mass Transfer Equipments- Batch and continuous Stage wise contactors and Differential contactors, Concept of HTU and NTU, Tower packings and packing characteristics, Non-isothermal absorbers, Case studies in absorption with chemical reactions.

Humidification Theory, Psychometric Chart, Adiabatic Saturator, Wet Bulb Theory, Methods of Humidification and dehumidification, Cooling tower theory, Design of cooling towers, Industrial cooling towers, Air conditioning process, Recirculating water gas humidification system.

Drying Theory and Mechanism, Drying Characteristics, Estimation of Drying time, drying rate curve, Classification of Driers, Through circulation driers design, Design of driers, Description and Application of Driers, Analysis of continuous driers.

Crystallization Theory, Solubility curve, Types of crystals, Principles of Crystallization, Supersaturation Theory, Factors governing nucleation and crystal growth. Theory of crystallization, Classification of crystallizers and their applications. Product size distribution by MSMPR model. Industrial crystallizers, Crystallizer Design.

REFERENCE BOOKS

1. *R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York, 1981.*
2. *N. Anantharaman and K.M.Meera Sheriffa Begum, "Mass Transfer Theory and Practice", Printice Hall of India Pvt. Ltd., New Delhi, 2013.*
3. *A.S.Foust, "Principles of Unit Operations", 2nd Edition, Wiley & Sons, New York, 1980.*
4. *J. M. Coulson and J. F. Richardson, "Chemical Engineering", 5th Edition Vol. II, P Butterworth Heinemann, New, 2002.*
5. *C.J.Geankoplis, "Transport Processes and Separation Process Principles," IV edition, Prentice Hall of India Pvt. Ltd, New Delhi, 2004.*
6. *W.L. McCabe, J.C. Smith and P. Harriot, "Unit Operations of Chemical Engineering", 7th Edn., McGraw Hill Book Co., New York, 2004.*

COURSE OUTCOMES

On completion of the course, the student

CO1	will be familiar with the basic phenomenon of mass transfer involving phases.
CO2	will be able to apply the mathematical and design concepts of mass transfer in gas-liquid systems like absorption, humidification, drying and crystallization.
CO3	will be gaining good knowledge of required optimum condition for a gas-liquid system

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC21**
Course Title	**:**	**HEAT TRANSFER**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To study the fundamental concepts of heat transfer viz., conduction, convection, radiation,boiling and condensation.
2. To use these fundamentals in typical engineering applications (Heat exchanger and Evaporator) and current research.

COURSE CONTENT

Basic modes of heat transfer and the laws governing them. Steady state conduction through plane and composite walls general heat conduction equation, concepts of thermal diffusivity and equivalent thermal conductivity. Radial Heat conduction through thick cylindrical and spherical vessels, Transient heat conduction.

Convection – Dimensional analysis and empirical correlations, critical insulation thickness for cylindrical and spherical surfaces, Hydrodynamic and thermal Boundary layers, physical significance of the dimensionless groups.

Thermal Radiation laws, spectrum of electromagnetic radiation, Black and Gray bodies, and configuration factor – typical examples. Boiling and condensation.

Heat Exchangers – classification and design, overall and individual film coefficients, mean temperature difference, LMTD correction factor for multiple pass exchanger, NTU and efficiency of Heat exchangers, use of efficiency charts.

Evaporation, single and multiple effect operation, material and Energy balance in evaporators, boiling point elevation, Duhring's rule, effect of liquid head, illustrative examples.

REFERENCE BOOKS

1. *W. L. McCabe and J. C. Smith, "Unit Operations In Chemical Engineering", 7th Edn.,McGraw Hill Publishing Co., 2004.*
2. *Binay K. Dutta, "Heat Transfer Principles and applications" Prentice Hall of India Pvt. Ltd., 2003*
3. *S. Foust, L. A. Wenzel, C. W. Clump, Louis maus and L. B. Anderson Principles of UnitOperations" John Wily, New York.*
4. *D.Q. Kern," Process Heat Transfer," McGraw Hill Publishing*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to estimate steady state and transient heat transfer rates from/to object such astanks, pipes, building etc.
CO2	able to develop equations for different types of convection and solve for heat transfer rate by convection.
CO3	able to estimate the rate of radiation heat transfer with and without participating medium. Ability to identify the roll of re-radiating surface, radiation shields, boiling and condensation.
CO4	able to carry out thermal analysis of heat exchanger using LMTD and effectiveness method.
CO5	able to estimate steam economy, capacity of single and multiple effect evaporators.
CO6	able to use the fundamentals learnt to understand the current research in heattransfer.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC22**
Course Title	**:**	**SAFETY IN CHEMICAL INDUSTRIES**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC16**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To provide a general idea about safety in chemical industries.
2. To imbibe in students a culture of safer practices.

COURSE CONTENT

Introduction: Role of chemical engineer in process industries; Industrial Hazards –.Fire hazards and it's prevention, Radiation hazards and control of exposure to radiation, Mechanical hazards, Electrical hazards, Construction hazards.

Psychology, hygiene & other industrial hazards: Industrial psychology, Industrial hygiene, Housekeeping, Industrial lighting and ventilation, Industrial noise, Occupational diseases and prevention methods, Personal protective equipments; Site selection and plant layout,

Instrumentation and control for safe operation: Pressure, Temperature and Level controllers; Risk Management and Hazard Analysis – Steps in risk management, Risk analysis using HAZOP, FTA etc.

Case studies pertaining to chemical industries: Bhopal gas tragedy, causes, affects & lessons learnt, other cases; Economics of safety – Financial costs to individual, family, organization and society.

Legal framework for safety and environment: The Factories Act, The Environmental (Protection)Act, The Workmen's compensation Act, The Employee State Insurance Act.

REFERENCE BOOKS

1. *Sam Mannan, Frank P. Lees, "Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control", 4th Edition, Butterworth-Heinemann, 2005.*
2. *H.H. Fawcett and W. S .Wood, "Safety and Accident Prevention in Chemical Operation", 2nd Ed, Wiley Interscience, 1982.*
3. *Guide for Safety in the Chemical laboratory Second edition 1977, Manufacturing ChemistsAssociation. Van Nostrand Reinhold Company, New York.*
4. *Industrial Safety and Laws, 1993, by Indian School of Labour Education, Madras.*
5. *Daniel A. Crowl and Joseph F. Louvar, "Chemical Process Safety, Fundamentals withApplications", 2nd Edition, Prentice Hall, Inc. ISBN 0-13-018176-5.*

COURSE OUTCOMES

On completion of the course, the students are expected to be with familiar with

CO1	hazards in chemical industries and their mitigation
CO2	safety aspects in plan site selection, design & layout and psychological approach to process safety
CO3	occupational diseases and their prevention, process control for process safety
CO4	case studies of industrial disasters and risk management methodologies
CO5	legislations for safety in chemical industries & environmental protection, economics of providing safety

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR12**
Course Title	**:**	**INSTRUMENTAL ANALYSIS AND THERMODYNAMICS LAB.**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC17**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

1. To provide hands on training to the students to familiarize various analytical instruments for theanalysis of Chemicals (Bleaching powder, Coal, Cement and water)
2. To provide practical experience on the principles, viz., thermodynamic laws, Solution thermodynamics, Phase equilibrium and reaction equilibrium.

LIST OF EXPERIMENTS

1. Estimation of Bleaching Powder
2. Proximate analysis of Coal
3. Analysis of Water (pH, turbidity, conductivity, resistivity, Suspended particles)
4. Estimation of Salinity of Water
5. Analysis of Cement
6. Heat of Solution by Solubility Method
7. Equilibrium Constant Determination
8. Liquid – Liquid Equilibrium
9. Excess Property Determination
10. Vapour Compression Refrigeration
11. VLE using Othmer Still

REFERENCE BOOKS

1. *J. M. Smith, H.C. Van Ness and and M. M. Abbot, "Introduction to Engineering Thermodynamics", McGraw Hill, New York, 7th Edition, 2004*
2. *K.V. Narayanan, "A Text Book of Chemical Engineering Thermodynamics," Second secondEdition, Prentice Hall of India, 2013.*
3. *Laboratory Manual*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	able to calibrate and perform analysis the chemicals using instruments
CO2	able to verify the fundamentals learnt viz., application of thermodynamic laws, solution thermodynamics, phase equilibrium and reaction equilibrium in Chemical Engineering thermodynamics by conducting experiments and carry out theevaluation

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR13**
Course Title	**:**	**PARTICULATE SCIENCE AND TECHNOLOGY LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC18**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

To gain knowledge through conducting experiments on characterization of single particle and powder samples, particulate process such as comminution, Screen Analysis, filtration, mixing, sedimentation and Elutriation.

LIST OF EXPERIMENTS

1. Particle Size Characterization Image Analysis
   Settling Velocity Particle Density
   Bulk Density (Tap Density, Repose Density)Angle of Repose
2. Screen Analysis
   Evaluation of Effectiveness of a screen
3. Comminution
   Influence of Flight on comminution in a Ball Mill Evaluation of Energy Requirement in Jaw Crusher
4. Filtration
   Evaluation of Characteristics for cake and filter medium
5. Mixing
   Evaluation of Mixing Characteristics and influence of Baffles
6. Sedimentation
   Evaluation of effect of inclination on sedimentation of suspension
7. Elutriation
   Evaluation of elutriation parameters

REFERENCE BOOKS

1. *Martin Rhodes [2001], "Introduction to Particle Technology" 2ndEdn. Elsevier Publicaitons*
2. *Lab manual*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	able to verify the fundamental concepts underlying the behavior of particulate materials

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC23**
Course Title	**:**	**CHEMICAL REACTION ENGINEERING - II**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC19**
Course Type	**:**	**PC**

COURSE OBJECTIVES

1. To derive the reaction mechanisms, rate expressions and reactor design for the heterogeneous catalytic, non-catalytic reaction and fluid-fluid reaction
2. To understand the preparation, properties of the catalyst and catalyst deactivation
3. To understand the importance of both external and internal mass transfer effects in heterogeneous catalytic reaction systems

CONTENT

Modes of contacting different phases: Self mixing of single fluids, mixing of two miscible fluids, Introduction. Design for heterogeneous reacting systems.

Design of reactor for non-catalytic reactions: Fluid-particle systems: Models for non-catalytic heterogeneous reactions, their limitations, selection and their applications to design.

Design of Slurry Reactor: Fluid- Fluid Reactions: Rate equations for instantaneous, fast, intermediate, slow, and infinitely slow reactions. Slurry reaction kinetics. Application to design.

Characterisation of catalyst: Catalysis: Introduction. Physical and chemical adsorption catalysts. Preparation and properties. Promoters. Inhibitors. Poisons. Surface area by BET method. Pore size distribution, Catalysts deactivation.

Kinetics of heterogeneous chemical reaction: Kinetics and mechanism of heterogeneous catalytic reactions. Various models. Evaluation and elimination of internal and external diffusional resistances, effectiveness factor. Solid catalysed reactions, heat effects, controlling resistances, rates of chemisorption, adsorption isotherms, rates of adsorption and desorption.

REFERENCE BOOKS

1. O. Levenspiel, "Chemical Reaction Engineering", 3rdEdn., Wiley Eastern, New York, 1999.
2. J .M. Smith, “Chemical Kinetics", 3rdEdn., McGraw Hill,New York, 1981.
3. H. Scott Fogler, “Elements of Chemical Reaction Engineering”,4thEdn., Prentice Hall of India Ltd.,2008.

COURSE OUTCOMES

On completion of the course, the student can

CO1	classify the heterogeneous reactions kinetics, reactor design and determine the catalyst properties such as surface area and pore volume distribution.
CO2	analyze and interpret kinetic data to determine the rate controlling step and design a reactor for various heterogeneous catalytic, non-catalytic reaction and fluid-fluid reaction.
CO3	design a suitable reactor for a given chemical engineering process.

Mapping of Course outcomes with Program outcomes

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

Course Code	**:**	**CLPC24**
Course Title	**:**	**EQUILIBRIUM STAGED OPERATIONS**
Number of Credits	**:**	**4**
Prerequisites	**:**	**CLPC20**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To impart the basic concept of conventional mass transfer operations.
2. To learn the equilibrium characteristics of two phase mass transfer processes.
3. To understand the hydrodynamics and modes of operations in mass transfer equipment.
4. To develop the skill in the design and analysis of mass transfer equipment in process industries.

COURSE CONTENT

Distillation-Principle, theory, Vapor- Liquid Equilibria calculations- Effect of Pressure and temperature on VLE- Methods of distillations- flash, steam, simple, vacuum, molecular distillations- Azeotropic and Extractive distillation - Design of single stage flash , simple and steam distillation columns. Multicomponent Flash distillation.

Design of Distillation -Stage-wise and continuous Differential contact operations- Design calculations using Ponchon-Savarit and Mc-Cabe Thiele Methods- Separation efficiency- Murphree Plate Efficiency, Point and overall efficiency interrelations- Reboilers and condensers- Open steam Distillation – Design of Packed bed distillation towers-HTU and NTU calculations. Case Study: Multicomponent distillation of Petroleum crude and design of distillation tower.

Extraction- Theory, LLE for different systems, Effect of Pressure and Temperature on LLE- Solubility criteria- Design of Batch and continuous extraction towers for miscible and immiscible systems. Case Study- Extractors with reflux.

Leaching-Theory, Mechanism, Types of leaching, Solid - Liquid equilibria- Design of Batch and continuous extractors- Equipments and industrial applications.

Adsorption-Types of adsorption, nature of adsorbents-Adsorption hysteresis- Adsorption isotherms- Operation of adsorption columns- Design of Batch and continuous adsorbers- Mechanism of Break Through plot and its effect. Case study: Application of adsorbers in sugar industry.

REFERENCE BOOKS

1. *R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York,1981.*
2. *N. Anantharaman and K.M.Meera Sheriffa Begum, "Mass Transfer Theory and Practice",Printice Hall of India Pvt. Ltd., New Delhi, 2013.*
3. *A.S. Foust, "Principles of Unit Operations",2nd Edn., Wiley & Sons, New York, 1980.*
4. *M. Coulson and J. F. Richardson, "Chemical Engineering.", Vol - II, 5th Edn., Pergamon Press, New York, 2002.*
5. *C. J. Geankopolis, "Transport Processes in Chemical Operations", 4th Edn., Prentice Hall ofIndia, New Delhi, 2004.*
6. *W. L. Mccabe, J. C. Smith and P. Harriot, "Unit Operations in Chemical Engg.",7th Edn., McGraw Hill Book Co., New York, 2004.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	acquire sufficient knowledge in the concepts of mass transfer operations in Chemical Process industries.
CO2	able to analyze the two phase mass transfer processes and apply in Process industries.
CO3	able to develop equilibrium characteristics for the design of transfer operations.
CO4	able to apply mathematical skills in the design of equipments for the separation of components in Chemical engineering Practice.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC25**
Course Title	**:**	**PROCESS DYNAMICS AND CONTROL**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLIR10**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To introduce students to the terminology, concepts and practices of input/output modelingand automatic process control.
2. To impart knowledgeable in the design of control systems and controller tuning for chemical processes.

COURSE CONTENT

Introduction - Control system, components of a feedback control system, Lags in the control system – transfer lag, transportation lag, pneumatic PID controller, control valve – valve characteristics.

Laplace transforms - properties of Laplace transform, solution of linear differential equations using Laplace transform techniques, piecewise continuous functions

Dynamic behaviour of systems - derivation of transfer functions for first and second order systems, liquid level, temperature, pressure, flow and concentration control processes, linearization of nonlinear systems, interacting and non-interacting systems.

Transient response of first and second order systems, natural frequency, damping factor, overshoot, decay ratio, rise time and settling time.

Transient analysis of control systems - block diagram algebra, overall transfer function of closed loop control systems, regulator and servo problems, transient response of first and second order systems with P, PI and PID controller.

Definition of stability of control systems, Routh test, limitations of Routh test, Pade's approximation of time delay systems.

Introduction to frequency response - Bode diagrams, Bode diagrams for first and second order systems, P, PI, PID controllers, transportation lag. Bode stability criteria, phase margin and gain margin, Nichols chart, Ziegler - Nichols Optimum controller settings. Nyquist stability criteria, calculation of phase margin, gain margin, peak gain and resonant frequency using Nyquist plot.

REFERENCE BOOKS

1. *D.R. Coughanowr and S. E. LeBlanc, 'Process Systems Analysis and Control', Mc.GrawHill, III Edition, 2009.*
2. *D. E. Seborg, T. F. Edger, D. A. Millichamp and F.J. Doyle III, 'Process Dynamics andControl', Wiley, III Edition, 2013.*
3. *C.A.Smith and A.B.Corripio, 'Principle and Practice of Automatic Process Control', John Wiley and Sons, 1985.*
4. *W.L.Luyben, 'Process Modelling Simulation and Control for Chemical Engineers', McGrawHill, II Edition, 1990.*
5. *G. Stephanopoulous, 'Chemical Process Control – Theory and Practice', Prentice Hall*

ofIndia Ltd.,1984

COURSE OUTCOMES

On completion of the course, the student can

CO1	construct a model of the chemical processes and other elements used in feedback control systems from first principles leading to the development of transfer function models
CO2	compute the response of the developed transfer function for various forcing functions providing an understanding of the transient response of the system
CO3	derive transfer function models of controllers and compute the transient response under closed loop conditions.
CO4	evaluate the stability of the control system given a mathematical model of a control system including its components.
CO5	design a control system for robust performance using frequency response methods.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR14**
Course Title	**:**	**HEAT TRANSFER LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC21**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

To provide experience on testing, and analysis of heat transfer concepts and heat transfer equipment

LIST OF EXPERIMENTS

1. Natural convection
2. Agitated vessel with cooling coil
3. Jacketed agitated vessel
4. Temperature profile
5. Radiator
6. Forced convection
7. Emissivity apparatus
8. Transient heat conduction
9. Vertical condenser
10. Horizontal condenser
11. Pin fin apparatus
12. Stefan Boltzmann constant

REFERENCE BOOKS

1. Heat transfer laboratory manual

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to verify the basis learnt in theory and also to evaluate the performance of heat transfer equipment.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR15**
Course Title	**:**	**CHEMICAL REACTION ENGINEERING LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC19**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

To provide experience on experimentally finding activation energy and kinetics of particular chemical reaction, evaluation of performance of single and multiples reactors and evaluationof performance of non-ideal reactors

LIST OF EXPERIMENTS

1. Adiabatic Reactor
2. Batch reactor –I
3. Batch reactor –II
4. Mixed Flow Reactor
5. Mixed Flow Reactor in series
6. Plug Flow Reactor
7. Mixed Flow Reactor followed by Plug Flow Reactor
8. RTD studies in Mixed Flow Reactor
9. RTD studies in Plug Flow Reactor

REFERENCE BOOKS

1. *O. Levenspiel, "Chemical Reaction Engineering", 3rd Edn., Wiley Easter Ltd., New York,1999.*
2. *K. A. Gavhane Chemical Reaction Engineering -I, Nirali Prakashan Publications,Pune, 2013*
3. *Chemical reaction engineering laboratory manual.*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	able to verify the basis learnt in theory on finding activation energy and finding kinetics of particular chemical reaction, evaluation of performance of single and multiples reactors and evaluation of performance of non-ideal reactors

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC26**
Course Title	**:**	**BIOCHEMICAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC19**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of biochemical engineering
2. To develop understanding about biochemistry and bioprocesses

COURSE CONTENT

Introduction to Bioscience: Types of Microorganisms: Structure and function of microbial cells. Fundamentals of microbial growth, batch and continuous culture. Isolation and purification of Enzymes from cells. Cell Growth Measurement.

Functioning of Cells and Fundamental Molecular Biology: Metabolism and bio-energetics, Photosynthesis, carbon metabolism, EMP pathway, tricarbocyclic cycle and electron transport chain, aerobic and anaerobic metabolic pathways. Synthesis and regulation of biomolecules, fundamentals of microbial genetics, role of RNA and DNA.

Enzyme kinetics: Simple enzyme kinetics, Enzyme reactor with simple kinetics. Inhibition of enzyme reactions. Other influences on enzyme activity. Immobilization of enzymes. Effect of mass transfer in immobilised enzyme particle systems. Industrial applications of enzymes.

Cell kinetics and fermenter design: Growth cycle for batch cultivation, Stirred-tank fermenter, Multiple fermenters connected in series. Cell recycling. Structured Model.

Introduction to Bioreactor design: Continuously Stirred aerated tank bioreactors. Mixing power correlation. Determination of volumetric mass transfer rate of oxygen from air bubbles and effectof mechanical mixing and aeration on oxygen transfer rate, heat transfer and power consumption. Multiphase bioreactors and their applications. Downstream processing and product recovery in bioprocesses.

REFERENCE BOOKS

1. *J. E. Bailey and D. F. Ollis. " Biochemical Engineering Fundamentals", 2nd Edn., McGraw Hill, New York , 1986.*
2. *Trevan, Boffey, Goulding and Stanbury," Biotechnology", Tata McGraw Hill Publishing Co., New Delhi, 1987.*
3. H. W. Blanch and D. S. Clark, "*Biochemical Engineering*", Marcel Dekker, Inc., New York, 1996.
4. *M. L. Shuler and F. Kargi, "Bio Process Engineering: Basic concepts", 2ndEdn., Prentice Hall of India, New Delhi, 2002.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	enhance his knowledge in the aspects of cell structure and its functions
CO2	identify the importance of biomolecules in metabolic processes.
CO3	analyze the kinetics of enzymatic reactions and their inhibitions.
CO4	evaluate and model the cell growth kinetics in a bioreactor.
CO5	design a bioprocess with various unit operations involved in it.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC27**
Course Title	**:**	**CHEMICAL PROCESS EQUIPMENT DESIGN**
Number of Credits	:	**4**
Prerequisites	**:**	**CLPC10, CLPC19, CLPC20, CLPC21**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To apply the basic principles/concepts learned in the subjects of Fluid Mechanics, Heat Transfer, Mass Transfer, and Mechanical Operation in the design of chemical process equipment.
2. To develop the skill to select and design the appropriate process equipment for the required unit or process operation.
3. To analyses and evaluate the performance of existing equipment.

COURSE CONTENT

Design of Pressure Vessels: Design of vessels and its components under internal pressure, external pressure and combined loadings, design of heads/closures, design of supports and designof high pressure vessels.

Design of Storage tanks, Agitated vessels and Reaction vessels.

Design of Phase Separation Equipment - Design of physical separation equipments.

Design of Heat Transfer Equipments - Design of Heat Transfer Equipments such as heat exchangers without and with phase change.

Design of Mass Transfer Equipments: Design of mass transfer equipments such as distillation columns, absorption columns, extraction columns.

Design of Simultaneous Heat & Mass Transfer Equipments: Design of dryers and cooling towers.

REFERENCE BOOKS

1. *R. H. Perry, "Chemical Engineers' Handbook", 7th Edn., McGraw Hill , NewYork, 1998.*
2. *R. K. Sinnott, "Chemical Engineering Design", Coulson and Richardson's Chemical Engineering Series, Volume-6, Fourth Edition, Butterwoth-Heinemann, Elsevier, New Delhi, 2005.*
3. *L. E. Brownell and E.H. Young, "Process Equipment Design - Vessel Design", Wiley EasternEdn. New York, 1968.*
4. *B.C. Bhattacharyya, "Introduction to Chemical Equipment Design Mechanical Aspects", CBS Publishers & Distributors, NewDelhi.*
5. *D.Q.Kern "Process Heat Transfer", Tata McGraw Hill Edn., 2004.*
6. *V. V.Mahajani and S. B. Umarjii, "Joshi's Process Equipment Design", 4th Edn., Mac Millan Publishers India Limited, New Delhi, 2009.*

COURSE OUTCOMES

On completion of the course, student can

CO1	perform the mechanical design of vessel and its auxiliaries
CO2	integrate the knowledge acquired from core chemical engineering subjects for design of chemical process equipment (pressure vessels, storage tanks, reactor vessels, phase separation equipment)
CO3	identify the process equipment problems and provide suitable alternate solutions

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPC28**
Course Title	**:**	**PROJECT ENGINEERING AND ECONOMICS**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC16**
Course Type	**:**	**PC**

COURSE LEARNING OBJECTIVES

1. To provide basic knowledge on chemical engineering research.
2. To enable the students to gain experience in organization and implementation of a small project and thus acquire the necessary confidence to carry out the main project in the final year.
3. To gain knowledge on cost analysis when it comes to start up a new industry after undergoing all major subjects of chemical engineering.
4. To make the students understand all the facility required for starting up a new industry apartfrom various unit operation/mass/heat transfer equipments.
5. To make the students gain all the knowledge in terms of financial analysis for starting up a new chemical industry.
6. To give a clear linkage between technical knowledge and commercial aspects of the major chemical engineering unit operations and design.

COURSE CONTENT

Plant location and site selection, CCOE Clearance, MoEF Clearance, plant layout, factors affecting plant location, project planning and scheduling of projects, project financing, Flow sheeting, Selection of Process Equipment. Process utilities, process water, boiler feed water, steam distribution including appropriate mechanical valves and instrumentation, process pumps, compressors, Refrigeration plant.

Piping design and piping, Connecting pipes to process equipment, layout, Support for piping insulation, plant constructions, star-up and commissioning.

Value of money, Equations for economic studies and equivalence. Amortization, Capital recovery and Depreciation. Project implementation steps, Feasibility studies, Capital requirements for process plants, Cost indices, Equipment cost, Service facilities.

Balance sheet, Variable cost, Fixed cost, Income statement, Economic production charts. Capacity factors, Taxes and Insurance, Cash flow analysis.

Economics of Selecting Alternates: Annual cost method, Present worth method, Equivalent alternates, Rate of return and Payout time. Overall Cost Analysis and Economic Trade Offs: Economic balance: Economic balance in batch operations, Overall cost analysis for the plant, Economic tradeoffs.

REFERENCE BOOKS

1. *J.M. Coulson, JF Richardson, RK Sinnott Butterworth Heinman, Chemical Engineering Volume 6, Revised Second Edition, Butterworth-Heinemann, 1996.*
2. *H. E. Schweyer, "Process Engineering Economics", McGraw Hill Book Co., N.Y.*
3. *Rase and Barrow, Project Engineering of Process Plants, John Wiley.1964.*
4. *M. S. Peters & K. D. Timmerhaus, 'Plant design & Economics for Chemical Engg.' McGraw-Hill Science/Engineering/Math 5th Ed., 2002.*
5. *Industrial Boilers, and Heat recovery Steam Generators Design, Applications and*

calculations by V.ganapathy, Marcel Dekker, Inc, 2003.
6. *F. C. Jelen, "Cost and Optimization Engineering", McGraw Hill Book Co., New York, 1970.*
7. *Robin Smith, "Chemical Process Design", McGraw Hill Book Co., New York, 1995.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	understand how a project has to be started, their pre-requirements, flow chart preparation, economic calculation and so on.
CO2	work out the balance sheet and Income statement for a particular concern.
CO3	gain a good knowledge on when to run an industry in a profitable or without loss/gain of a particular concern.
CO4	choose between the equipment/instruments of the same function based on both technical and commercial point of view.
CO5	draw a complete flowchart of a plant with complete cost analysis.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	:	**CLPC29**
Course Title	:	**TRANSPORT PHENOMENA**
Number of Credits	:	**3**
Prerequisites	:	**CLPC14, CLPC20, CLPC21**
Course Type	:	**PC**

COURSE LEARNING OBJECTIVES

1. To find the velocity distribution in laminar and turbulent flow of Newtonian and non-Newtonian fluid
2. To obtain the temperature and concentration profiles in solids and in fluids respectively.

COURSE CONTENT

Laminar Flow: Velocity distribution in Laminar flow - Shell momentum balances - Flow through tubes, surfaces. Flow of non - Newtonian fluids

Equation of Motion: Equation of change for isothermal process – One dimensional equation of motion and continuity - Euler and Navier – Stokes equation. Dimensional analysis of equation ofchange

Turbulent Flow: Velocity distribution in turbulent flow - Semi empirical expressions for Reynolds stress. Interphase transport in isothermal system - Ergun's equation.

Heat Transfer analysis: Temperature distribution in solids and fluids in laminar flow - Equations of change for multi component systems.

Mass Transfer analysis: Concentration distribution in solids and in fluids laminar flow - Equations of change for multi component systems.

REFERENCE BOOKS

1. *Bird R.B., Stewart W.E. and Light Foot E.N. Transport Phenomena, 2nd Edition, John Wileyand Sons., 2007.*
2. *Geankoplis C.J., Transport Processes and Separation Process Principles, 4th Edition, Prentice Hall Inc., 2009.*
3. *J.L. Stuart, "Transport Phenomena", John Wiley, New York, 1982*
4. *W. J. Thomson, "Introduction to Transport Phenomena", Prentice Hall, 2000*

COURSE OUTCOMES

On completion of the course, the student can

CO1	understand the analogy among momentum, heat and mass transport
CO2	develop differential momentum, heat, and mass balances for 1-D steady state problems using conservation principles
CO3	formulate a mathematical representation of velocity, temperature and concentration profiles in momentum, heat and mass transfer respectively in laminar flow.
CO4	identify the similarity among the correlations for floe, heat and mass transfer at interface
CO5	solve the flow, heat and mass transfer problems

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR16**
Course Title	**:**	**MASS TRANSFER LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC20, CLPC24**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

To make students understand the basics of mass transfer and also apply the concepts of mass transfer. They will also be taught to estimate the parameters like diffusion coefficient, mass transfer coefficient etc in laboratory.

LIST OF EXPERIMENTS

1. Determination of relative volatility and verification of Rayleigh's equation by Simple Distillation
2. Estimation of Vaporization efficiency and Thermal efficiency for Steam Distillation
3. Determination of Mass transfer coefficient and the effect of temperature on surface evaporation.
4. Determination of optimum number of stages for leaching using a given amount of solvent.
5. Evaluate the isotherm parameters for Freundlich adsorption isotherm.
6. Determination of diffusion coefficient for acetone in air and naphthalene in air.
7. Determination of air drying characteristics for a given specimen and estimation of masstransfer coefficient.
8. Determination of mass transfer coefficient using a wetted wall column
9. Determination of drying characteristics for given specimen under vacuum and estimation ofmass transfer coefficient
10. Determination of break through point in Continuous adsorption

REFERENCE BOOKS

1. *R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York,1981.*
2. *N. Anantharaman and K.M.Meera Sheriffa Begum, "Mass Transfer Theory and Practice",Printice Hall of India Pvt. Ltd., New Delhi, 2013.*
3. *C. J. Geankopolis, "Transport Processes in Chemical Operations", 4th Edn., Prentice Hall ofIndia, New Delhi, 2004.*
4. *Mass transfer laboratory manual*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	able to verify the basics learnt in theory and apply those concepts.
CO2	able to interpret and apply the data collected in the laboratory

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLLR17**
Course Title	**:**	**PROCESS DYNAMICS AND CONTROL LAB**
Number of Credits	**:**	**2**
Prerequisites	**:**	**CLPC25**
Course Type	**:**	**ELR**

COURSE LEARNING OBJECTIVES

To impart hands on experience on various process control systems and instrumentation

LIST OF EXPERIMENTS

1. I & II Order System Dynamics
2. Interacting & non interacting Systems
3. Flapper - Nozzle system
4. Control valve characteristics
5. Level control system
6. Flow control system
7. Pressure control system
8. Control of a thermal system
9. Design of control system for a given process
10. Simulation of a closed loop system
11. Demo Experiment using Aspen Software of a given process

REFERENCE BOOKS

1. *Process Control Laboratory Manual*
2. *D.R. Coughanowr and S. E. LeBlanc, 'Process Systems Analysis and Control', Mc.GrawHill, III Edition, 2009.*

COURSE OUTCOMES

On completion of the course, the student can be

CO1	able to apply the theoretical knowledge while performing experiments for differentchemical engineering processes

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE10**
Course Title	**:**	**PETROLEUM AND PETROCHEMICAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To impart introductory knowledge of petroleum refining and corresponding processes.
2. To provide an insight into petrochemical industry.

COURSE CONTENT

Introduction & primary processing: Origin & formation of crude oil, Classification of crude, Characterization of crude, Distillation practise, Atmospheric distillation, Vacuum distillation.

Secondary Processing: FCCU, Hydro cracking, Visbreaking, Coking, Reforming, Alkylation, Isomerisation and polymerization processes.

Treatment Techniques: Physical & chemical impurities in petroleum fractions, General mechanisms for removal of Sulphur, Treatment of LPG, Gasoline, Kerosene, Diesel and Lube oils. Properties of ATF and Bitumen.

Petrochemical: Building blocks, intermediates, major petrochemicals and their applications, Chemicals from methane and synthesis gas, Chemicals from olefins, Chemicals from aromatics, Synthetic fibres, plastics and rubber.

Environment and safety: Gaseous contaminants in refinery - sources & treatment, Process waste water - sources and treatment, Fire hazards – active & passive prevention, Occupational diseases and personal protective equipment, Site selection & plant layout.

REFERENCE BOOKS

1. *W.L. Nelson, "Petroleum Refinery Engineering", 4th Edn., McGraw Hill, New York,1985*
2. *B. K. Bhaskara Rao, "Modern Petroleum Refining Processes", 5th Edn., Oxford and IBHPublishing Company, New Delhi, 2012.*
3. *G. D. Hobson and W. Pohl., "Modern Petroleum Technology", John Wiley & sons Publishers, 4th Edn. 2004.*
4. *R. A. Meyers, "Hand book of Petroleum Refining Processes", McGraw Hill, 3rd Edn. 2003.*

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1	develop overview of petroleum industry and know about origin, formation,composition and characterization of crude oil.
CO2	comprehend primary processing mechanisms of crude to obtain various petroleumcuts.
CO3	know about secondary conversion techniques and treatment processes in petroleum refinery to get products of desired yield and quality.
CO4	understand manufacturing processes and applications of various petrochemicals.
CO5	grasp environmental and safety aspects in petroleum refinery and petrochemical industries.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE11**
Course Title	**:**	**FERTILIZER TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. Introduce students to the knowledge of different fertilizers and their manufacturing methodsto improve soil productivity and crop yield.
2. Emphasis is on the different types of the nitrogenous, phosphatic and potash fertilizers.

COURSE CONTENT

Introduction to Chemical Fertilizers: Chemical inorganic Fertilizers and Organic manures. Types of fertilizers: Mixed, complex and Granulated, plant nutrients.

Processes for Raw Materials: Processes for manufacture of ammonia, nitric acid, phosphoric acid and sulphuric acid.

Nitrogenous and Potassium Fertilizers: Processes for urea and di-ammonium phosphate. Recovery of Potassium salts, processes for ammonium chloride and ammonium sulphate.

Complex Fertilizers: Processes for nitro - phosphates and complex NPK fertilizers liquid fertilizers

Phosphatic Fertilizers and Indian Fertilizer Industry: Single and Triple Superphosphate, biofertilizer. Fertilizer Industry in India

REFERENCE BOOKS

1. *Strelzoff, "Technology and Manufacture of Ammonia", 2nd Edn., Wiley, 1981.*
2. *L. J. Carpentire, "New Developments in Phosphate Fertilizer Technology", Elsevier, 1971.*
3. *"Handbook on Fertilizer Technology", Fertilizer Association of India, Near JNU, New Delhi 1992.*
4. *V. Slack, "Phosphoric Acid", 2nd Edn., Marcell Dekkar , 1968.*

COURSE OUTCOMES

At the end of the course, student will be able to

CO1	use reactions and unit operations in manufacturing of various fertilizers.
CO2	characterize fertilizers on the basis of different properties.
CO3	acquire sufficient knowledge on fertilizers and identify the engineering problems in fertilizer manufacturing
CO4	become aware of different fertilizer combinations and methods of applications of these materials.
CO5	produce fertilizer at desired rates.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE12**
Course Title	**:**	**INDUSTRIAL PROCESS BIOTECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of bioprocesses
2. To develop understanding about application of engineering principles in bioprocesses.

COURSE CONTENT

Rates and Patterns of Changes in cell cultures: Kinetics of substrate utilization, biomass and product formation in cellular cultures. Stoichiometry of growth and product formation

Physical Parameters in Bioreactors and Downstream Separations: Transport phenomena and modelling in Bioprocesses. Product recovery operations.

Sensors, Monitoring and control systems in Bioprocesses: Instrumentation and process control inBioprocesses.

Biochemical Reaction Engineering and Bioreactor design: Design and analysis of Bioreactors. Dynamic models and stability, non-ideal mixing, residence time. Sterilisation reactors. Immobilised bio-catalysts and multiphase bio reactors.

Fermentation Technology and R-DNA Technology: Bio-process Technology and Genetic Engineering.

REFERENCE BOOKS

1. *J. E. Bailey and D. F. Ollis, "Biochemical Engineering Fundamentals", 2nd Edn., McGraw Hill, New York, 1986.*
2. *M. D. Trevan, S. Boffly, K.H. Golding and P. Stanbury, "Biotechnology", Tata McGraw Publishing Company, New Delhi 1987.*
3. *R.Lovitt and M.Jones, "Biochemical Reaction Engineering" in Chemical Engineering, Vol. III, 3rd Edn., Edited by J. F. Richardson and Peacock, Pergamon, London, 1994.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	analyze the kinetics of cell growth and product formation from biomass**.**
CO2	model bioprocesses and design downstream processes involved in product recovery.
CO3	identify instruments and model control systems involved in bioprocesses.
CO4	design and analyze bioreactors.
CO5	identify and familiarize with advanced technologies in bioprocesses.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE13**
Course Title	**:**	**POLYMER SCIENCE AND TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To provide a fundamental knowledge on polymers and their chemical, physical and mechanical behavior.
2. Emphasis is on the processing techniques, along with the production of polymers.

COURSE CONTENT

Characteristics, Analysis of Polymers: The science of large molecules. Theory of polymer solutions. Measurement of molecular weight and size. Analysis and testing of polymers.

Polymer material structure and Properties: Deformation, flow and melt characteristics. Morphology and order in crystalline polymers. Rheology and the mechanical properties of polymers. Polymer structure and physical properties.

Polymer synthesis and reaction engineering: Condensation polymerization. Addition polymerization. Ionic and coordination polymerization. copolymerisation. polymerization conditions and polymer reactions.

Industrial polymers: Manufacturing processes and applications: Hydrocarbon plastics and elastomers. Other carbon chain polymers. Heterochain thermoplastics. Thermosetting resins.

Processing of polymers: Plastics, Fibres and Elastomers: Polymers developed for synthetic plastics, fibres and elastomer applications. Plastics technology. Fiber technology. Elastomer technology.

REFERENCE BOOKS

1. F. W. Billmeyer Jr., "Text Book of Polymer Science", 3rd Edn., Wiley- Inter Science, 1984.
2. F. Rodriguez, Claude Cohen, Christopher K. Ober and Lynden A. Archer "Principals of Polymer Systems", 5th Edn., Taylor and Francis, Washington, 2003.
3. "Encyclopedia of Polymer Science and Technology", John Wiley-Inter Science.

COURSE OUTCOMES

At the end of the course, the student can be able to

CO1	apply the knowledge and to understand the properties and use of polymeric materials and other related environmental aspects.
CO2	acquire sufficient knowledge on how polymeric materials are build-up from molecular level to macroscopic level and the relationship between structure and material properties.
CO3	equipped with knowledge on synthesis/modification, characterization, processing and applications of synthetic polymers.
CO4	understand and apply the various processing and manufacturing techniques.
CO5	correlate structure-processing-property relationships for polymers, blends and composites.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE14**
Course Title	**:**	**NEW SEPERATION PROCESSES**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC20**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1) This subject deals with the application of the science and engineering science that you have learned to the separation of chemical and wastewater.
2) To understand how separation work, and to further develop your ability to apply basic principles to the solution of specific problems.

COURSE CONTENT

Review of Conventional Processes, Recent advances in Separation Techniques based on size, surface properties, ionic properties and other special characteristics of substances, Process concept, Theory and Equipment used in cross flow Filtration, cross flow Electro Filtration, Surface based solid – liquid separations involving a second liquid.

Sorption Techniques: Types and choice of adsorbents, Normal Adsorption techniques, chromatographic techniques, types and Retention theory mechanism Equipment and commercial processes, Recent advances and economics, Molecular Sieves.

Types and choice of Membranes, Plate and Frame, tubular, spiral wound and hollow fiber Membrane Reactors and their relative merits, commercial, Pilot Plant and Laboratory Membrane permeators involving Dialysis, Reverse Osmosis, Nanofiltration, Ultra filtration and Micro filtration, Ceramic- Hybrid process and Biological Membranes

Ionic Separation: Controlling factors, Applications, Equipments for Electrophoresis, Dielectrophoresis, Electro Dialysis and Ion - Exchange, Commercial processes.

Other Techniques: Separation involving Lyophilisation, Pervaporation and Permeation Techniques for solids, liquids and gases, zone melting, Adductive Crystallization, other Separation Processes, Supercritical fluid Extraction, Oil spill Management, Industrial Effluent Treatment by Modern Techniques

REFERENCE BOOKS

1. *H. M. Schoen, "New Chemical Engineering Separation Techniques", Inter Science Publications, New York, 1972.*
2. Nakagawal, O. V., “Membrane Science and Technology”’ Marcel Dekkar, 1992
3. *B.Sivasankar, “Bioseparations – Principles and Techniques”, Prentice Hall of India Pvt. Ltd, New Delhi, 2005.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	know the various conventional processes and non-conventional for liquid separation.
CO2	able to select appropriate separation technique by adsorption and chromatographic for intended problem.
CO3	able to understand membrane separation process for multi-component mixtures, liquids and gas from industry and process.
CO4	understand controlling factors, Applications, Equipment for Electrophoresis andionic separation.
CO5	able to design separation system for solids, liquids and gases and find effective solution of intended problem.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE16**
Course Title	**:**	**FLUIDIZATION ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC14, CLPC18**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1) To introduce students to the concepts and applications of fluidized bed systems
2) To introduce the students to development of models for fluidized bed systems
3) To impart knowledge on Heat and mass transfer in fluidized bed systems
4) To impart knowledgeable on the importance on Entrainment and elutriation in fluidized bed systems

COURSE CONTENT

Introduction and applications: Introduction to fluidised bed systems. Fundamentals of fluidisation. Industrial applications of fluidised beds - Physical operations. Synthesis reactions, cracking and reforming of hydrocarbons, Gasification, Carbonisation, Gas-solid reactions, calcining and clinkering

Gross behaviour of Fluidised beds: Gross behaviour of fluidised beds. Minimum and terminal velocities in fluidised beds. Types of fluidisation. Design of distributors. Voidage in fluidised beds. TDH, variation in size distribution with height, viscosity and fluidity of fluidised beds, Power consumption

Analysis of bubble and emulsion Phase: Davidson's model, Frequency measurements, bubbles inordinary bubbling bed model for bubble phase. Emulsion phase: Experimental findings. Turn over rate of solids. Bubbling bed model for emulsion phase . Interchange co-efficients

Flow pattern of Gas and heat & mass transfer in Fluidised beds: Flow pattern of gas through fluidised beds. Experimental findings. The bubbling bed models for gas inter change Interpretation of Gas mixing data. Heat and Mass Transfer between fluid and solid: Experiment findings on Heat and Mass Transfer. Heat and mass transfer rates from bubbling bed model

Heat transfer between Fluidised beds and surfaces - Entrainment & Elutriation: Heat transfer between fluidised beds and surfaces: Experiment finding theories of bed heat transfer comparison of theories. Entrainment of or above TDH, model for Entrainment and application ofthe entrainment model to elutriation

REFERENCE BOOKS

1. *D. Kunii and O. Levenspiel, "Fluidisation Engineering", 2nd Edn., Butterworth Heinemann, 1991.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	analyze and apply fluidized bed systems for Industrial applications
CO2	analyze the fluidized bed systems and apply models to predict the bubble behaviors
CO3	analyze and estimate heat and mass transfer in fluidised beds
CO4	analyse entrainments and elutriation in fluidized bed systems and value its importancein the design of fluidized bed columns.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE17**
Course Title	**:**	**PHARMACEUTICAL TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1) To provide the basic knowledge on functional group identification, chemical bonding with their mechanism
2) To provide the basic knowledge of principles involved in the identification and estimation ofPharmaceutical substances.
3) To understand the properties and principles of medicinal agents that originates from organic and inorganic sources and their application in pharmaceutical industry.

COURSE CONTENT

Introduction to Physical Pharmaceutics: Metrology and Calculations, Molecular structure, properties and States of Matter, Solutions, Phase Equilibra, Micromeritic and Powder Rheology, Surface and Interfacial Phenomena, Dispersion Systems

Diffusion & Dissolution, Kinetics and drug stability, Viscosity & Rheology, and Polymer Science and Applications.

Formulations and Development, Packaging, Introduction to Industrial Processing, Transport Phenomena (Fluid Flow, Heat Transfer and Mass Transfer)

Particulate Technology (Particle Size, Size reduction, Size Separation, Powder Flow and Compaction), Unit Operations (Mixing, Evaporation, Filtration, Centrifugation, Extraction, Distillation, and Drying)

Materials of Pharmaceutical Plant Construction, Good Manufacturing Practice (GMP's) Guidelines

REFERENCE BOOKS

1. *Alfred n.Martin, "Physical Chemical and Biopharmaceutical Principles in the Pharmaceutical Sciences", 6th Edn.,* Lippincott Williams & Wilkins*, 2006.*
2. *David B. Troy, Paul Beringer, "Remington: The Science and Practice of Pharmacy", 21stEdn.,* Lippincott Williams & Wilkins.
3. *Sidney James Carter, "Cooper and Gunn's Tutorial Pharmacy",* CBS Publishers & Distributors, 1986.

COURSE OUTCOMES

After completion of the course, the students can

CO1	acquire basic knowledge of preformulation and formulation of drugs, pharmaceutical unit operations and manufacturing, packaging and quality control of pharmaceutical dosage forms.
CO2	acquire a knowledge on pharmaceutical unit operations and manufacturing, packaging and quality control of pharmaceutical dosage forms.
CO3	trained to conceptualize, design, build up, maintain and operate various industrial processes and machineries involved in the process.
CO4	understand and apply the various processing and manufacturing techniques.
CO5	formulate a pure drug substance into a dosage form.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE18**
Course Title	**:**	**PROCESS INTENSIFICATION**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC21**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

To understand the scientific background, techniques and applications of intensification in the process industries

COURSE CONTENT

Introduction: Theory of Process Intensification, Process Intensification (PI) Applications, Main benefits from process intensification, Process-Intensifying equipment, Process intensificationtoolbox, Techniques for PI application.

Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Design rules, Implementation of Micro-reaction Technology, Micro-fabrication of reaction and unit operation devices - Wet and Dry Etching processes.

Scales of mixing, Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Atomizer, Nebulizers, Static mixers, design of mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Applications of static mixers, Higee reactors.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Reactive absorption, Reactive distillation, Reactive Extraction - Case Studies.

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Micro channel heat exchangers, Phase-change heat transfer, Selection of heat exchanger and design technology, Integrated heat exchangers in separation processes.

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation reactors, Nusselt-flow model and mass transfer, The Rotating electrolytic Cell, Electrostatic fields, Sonocrystallization, Supercritical fluids.

REFERENCE BOOKS

1. *Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.*
2. *Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	apply process intensification in industrial processes.
CO2	implement methodologies for process intensification.
CO3	understand scale up issues in the chemical processes.
CO4	identify and solve process challenges using intensification technologies.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE19**
Course Title	**:**	**ELECTROCHEMICAL REACTION ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC19, CLPC20**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

To familiarize in the aspects of current-voltage relationships & estimation of mass transfer coefficient, PFR & CSTR systems model

COURSE CONTENT

A general view of electrolytic processes; current-voltage relationships in electrolytic reactors; thelimiting current plateau; mass & energy balance, and efficiency in electrochemical reactors; The estimation of mass transport coefficients at commonly occurring electrodes; The estimation of mass transport coefficients under enhanced convection conditions.

A general view of plug flow model of electrolytic reactors: plug flow model of electrochemical reactors employing parallel plate reactor; Plug flow model under constant mass flux conditions; PFM analysis with electrolyte recycling PFM and real electrochemical reactors. General view of simple CSTER systems; CSTER in cascades; CSTER analysis of batch electrochemical reactors, CSTER analysis of semi-continuous electrochemical reactors.

CSTER analysis of electrolyte recycling; Batch reactor combined with electrolyte recycling. General aspects of thermal behaviour in electrochemical reactor; Thermal behaviour under CSTER conditions; The estimation of heat losses; the thermal behaviour under PFR conditions;Thermal behaviour of batch electrochemical reactors.

Convective diffusion equation and migration effects –derivation of convective diffusion equationtheory – scope and limitation – migration effects – Electroneutrality conditions – supporting electrolyte effect – fundamental of Nernst layer model – Estimation of true limiting current.

General aspects of dispersion models-tracer input signal/output signal - axial dispersion in electrochemical reactors - axial dispersion and reactor performance - axial dispersion analysis via tank-in-series model - general notions on optimization of electrochemical reactor – elementary process optimization – IBL formula – optimization of electro refining process – Jaskula formula – optimization of a general electrolytic process – The Beck formula.

REFERENCE BOOKS

1. *Scott K, “Electrochemical Reaction Engineering”, Plenum Press, New York, 1991.*
2. *Goodridge F, Scott K, “Electrochemical Process Engineering”, Plenum Press, New York,1995.*
3. *T.Z.Fahidy, “Principles of Electrochemical Reactor Analysis”, Elsevier, 1985*
4. *D.J. Pickett, “Electrochemical Reactor Designs”, Elsevier Scientific Publishing Company, New York, 1979.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to understand Kinetics of single and multiple electrochemical reaction
CO2	able to understand Mass transport process in the electrochemical system
CO3	able to design of Electrochemical reactors.
CO4	able to analyze electrochemical design models, thermal behaviour of reactors and electrochemical reactors.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLPE20**
Course Title	**:**	**FOOD PROCESSING TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

The course is aimed to impart knowledge of various areas related to Food processing and technology.

COURSE CONTENT

Biotechnology in relation to the food industry; Nutritive value of food; types of microorganisms associated with food, its sources, types and behavior in foods.

Preservation of meat, Fisheries, Vegetables, dairy products; Enzymes and Chemicals used in food processing, Thermal inactivation of micro-organisms; Thermal process evaluations; Freezing and thawing of foods.

Dairy products, meat, fishery, non beverage plant products, Beverages and related products of baking.

Food borne illness, quality control. Case studies on Biotechnology in the evolution of food quality, HFCS (High fructose corn syrup) and Myco-proteins.

Rheology and Fluid flow; Calculation of power requirements for pumping of food materials Material and energy balances in Food processing; Thermal processing of food; Microwave heating; Biochemical engineering for flavor and food production

REFERENCE BOOKS

1. *William Frazier, Dennis Westhoff, Food Microbiology, 4th Edition, Mcgraw Hill Education, 2008.*
2. *Roger Angold, Gordon A. Beech, John Taggart, Food Biotechnology, Volume 7, CambridgeUniversity Press, 1989.*
3. *George J Banward, Basic Food Microbiology, CBS Publishers, New Delhi, 1987.*
4. *Lindsay, Biotechnology challenges for the flavour and food industry, Elsevier Applied Science, 1988.*
5. *H.G.Muller, An Introduction to Tropical Food Science, C L P Edition, Cambridge, University Press, 1989.*

COURSE OUTCOMES

On completion of the course, the students will be familiar with

CO1	application of biotechnology in food industry.
CO2	appropriate processing, preservation, and packaging methods.
CO3	the aspects of food safety.
CO4	opportunities for higher studies in food science, chemical engineering,biotechnology, and allied fields.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE10**
Course Title	**:**	**ENVIRONMENTAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**OE**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of environmental engineering
2. To understand the problems of pollution and its treatment methodology.
3. To understand the control methodologies of pollutants and uses Environmental Impact Assessment (EIA)

COURSE CONTENT

Environment, Environmental quality and degradation, Industrial scenario in India. Sources and classification of Air Pollutants, Air quality standards – Meteorology and Air Pollution: Atmospheric stability and inversions-mixing height-plume rise estimation – effluent dispersion theories effects of air pollution on the environment, on materials, on human health, on animals. Measurements of air pollution, Equipments for control of air pollution.

Sources and types of industrial wastewater – Nature and Origin of Pollutants - Industrial wastewater and environmental impacts. Regulatory requirements for treatment of industrial wastewater. Industrial Wastewater Treatment methods: Equalization - Neutralization – Oil separation – Flotation – Precipitation, Aerobic and anaerobic biological treatment, Chemical oxidation – Ozonation – carbon adsorption -Photo catalysis, Ion Exchange – Membrane Technologies

Solid Waste Management**:** Type of waste collection systems, analysis of collection system – alternative techniques for collection system. Separation and Processing and Transformation

of Solid Waste: unit operations user for separation and processing, Landfills**:** Site selection, design and operation, drainage and leachate collection systems – e waste - sources, collection, treatment and reuse management. Hazardous waste treatment technologies

Sources of noise pollution. Noise pollution standards and measurements - controlling methods ofnoise pollution. Effects on human being.

Historical development of Environmental Impact Assessment (EIA). EIA in Project Cycle. Legaland Regulatory aspects in India. – Types and limitations of EIA – Cross sectoral issues and termsof reference in EIA – Public Participation in EIA. EIA process- screening – scoping - setting – analysis – mitigation, Software packages for EIA – Expert systems in EIA. Prediction tools for EIA – Mathematical modeling for impact prediction.

REFERENCE BOOKS

1. *M.N. Rao, "Air Pollution", Tata McGraw Hill, 1989.*
2. *Metcalf and Eddy, Wastewater Engineering, Treatment and Reuse, Tata McGraw Hill,NewDelhi, 2003.*
3. *George Techobanoglous et al, "Integrated Solid Waste Management", McGraw-Hill, Publication, 1993.*
4. *Canter, L.W., Environmental Impact Assessment, McGraw Hill, New York. 1996*
5. *C. S. Rao, "Environmental Pollution Control Engineering", New Age International Pvt. Ltd., 2003.*
6. *Richard W. Boubel et al "Fundamentals of Air pollution", Academic Press, New York,1994*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to understand the sources and effects of pollutants to the environment
CO2	understand the various treatment technologies for wastewater, air effluents, solid waste, noise pollution released from Process industries
CO3	understand the development and applications of various unit operation to control the toxic elements
CO4	understand the Limitation and Importance of Environmental Impact Assessment (EIA)

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE11**
Course Title	**:**	**NUCLEAR ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**OE**

COURSE LEARNING OBJECTIVES

1. To teach the fundamental physics as applied to Nuclear energy and Radioactivity.
2. To understand the process of power generation from Nuclear energy and Nuclear waste Management.

COURSE CONTENT

Principles of nuclear power generation,nuclear fission and fusion, energy from fission and fuel burn up.

Radioactivity, neutron energies, thermal neutrons, nuclear cross sections, Fission reactor types,reactor control, fuel arrangements in a thermal reactor.

Pressurized water reactor, PWR power plant, Boiling water reactor, BWR power plant, Gas cooled reactor, high temperature gas cooled reactor, Pressurized Heavy water reactor.

Concept of breeding, fast breeder reactors, Liquid metal fast breeder reactor and accessories.

Thermal pollution by nuclear power plants, Radio-active pollution of environment by nuclear power plants, radio-active waste disposal.

REFERENCE BOOKS

1. *S. Glasstone, and A. Sesonske.,"Nuclear Reactor Engineering: Reactor Design Basics", 4th edition, Springer, 2004.*
2. *M.N. El Vakil, "Nuclear Power Engineering", McGraw-Hill Book Company, Inc., 1962.*
3. *J. Kenneth Shultis & Richard E. Faw, "Fundamentals of Nuclear Science and Engineering",Marcel CRC Press (2nd edition), 2008.*
4. *Manson Benedict, Thomas H. Pigford, Hans Wolfgang Levi, "Nuclear Chemical Engineering", 2nd edition, McGraw-Hill Book Company, 1981.*
5. *Raymond L Murray, "Nuclear Energy", 3rd edition, Pergamon press, 1988.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	Awareness of nuclear industry, principle of nuclear power generation and definitions or terms involved in nuclear industry
CO2	Radioactivity, types of reactors, control of reaction mechanisms, fuel preparation andfuel arrangement
CO3	Concept and schematic of PWR, PHWR, BWR, and Gas cooled reactors
CO4	Concept of Breeding and Fast breeder reactors
CO5	Nuclear waste management and Radioactive impact on environmental and their prevention studies

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE12**
Course Title	**:**	**RENEWABLE ENERGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**OE**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of renewable energy.
2. To explain the technological basis for exploiting renewable energy sources

COURSE CONTENT

Introduction: Energy: Past, Today, and Future. A brief history of energy consumption. Energy & Environment.. Renewable Energy – Quality, quantity, availability, advantageous and limitations.

Solar energy: Sun and its Energy: Basics of Solar Energy. Solar Energy in the Past. Solar Thermal Energy Solar Photovoltaic.

Bio energy & Geothermal energy: Conversion. Bio degradation. Biogas generation. Fuel properties. Biomass gasifier. Geothermal Resources • Geothermal Technologies

Wind energy: Wind Resources. Wind Turbines. Environmental Impact. Data and energy estimation. Conversion. Wind mill Performance and applications.

Tidal energy: Ocean Energy Potential against Wind and Solar. Wave Characteristics and Statistics. Wave Energy Devices. Tide Energy Technologies. Ocean Thermal Energy. Osmotic Power. Ocean Bio-mass.

REFERENCES BOOKS

1) *Rao, S. and Parulekar, R.B., "Energy Technology - Nonconventional, Renewable and Conventional", Khanna Publishers, 1995.*
2) *G.D.Rai, "Non conventional energy sources," Khanna Publishers, New Delhi, 2011.*
3) *John Twidell and Tony Weir, "Renewable Energy Resources", Taylor and Francis, 2000.*
4) *Boyle, Godfrey., "Renewable Energy", 2nd edition, Oxford University Press, 2004.*

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1	list and describe the primary renewable energy resources and technologies
CO2	identify the challenges associated with the use of various energy sources.
CO3	recognize renewable energy technologies as a basis for further analysis and evaluation.
CO4	exploit basic electrical concepts and system components.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE13**
Course Title	**:**	**PIPELINE CORROSION AND CATHODIC PROTECTION**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**OE**

COURSE LEARNING OBJECTIVES

1. To provide knowledge on corrosion theory, cathodic protection principles and systems.
2. To provide knowledge and information concerning practices, techniques, materials and equipment, measurement practice, typical method of installation of cathodic protection (CP) system adopted by corrosion engineers.
3. To provide knowledge on the design, operation and maintenance of CP system in controlling the pipeline corrosion.
4. To impart knowledge for the economic justification of cathodic protection alternatives with illustrative problems.

COURSE CONTENT

Basic concepts in corrosion, reference electrodes, factors influencing corrosion, forms of corrosion, outlines of corrosion control methods, pipeline corrosion – types of corrosion cells on pipelines, underground pipeline coatings – types and applications.

Principles of cathodic protection, criteria for cathodic protection, potential – pH diagram for Iron-Water system, derivation of protective potential for iron, galvanic anode system – galvanic andoes – composition and electro chemical properties, impressed current CP (ICCP) system – ICCP anodes, DC power sources, cables for CP.

Field surveys for collection of data on pipeline and environmental factors, illustrative problems on various surveys, types of ground bed and calculations on ground bed, design of CP system forunderground pipeline – sacrificial and impressed current system.

Types of test stations, cable to pipe connection, cable laying, installation of galvanic anodes – prepackaged anodes and non-prepackaged anodes, installation of impressed current anodes – various types of ground beds, installation of rectifiers, field measurements – PSP data–closed interval potential, current measurement and applications of current measurement, resistance measurement, monitoring of CP system, commissioning of CP system.

Stray current corrosion – sources, detection and remedial measurements, interference in CP system – basic solutions, failures in ICCP system – rectifier ground bed – failure from protected structure and protective devices, DC output changes – troubleshooting in voltage and current output values, causes for failures in sacrificial anode system, economic decision making in CP system.

REFERENCE BOOKS

1. *Peabody, A. W., Peabody's Control of Pipeline Corrosion, Edited by R.L. Bianchetti, NACE Houston, Texas, II Edition, 2001*
2. *Zaki Ahmad, Principles of Corrosion Engineering and Corrosion Control, Butterworth Heinemann, London, I, 2006.*
3. *Marshall E.Parker, Edward G.Peattie, Pipeline Corrosion and Cathodic Protection, Gulf Publishing company, Houston, Texas, III, Edition1984.*
4. *John H. Morgan, Cathodic Protection, NACE international, Houston, Texas, II Edition, 1987.*
5. *M.G.Fontana and N.D. Greene, Corrosion Engineering, McGraw Hill, New York, III*

Edition, 1978.

6. *V.Ashwoth and C.Googan, Cathodic Protection-Theory and Practice, Institute of Corrosion,London, 1993*

COURSE OUTCOMES

On completion of this course, the student can

CO1	understand the basics of corrosion, principles of cathodic protection and practicing of cathodic protection in the field
CO2	design the cathodic protection systems for the protection of underground pipelines by sacrificial and impressed current methods
CO3	gain knowledge on the installation, operation and maintenance of cathodic protection system for corrosion control of underground pipelines.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE14**
Course Title	**:**	**ELECTROCHEMICAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**OE**

COURSE LEARNING OBJECTIVES

1. To acquire fundamental knowledge of electrochemistry/electrochemical engineering including electro kinetic phenomena
2. To build an expertise sufficient to understand electrochemical phenomena from first principles.
3. To understand general methodologies for analysis and design of electrochemical systems.

COURSE CONTENT

Introduction and Thermodynamic in terms of electrochemical potential-phase equilibrium, chemical and electrochemical potentials, cells with solution of uniform concentration, transport processes in junction regions, cells with a single electrolyte of varying concentration. The Electric potential-the electrostatic potential, intermolecular forces, outer and inner potential,potentials of reference electrode, the electric potential in thermodynamics. Activity coefficients- ionic distributions in dilute solutions, electrical contribution to the free energy, measurement of activity coefficients.

Reference Electrode-criteria of reference electrodes, hydrogen electrode, the calomel electrode and other mercury and mercurous salt electrodes, silver-silver halide electrodes. Potentials of cells with junction- the Nernst equation, types of liquid junctions, cells with liquid junction, potentials across membranes. Structure of the electric double layer-qualitative description of double layers, the Gibbs adsorption isotherm, the Lippmann equation, the diffused part of the double layer. Electrode kinetics, Electrokinetic phenomena, Electro capillary phenomena.

Infinitely dilute solutions-transport laws, conductivity, diffusional potential and transference numbers, conservation of charge, binary electrolyte, supporting electrolyte, multicomponent diffusion by elemination of the electric field. Mobilities and diffusion coefficients. Neutrality and Laplace's equation. Concentrated solutions- liquid junction potentials. Thermal effects-thermal diffusion, heat generation, conservation and transfer. Thermogalvanic cells.

Transport properties- single and multicomponent solutions. Fluid mechanics-stress in a Newtonian fluid, magnitude of electrical forces. Transport in dilutes solutions, simplification for convective transport, the Graetz problem, two-dimensional diffusion layer in laminar forced convection, axisymmetric diffusion layers in forced convection.

Application of potential theory- primary and secondary current distribution. Numerical solution. Effect of migration on limiting currents-Correction factors for limiting currents. Concentration variation of supporting electrolyte, limiting currents for free convection. Concentration overpotential-binary electrolyte, supporting electrolyte. Currents below the limiting current

REFERENCE BOOKS

1. *Newman, J., Englewood Cliffs, "Electrochemical Systems", 3rd Edition, Prentice Hall, NJ, 2004.*
2. *Prentice, G., Englewood Cliffs, "Electrochemical Engineering Principles", Prentice Hall, NJ,1991.*
3. *Rouser, I., Micka, K., & Kimla, A, "Electrochemical Engineering I & II", Elsevier, New York,1986.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to describe mathematically the kinetics of electrochemical reactions
CO2	understand the principles involved in the numerical calculation of potential, concentration and current density distributions in electrochemical reactors.
CO3	able to apply knowledge of electro-kinetic phenomena to design microfluidic unit operation
CO4	get knowledge of major industrial electrochemical processes and electrochemical reactor design including economic and environmental considerations

Mapping of Course Outcomes with Program Outcomes

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

Course Code	**:**	**CLOE15**
Course Title	**:**	**ENERGY ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To identify different types of fuel sources for energy production.
2. To appreciate the advantages of energy production from renewable energy resources.

COURSE CONTENT

Coal - Coal and Coal derived fuels; Characteristics, production methods and uses. Coal combustion technology, waste heat recovery.

Oil and Gases- Fuels from oil and gases: Characteristics, production methods and uses. Technology for combustion of fuels derived from oil and gas.

Solar Energy - Solar energy utilization, Thermal application and photovoltaic applications; wind,geothermal and hydro energy utilization.

Bio Energy - Biomass conversion for fuels; production methods based on thermochemical andbioconversion. Characteristics and uses; Design of digestors.

Nuclear Energy - Nuclear Energy; Nuclear fission fuels processing, Nuclear reactions and nuclear reactors, Nuclear Engineering.

REFERENCE BOOKS

1. *G.D.Rai, "Non conventional energy sources," Khanna Publishers, New Delhi, 2011.*
2. *Samir Sarkar, "Fuels and Combustion", 3rd Edn, University press Publication, 2008.*
3. *D.A.Reay, "Industrial energy conservation: a handbook for engineers and managers, Pergamon Press, Oxford,UK, 1977.*
4. *O.P.Gupta, "Fundamentals of Nuclear power reactors", Khanna Publishers, New Delhi, 1983.*

COURSE OUTCOMES

On completion of the course, the students can

CO1	familiar with energy production from conventional fuels and renewable energy resources.
CO2	compare the process of energy generation by conventional as well as renewable resources.
CO3	familiar with energy conservation through waste heat recovery.
CO4	familiar with the challenges associated with the use of various energy sources.
CO5	familiar with information on renewable energy technologies as a basis for further analysis and evaluation.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE16**
Course Title	**:**	**PROCESS INSTRUMENTATION**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

To understand the measurement techniques for the process variables such as temperature.Pressure, flow, level, composition etc.

COURSE CONTENT

Characteristics of Measurement System -Elements of instruments, static and dynamic characteristics, basic concepts and qualities of measurement, basic concepts of response of first order type instruments, mercury in glass thermometer

Pressure measurement: Pressure, Methods of pressure measurement, Manometers, Elastic pressure transducers, Measurement of vacuum, Force-balance pressure gauges, Electrical pressure transducers, Pressure switches, Calibration of pressure measuring instruments, Maintenance and repair of pressure measuring instruments, Troubleshooting

Temperature measurement: Temperature, Temperature scales, Methods of temperature measurement, Expansion temperature, Filled-system thermometers, Electrical temperature instruments. Pyrometers: Radiation and optical

Flow Measurement: Methods of flow measurement, Inferential flow measurement, Quantity flowmeters, Mass flowmeters, Calibration of flowmeters, Selection of flowmeters.

Level measurement: Methods of liquid level measurement, Direct methods, level measurement in pressure vessels, measurement of interface level, level of dry materials. Instruments for Analysis - recording instruments, indicating and signaling instruments, instrumentation diagram.

Methods of composition analysis: Spectroscopic analysis, Absorption spectroscopy, Emission spectroscopy, Mass spectroscopy

REFERENCE BOOKS

1. *D. P. Eckman, Industrial Instrumentation, Wiley Eastern Ltd.,2004*
2. *J. P. Bentley, Principles of Measurement Systems, Longman*
3. *G. C. Barney, Intelligent Instrumentation, PHI Pvt Ltd.*
4. *D. Patranabis, Principles of Industrial Instrumentation, 2nd Edition, Tata McGraw Hill Publishing Company, New Delhi, 1999.*
5. *William C. Dunn, Fundamentals of Industrial Instrumentation and Process Control, 1stEdition, Tata McGraw-Hill Education Private Limited, 2009.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	analyze repeatability, precision and accuracy of the instruments
CO2	understand the measurement techniques for pressure
CO3	understand the measurement techniques for temperature
CO4	understand the measurement techniques for flow and Level
CO5	understand the measurement techniques for composition

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE17**
Course Title	**:**	**DESIGN AND ANALYSIS OF EXPERIMENTS**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. Describe how to design experiments, carry them out, and analyze the data they yield.
2. Understand the process of designing an experiment including factorial and fractional factorialdesigns.
3. Investigate the logic of hypothesis testing, including analysis of variance and the detailedanalysis of experimental data.
4. Formulate understanding of the subject using real examples, including experimentation in thesocial and economic sciences.
5. Learn the technique of regression analysis, and how it compares and contrasts with othertechniques studied in the course.
6. Understand the role of response surface methodology and its basic underpinnings.
7. Gain an understanding of how the analysis of experimental design data is carried out usingthe most common software packages.

COURSE CONTENT

Statistics, Simple Comparative Experiments, Experiments of a single factor, analysis of varianceRandomized blocks, Latin squares, The 2^k factor design, Blocking and confounding

Two level fractional Factorial design, Three level and mixed level factorial and fractional factorial design.

Fitting regression methods, LS method, Robust parameter design, Experiment with randomfactors, Nested design

Response surfaces, EVOP, Multivariate data analysis

REFERENCE BOOKS

1. *Douglas C. Montgomery, Design and Analysis of Experiments, Wiley, 6th Edition*
2. *Zivorad R. Lazic, Design of Experiments in Chemical Engineering: A Practical Guide, JhonWiley &Sons Inc.*
3. *Robert L. Mason, Richard F. Gunst, James L. Hess, Statistical Design and Analysis ofExperiments: With Applications to Engineering and Science, Jhon Wiley &Sons Inc.2nd ed.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	plan experiments according to a proper and correct design plan.
CO2	analyze and evaluate experimental results (statistically), according to chosen experimental design (ANOVA, regression models).
CO3	use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional design and other design methods/techniques and so on.
CO4	know the fundamentals of multivariate analysis and chemo metric methods (PCA and PLS) with simple applications.

Mapping of Course outcomes with Programme outcomes

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

Course Code	**:**	**CLOE18**
Course Title	**:**	**NANO TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of nanomaterials and nanotechnology
2. To understand the synthesis and applications of nanomaterials.

COURSE CONTENT

Overview of nanoscience: Nanorevolution, Properties at nanoscale. Theory, definitions and scaling. Supramolecular Chemistry, Definition and examples of the main intermolecular forces used in supramolecular chemistry. Self-assembly processes in organic systems.

Nanomaterials: Metal and Semiconductor Nanomaterials, Quantum Dots, Wells and Wires, Molecule to bulk transitions, Bucky balls and Carbon Nanotubes.

Methods of synthesis of Nanometerials: Equipment and processes needed to fabricate nanodevices and structures such as bio-chips, power devices, and opto-electronic structures. Bottom-up (building from molecular level) and top-down (breakdown of microcrystalline materials) approaches.

Instrumentation for Nanoscale Characterization: Instrumentation required for characterization of properties on the nanometer scale. The measurable properties and resolution limits of each technique, with an emphasis on measurements in the nanometer range.

Applications: Solar energy conversion and catalysis, Molecular electronics and printed electronics Nanoelectronics, Polymers with a special architecture, Liquid crystalline systems, Linear and nonlinear optical and electroopticals. Advanced organic materials for data storage, Photonics, Plasmonics, Chemical and biosensors, Nanomedicine and Nanobiotechnology.

REFERENCE BOOKS

1. *Jonathan Steed and Jerry Atwood, Supramolecular Chemistry.*
2. *Joel I. Gersten, "The Physics and Chemistry of Materials", Wiley, 2001.*
3. *Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press, 2002.*
4. *Guozhong Cao,"Nanostructures and Nanomaterials, synthesis, properties and applications",Imperial College Press, 2004.*
5. *C.Dupas, P.Houdy, M.Lahmani, Nanoscience: "Nanotechnologies and Nanophysics", Springer-Verlag Berlin Heidelberg, 2007*
6. *Nanobiotechnology; ed. C.M.Niemeyer, C.A.Mirkin. Springer Hand book of Nanotechnology, ed. Bharat Bhushan.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	understand the chemistry involved in the synthesis of nanomaterials.
CO2	identify and understand the peculiar properties of materials at nanoscale.
CO3	differentiate various synthesis techniques of nanomaterials for different applications.
CO4	analyze the properties and identify the instrumentation for characterization of nanomaterials.
CO5	find the importance of applications of nanomaterials in biological processes.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE19**
Course Title	**:**	**OPTIMIZATION TECHNIQUES**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To understand the concepts and origin of the different optimization methods.
2. To get a broad picture of the various applications of optimization methods used in Chemical Engineering.
3. Optimize the different methods in industry for design and production of products, both economically and efficiently.

COURSE CONTENT

General: Functions of single and multiple variables - optimality criteria, direct and indirect search methods.

Linearisation: Constraint optimality criteria, transformation methods based on linearisation.

Quadratic and Geometric Programming: Quadratic and geometric programming problems, calculus of variations.

Optimality Criteria & Optimal Control Problems: Euler-Lagrange optimality criteria,Pontryagin's maximum principle, optimal control problems. Numerical methods.

Artificial Intelligence in Optimization: Introduction to Artificial Intelligence in optimization.

REFERENCE BOOKS

1. *T.F. Edgar and D.M. Himmelblau," Optimization Techniques for Chemical Engineers", McGraw-Hill, New York, 1985.*
2. *S.S.Rao, "Engineering Optimization Theory and Practice", Third edition, New Age International Publishers, India.*
3. *K. Deo, "Optimization Techniques", Wiley Eastern, 1995.*
4. *R.Panneerselvam, "Operation Research", Second edition, PHI Learning private Ltd,New Delhi, India.*
5. *Prem Kumar Gupta and D.S.Hira, "Problems in Operations Research (Principles and Solutions)", S.Chand and company Ltd. New Delhi, India.*

COURSE OUTCOMES

After completion of course, the students can

CO1	able to apply the knowledge of different optimization methods for an optimum design.
CO2	acquire sufficient knowledge in this subject for chemical engineering applications, where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives.
CO3	implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques.
CO4	identify, formulate and solve a practical engineering problem of their interest byapplying or modifying an optimization technique.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE20**
Course Title	**:**	**MATERIAL SCIENCE AND TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

1. To impart the basic concept of material science.
2. To understand the various properties, corrosion and heat treatment of engineering materials
3. To understand the engineering requirement and selections of materials based on the properties for various applications.

COURSE CONTENT

Atomic Bonding: Classes of engineering materials - engineering requirement of materials - selection of materials - structure of atoms and molecules - Bonding in solids - types of bonds and comparison of bonds.

Structure and Imperfections in Crystals: Crystal structure Crystal geometry, structure of solids, methods of determining structures. Imperfection in crystals - types of imperfection. Point imperfection, diffusion in solids - self diffusion Fick's law, Applications of diffusion.

Properties and Corrosion of Material: Mechanical, Electrical and magnetic properties of materials - Deformation of materials - Heat Treatment techniques - corrosion, theories of corrosion - control and prevention of corrosion.

Metals: Engineering materials - ferrous metals - Iron and their alloys Iron and steel Iron carbon equilibrium diagram. Non-ferrous metals and alloys - Aluminium, copper, Zinc, lead, Nickel andtheir alloys with reference to the application in chemical industries.

Non Metals: Inorganic materials: Ceramics, Glass and refractories - organic materials: wood, plastics, and rubber and wood - Advanced materials (Biomaterials, nanomaterials and composites) with special reference to the applications in chemical Industries.

REFERENCE BOOKS

1. *Lawrence H. Van Vlack, "Elements of Material Science and Engineering", 1971.*
2. *S. K. Hajra Choudhury, "Material Science and processes", 1st Edn., 1977. Indian BookDistribution Co., Calcutta.*
3. *William D. Callister, "Materials Science and Engineering",7th edn, John Wiley & Sons, Inc.*
4. *V. Raghavan, Materials Science and Engineering, Prentice Hall*

COURSE OUTCOMES

After completion of the course, the students can

CO1	understand the basics knowledge such as internal structure, crystal geometry, crystal imperfection of the engineering materials
CO2	understand the various properties and corrosion behavior of the selected materials in chemical industries
CO3	provide experience in the metallic and nonmetallic material selection and handling material in chemical engineering in the areas of equipment design

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLOE21**
Course Title	**:**	**BIOENERGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**PE**

COURSE LEARNING OBJECTIVES

Gain a comprehensive understanding of the principle of generation of energy from biomass.

COURSE CONTENT

Biomass characteristics & preparation: Biomass sources and classification. Chemical composition and properties of biomass. Energy plantations. Size reduction, Briquetting of loose biomass, Drying, Storage and handling of biomass.

Biogas technology: Feedstock for producing biogas. Aqueous wastes containing biodegradable organic matter, animal residues sugar rich materials. Microbial and biochemical aspects and operating parameters for biogas production, Kinetics and mechanism. Dry and wet fermentation,Digestors for rural application-High rate digesters for industrial waste water treatment.

Pyrolysis and thermos-chemical conversion: Thermo-chemical conversion of ligno-cellulose biomass. Incineration for safe disposal of hazardous waste, Biomass processing for liquid fuel production, Pyrolysis of biomass-pyrolysis regime, effect of particle size, temperature, and products obtained.

Gasification of biomass: Thermochemical principles: Effect of pressure, temperature and of introducing steam and oxygen. Design and operation of Fixed and Fluidised Bed Gasifiers, Safety aspects.

Combustion of biomass and cogeneration systems: Combustion of woody biomass-theory, calculations and design of equipment, Cogeneration in biomass processing industries. Case studies: Combustion of rice husk, Use of bagasse for cogeneration.

REFERENCE BOOKS

1. *A.Chakraverthy, Biotechnology and Alternative Technologies for Utilisation of Biomass orAgricultural Wastes, Oxford & IBH publishing Co., New Delhi, 1989.*
2. *K.M.Mital, Biogas Systems: Principles and Applications, New Age International Publishers(p) Ltd., 1996.*
3. *P.VenkataRamana and S.N.Srinivas, Biomass Energy Systems, Tata Energy Research Institute, New Delhi, 1996.*
4. *D.L. Klass and G.M. Emert, Fuels from Biomass and Wastes, Ann Arbor Science publ. Inc.Michigan, 1985.*
5. *George J Banward, Basic Food Microbiology, CBS Publishers, New Delhi, 1987.*
6. *Lindsay, Biotechnology challenges for the flavour and food industry, Elsevier Applied Science, 1988.*
7. *H.G.Muller, An Introduction to Tropical Food Science, C L P Edition, Cambridge University Press, 1989.*

COURSE OUTCOMES

On completion of the course, the students will be familiar with

CO1	understanding of availability of biomass feedstocks and their potential attributes to biofuels production.
CO2	evaluation of methodologies for biomass preparation.
CO3	concepts of the second and third generation of bioenergy, and the conversion processes of biomass feedstock to biofuels.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLMI10**
Course Title	**:**	**CHEMICAL PROCESS CALCULATIONS**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**MI**

COURSE LEARNING OBJECTIVES

1. To give students fundamental knowledge on Unit processes and Unit operations, Units and conversions and also the basic laws governing chemical operations.
2. To impart knowledgeable on material and energy balance with and without reactions

COURSE CONTENT

Basics of Unit operations and Unit processes. Units and Dimensions.

Stoichiometric principles –composition relations, density and specific gravity. Behaviour of Ideal gases - application of ideal gas law - gaseous mixtures - volume changes with change in composition.

Vapour pressure - effect of Temperature on vapour pressure - vapour pressure plots - vapour pressure of immiscible liquids - solutions. Humidity and Solubility: Humidity - saturation - vaporization - wet and dry bulb thermometry.

Material Balance - Processes involving chemical reaction - Combustion of coal, fuel gases and sulphur - Recycling operations - bypassing streams - Degree of conversion – excess reactant - limiting reactant. Unsteady state problems

Energy Balance: Thermo chemistry - Hess's law of summation - heat of formation, reaction, combustion and mixing - mean specific heat - Theoretical flame Temperature.

REFERENCE BOOKS

1. *O. A .Hougen, K. M. Watson and R. A. Ragatz, "Chemical Process Principles", Vol- I, CBS Publishers and Distributors, New Delhi, 1995.*
2. *V.Venkataramani, N.Anantharaman and K.M. Meera Sheriffa Begum, 2nd Edn., 'Process Calculations' Prentice Hall of India Ltd, New Delhi. 2013*
3. *B. I. Bhatt, "Stoichiometry", 5th Edn., Tata McGraw Hill Publishers Ltd., New Delhi, 2010.*
4. *Himmelblau, "Basic Principles and Calculations in Chemical Engineering", 8th Edn.,Prentice Hall of India Ltd, India 2012.*

COURSE OUTCOMES

On completion of the course, the student will have

CO1	the capability to understand the need for study of unit operations and processes. Convert units and dimensions and also modify equations from system to another.
CO2	the capability to apply the laws of physics and chemistry in solving process industry related applications.
CO3	proficiency to integrate the data and formulate the mass and energy balanceproblems.
CO4	the capability to use mathematical knowledge for solving mass and energy balance problems with and without chemical reactions.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLMI11**
Course Title	**:**	**TRANSFER OPERATIONS - I**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**MI**

COURSE LEARNING OBJECTIVES

1. To impart the fundamental concepts of fluid statics, pressure distribution and dimensional analysis
2. To enable students to compute velocity profile, friction factor and head loss in pipes and fittings
3. To impart the knowledge of metering and transportation of fluids and fluid moving machinery performance
4. Understand basic principles of particle preparation and their characterization
5. Understand the performance of different equipments for separation of solids and size reduction

COURSE CONTENT

Properties of fluids and concept of pressure: Introduction - Nature of fluids - physical properties of fluids - types of fluids. Fluid statics: Pressure - density - height relationships. Pressure Measurement. Units and Dimensions - Dimensional analysis

Momentum Balance and their Applications: Kinematics of fluid flow: Stream line -stream tube - velocity potential. Newtonian and non-Newtonian fluids - Time dependent fluids - Reynolds number - experiment and significance - Bernoulli's equation - Correction for fluid friction - Correction for pump work.

Flow of Incompressible Fluids Through Ducts: Flow of incompressible fluids in pipes - laminar and turbulent flow through closed conduits - velocity profile & friction factor for smooth and rough pipes - Head loss due to friction in pipes, fitting etc. Transportation and Metering:Measurement of fluid flow: Orifice meter, venturi meter, pitot tube, rotameter

Characteristics of Particulate Material: Properties and characterisation of particulate solids, analysis and technical methods for size and surface area distribution of powder; Flow properties of particulates. Introduction to size reduction equipment, energy and power requirement in milling operations.

REFERENCE BOOKS

1. Mc Cabe and J.C.Smith," Unit Operation of Chemical Engineering", 7th Edn., McGrawHill., New York, 2004.
2. M. Coulson and J.F .Richardson, "Chemical Engineering", Vol. II, 5th Edn., Butterworth - Heinemann, 2002.

COURSE OUTCOMES

On completion of the course, the student can

CO1	understand the fundamental concepts in fluids statics and to use dimensional analysis for scaling experimental results
CO2	able to analyze frictional flow in pipes and piping networks and to compute the head loss and power requirements for chemical process equipments
CO3	able to select the metering equipments and fluid moving machinery for an appropriate chemical engineering operations
CO4	understand the basic principles of particles preparation and their characterization
CO5	have knowledge on different size reducing equipment and power requirements during size reduction

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLMI12**
Course Title	**:**	**TRANSFER OPERATIONS - II**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLMR11**
Course Type	**:**	**MI**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of transfer operations.
2. To understand the transfer operations and equipments in process industries.

COURSE CONTENT

Principles of Mass transfer: Fick's law of diffusion, unsteady state diffusion, Convective mass transfer, Inter phase mass transfer and mass transfer coefficients, Mass transfer theories. Equilibrium stages and transfer units, Equipments-Plate and Packed columns, stage efficiency.

Unit Processes in Mass Transfer: Principle and theory of Gas absorption, Distillation- Types of distillation, continuous fractionation, Liquid-Liquid extraction, Leaching, Adsorption.

Basic concepts of heat Transfer: Heat conduction, types and governing equation, natural and forced convection heat transfer coefficient, thermal boundary layer, laws of thermal radiation, shape factor, radiation shield, greenhouse effect.

Unit Processes in Heat Transfer: Concept of overall heat transfer coefficient, types of heat exchangers, charts, performance analysis of heat exchangers.

Simultaneous Heat and Mass Transfer: Humidification- cooling towers, Drying, Crystallization- Super saturation theory, crystallizers, evaporators and condensers.

REFERENCE BOOKS

1. *R. E. Treybal, "Mass Transfer Operations", 3rd Edn., McGraw Hill Book Co., New York, 1981.*
2. *W. L. Mccabe, J. C. Smith and P. Harriot, "Unit Operations in Chemical Engg.",7th Edn., McGraw Hill Book Co., New York, 2004.*
3. W.L.Badger and J.T.Banchero, "Introduction to Chemical Engineering", *McGraw Hill Book Co., New York, 1955.*
4. *Binay. K. Dutta, "Heat Transfer Principles and applications" Prentice Hall of India Pvt.Ltd., 2003.*
5. *D.Q. Kern," Process Heat Transfer," McGraw Hill Publishing Co., 1950.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	acquire sufficient knowledge in the concepts of heat and mass transfer operations
CO2	able to analyze the transfer operations and apply in the process industries
CO3	able to develop skills in operating the transfer equipments in Process industries

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLMI13**
Course Title	**:**	**CHEMICAL REACTION ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLMI10, CLMI11, CLMI12**
Course Type	**:**	**MI**

COURSE LEARNING OBJECTIVES

1. To understand and appreciate thermodynamics as applied to various Chemical EngineeringProcesses
2. Build up the concepts to analyze kinetic data and determine the rate expression for a reaction
3. This course will guide students to make use of key concepts and techniques of chemical kinetics and reactor design

COURSE CONTENT

Heat capacity- P-V-T Behavior of Pure fluids –Equations of state and limiting conditions for equations of state for real gases-Heat effects accompanying chemical Reactions

Phase Equilibria and Chemical Reaction Equilibria - Criteria for phase equilibrium, Criterion of stability, Phase equilibria in single and multiple component systems, Duhem's theorem, VLE for Ideal solutions, Calculation of activity coefficients- Reaction stoichiometry-Equilibrium constant- Feasibility of reaction- Effect of temperature, pressure, volume and other factors-Simultaneous Reactions

Basics of Kinetics: Introduction - kinetics of homogeneous reactions: Concentration dependent& Temperature dependent term of rate equation, Searching for a mechanism. Interpretation of Batch Reactor data.

Reactor Design: Introduction to Reactor Design. Single Ideal Reactors

Design of Multiple Reactor system for single reactions. Recycle reactor, auto catalytic reactions.

REFERENCE BOOKS

1. *J.M. Smith, Hendrick Van Ness, Michael M. Abbott, "Introduction to Engineering Thermodynamics", McGraw Hill, New York, 2005.*
2. *K.V.Narayanan, "A Textbook of Chemical Engineering Thermodynamics", PHI Learning, 2004.*
3. *O. Levenspiel, "Chemical Reaction Engineering", 3rd Edn., Wiley Easter Ltd., New York,1999*
4. *B.F. Dodge, "Chemical Engineering Thermodynamics", McGraw Hill, New York, 1971.*
5. *J.M. Smith, "Chemical Engineering Kinetics", 3rd Edn., McGraw Hill, New York, 1981.*
6. H. Scott Fogler, *Elements of Chemical Reaction Engineering*, 4th Edn., Prentice Hall of India Ltd.,2008

COURSE OUTCOMES

On completion of the course, the student can

CO1	understand the calculation of heat capacities and heat effects accompanying chemical reactions
CO2	gain the knowledge on equilibrium states for mixture of gases, phases and chemical reaction.
CO3	understand the fundamentals of chemical kinetics, reaction mechanism and factors affecting reaction
CO4	have knowledge on ideal reactor design and reactor combination and reactor trouble shooting.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLMI14**
Course Title	**:**	**CHEMICAL TECHNOLOGY**
Number of Credits	**:**	**3**
Prerequisites	**:**	**NONE**
Course Type	**:**	**MI**

COURSE LEARNING OBJECTIVES

1. To impart the basic concepts of chemical technology.
2. To develop understanding about unit process and unit operations in various industries.
3. To learn manufacturing processes of organic and Inorganic Chemicals and its applications.

COURSE CONTENT

Natural Products Processing: Production of pulp, paper and rayon, Manufacture of sugar

Petroleum and Petrochemicals: Characteristics, Fuels/chemicals from petroleum and petrochemicals, Primary and Secondary processing, Treatment techniques and applications. Building blocks of the petrochemicals.

Alkalies and Acids: Chlor - alkali Industries: Manufacture of Soda ash, Manufacture of caustic soda and chlorine - common salt. Sulphur and Sulphuric acid: Mining of sulphur and manufacture of sulphuric acid. Manufacture of hydrochloric acid.

Cement Gases, Water and Paints: Types and Manufacture of Portland cement, Glass:

Industrial Gases: Carbon dioxide, Nitrogen, Hydrogen, Oxygen and Acetylene - Manufacture of paints – Pigments

Fertilisers: Nitrogen Fertilisers; Synthetic ammonia, nitric acid, Urea, Phosphorous Fertilisers: Phosphate rock, phosphoric acid, super phosphate and Triple Super phosphate

REFERENCE BOOKS

1. *G.T. Austin, N. Shreve's Chemical Process Industries", 5th Edn., McGraw Hill, NewYork, 1984.*
2. *W.V.Mark, S.C. Bhatia "Chemical Process Industries volume I and II", 2nd Edition 2007*
3. *R. Gopal and M. Sittig " Dryden's Outlines of Chemical Technology: For The 21st Century" Third Edition, Affiliated East-West Publishers, 1997*.
4. *S. D. Shukla and G. N. Pandey, "Text book of Chemical Technology" Vol 2, 1984*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to understand the manufacturing process organic and Inorganic materials
CO2	understand the unit operation in process.
CO3	understand various chemical reaction in the process

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLHO10**
Course Title	**:**	**ADVANCED PROCESS CONTROL**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC25**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

Expose students to the advanced control methods used in industries and research. This course prepares the student to take up such challenges in his profession.

COURSE CONTENT

Review of Systems: Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Transient response. Block diagrams.

Stability Analysis: Frequency response, design of control system, controller tuning and process identification. Zeigler-Nichols and Cohen-Coon tuning methods, Bode and Nyquist stability criterion. Process identification.

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, adaptivecontrol, Smith predictor, internal model control, model predictive control.

Multivariable Control Analysis: Introduction to state-space methods, Control degrees of freedom analysis, Interaction, Bristol arrays, Niederlinski index, design of controllers, Tuning of multivariable controllers.

Sample Data Controllers: Basic review of Z transforms, Response of discrete systems to various inputs. Open and closed loop response to step, impulse and sinusoidal inputs, closed loopresponse of discrete systems. Design of digital controllers. Introduction to PLC and DCS.

REFERENCE BOOKS

1. *D.R. Coughanowr and S.E.LeBlanc, 'Process Systems Analysis and Control', Mc.Graw Hill,III Edition, 2009.*
2. *D.E.Seborg, T.F.Edger, D.A.Millichamp and F.J. Doyle III, 'Process Dynamics and Control', Wiley, III Edition, 2013.*
3. *B.A.Ogunnaike and W.H.Ray, "Process Dynamics, Modelling and Control", Oxford Press,1994.*
4. *B.W. Bequette, 'Process Control: Modeling, Design and Simulation', PHI, 2006.*
5. *S. Bhanot, 'Process Control: Principles and Applications', Oxford University Press, 2008.*

COURSE OUTCOMES

Upon completing the course, the students will be able to

CO1	analyze the transient response of a system and perform system identification
CO2	apply the knowledge of stability and perform controller design and tuning
CO3	design various advanced control algorithms for chemical processes having specific problems
CO4	analyze multivariable control systems and tuning of multivariable controllers
CO5	understand the sampled data systems and design of digital controllers

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLHO11**
Course Title	**:**	**ADVANCES IN FLUIDIZATION ENGINEEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC14, CLPC18**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

To learn the principle, technical concepts involved in the analysis and design of Fluidized bed systems

COURSE CONTENT

Applications of fluidized beds: Introduction, Industrial application of fluidized beds, Physical operations and reactions.

Fluidization and analysis of different phases: Gross behavior of fluidized beds. Bubbles in densebeds. The emulsion phase in dense bubbling beds. Flow pattern of gas through fluidized beds

Heat and Mass transfer in fluidized bed systems: Mass and heat transfer between fluid and solid.Gas conversion in bubbling beds. Heat transfer between fluidized bed and surfaces.

Elutriation and entrainment: TD and also distribution of solid in a fluidized bed. Circulation systems

Design of fluidized bed systems: design of fluidization columns for physical operations, catalyticand non- catalytic reactions, three phase fluidization.

REFERENCE BOOKS

1. *Diazo Kunji and O. Levenspiel, "Fluidization Engg". 2nd Ed., Butterworth Heinemann, 1991.*
2. *J. F. Davidson and Harrison, "Fluidization", 10th Ed, Academic Press, London, 1994.*
3. *Jackson, R., "The Dynamics of Fluidized Particles," Cambridge University Press, New York(2000).*
4. *Fan, L.-S. and C. Zhu, Principles of Gas-Solid Flows, Cambridge University Press, NewYork (1998).*

COURSE OUTCOMES

On completion of the course, the student can

CO1	evaluate the fluidization behavior and applications of Fluidized beds.
CO2	able to estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for the fluidized beds.
CO3	able to develop model equations for fluidized beds
CO4	able to design gas• solid fluidized bed reactors.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLHO12**
Course Title	**:**	**PROCESS MODELING AND SIMULATION**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC14, CLPC20, CLPC21**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

To develop mathematical model and dynamic simulator for chemical processes

COURSE CONTENTS

Introduction to process modeling - a systematic approach to model building, classification of models, Conservation principles, thermodynamic principles of process systems.

Development of steady state and dynamic lumped and distributed parameter models based onfirst principles. Analysis of ill-conditioned systems, Models with stiff differential equations.

Development of grey box models, Empirical model building, Statistical model calibration and validation, Introduction to population balance models, multi-scale modeling.

Solution strategies for lumped parameter models and stiff differential equations, Solution methods for initial value and boundary value problems. Euler's method. R-K methods, shooting method, finite difference methods – predictor corrector methods.

Solution strategies for distributed parameter models. Solving parabolic, elliptic and hyperbolic partial differential equations. Introduction to finite element and finite volume methods

REFERENCE BOOKS

1. *K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press,2001.*
2. *W.L. Luyben, "Process Modeling, Simulation and Control for Chemical Engineers", 2 ndEdn., McGraw Hill Book Co., New York, 1990.*
3. *Bruce A. Finlayson, Introduction to Chemical Engineering Computing, Wiley, 2010.*
4. *Amiya K. Jana, Chemical Process Modelling and Computer Simulation, Prentice Hall ofIndia, 2nd Edition, 2011*
5. *Laurene V. Fausett, Applied Numerical Analysis using MATLAB, Second edition, Pearson,2009*
6. *Felder, R. M. and Rousseau, R. W., "Elementary Principles of Chemical Processes", JohnWiley, 2000.*

COURSE OUTCOMES

On completion of the course, the student can

CO1	develop process models based on conservation principles and process data.
CO2	able to apply computational techniques to solve the modeling equations
CO3	apply different methods for parameter estimation
CO4	able to simulate process models using MATLAB/SCILAB

Mapping of Course Outcomes with Program Outcomes

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

Course Code	**:**	**CLHO13**
Course Title	**:**	**PINCH ANALYSIS AND HEAT EXCHANGER NETWORK DESIGN**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC17, CLPC21**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

1. Understanding on Pinch concept, and application to Process Heat Exchange Networking.
2. Identification of Energy Minimization in the Process
3. Retrofitting Concepts and Setting up Targets for Energy Minimization

COURSE CONTENT

Thermodynamical review of the process, Pinch Concept, significance of pinch, pinch in grid representation, Threshold problems, capital cost implication of the pinch.

Targeting: Heat exchanger networks, energy targeting, area targeting, unit targeting, shell targeting, cost targeting, super targeting, continuous targeting.

Pinch Methodology: Problem representation, temperature enthalpy diagram, simple match matrix. Heat content diagram, Temperature interval diagram.

Pinch Design and Optimization: Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch, cp table, the tick of heuristic, case studies, optimization of heat exchanger network optimality for a minimum area network, Sensitivity analysis.

Energy and Resource Analysis of various processes, Batch process, flexible process, distillation process, evaporation process, reaction process, process using mass separating agent. Heat pipes and Heat pumps,

REFERENCE BOOKS

1. *V. UdayShenoy" Heat Exchanger network synthesis" Gulf Publishing Co, USA, 1995*
2. *D.W. Linnhoff et al., "User Guide on Process Integration for the efficient use of Energy", Institution of Chemical Engineers, U.K., 1994.*
3. *James M. Douglas "Conceptual Design of Chemical Process", McGraw Hill, New York, 1988.*
4. *Anil Kumar, "Chemical Process Synthesis and Engineering Design", Tata McGraw HillNew Delhi, 1977.*

COURSE OUTCOMES

On completion of the course, the student can understand

CO1	concept of the Pinch analysis and appreciate the pinch analysis concept and process thermodynamics.
CO2	identification of the minimum energy targets, identification of different choices and constraint during heat exchange networking.
CO3	pinch Methodology for graphical representations.
CO4	pinch design and Optimization.
CO5	strategies for retrofitting existing process plant, integration of energy demands ofmultiple processes.

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLHO14**
Course Title	**:**	**APPLIED MATHEMATICS IN CHEMICAL ENGINEERING**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC19, CLPC20, CLPC21**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

1. Describe chemical engineering processes in mathematical form by employing the appropriatemicroscopic and macroscopic balances
2. Identify if an analytical solution to the differential equations is possible
3. Derive and interpret physically the solution to differential equations amenable to analytical solution

COURSE CONTENTS

Design of engineering experiments: Treatment of experimental data and interpretation of results. Experiments with a single factor: the analysis of variance. Factorial designs. Curve fitting methods, Interpolation and extrapolation.

Formulation of physical problems: Mathematical modelling of chemical engineering processes based on the first principles.

Analytical solutions of equations: Separable forms, homogeneous equations, exact solutions, singular solutions.

Numerical solution of non-linear equations: Linearization of nonlinear equations. Numerical solution of ordinary differential equations: Initial value and boundary value problems. Stiff differential equations. Numerical solution of partial differential equations.

Optimization: Types of optimization problems, optimization of a function of single variable, unconstrained minimization, constrained minimization.

REFERENCE BOOKS

1. *Douglas C. Montgomery, "Design and Analysis of Experiments" John Wiley, 8th Edition, 2012*
2. *Harold S. Mickley, Thomas S. Sherwood, Charles E. Reed, "Applied Mathematics in Chemical Engineering" Tata McGraw Hill Publishing Company Limited, Second Edition, 1975.*
3. *Richard G. Rice & Duong D. D, "Applied Mathematics and Modelling for Chemical Engineers" John Wiley & Sons, 1995.*
4. *Mark E. Davis, "Numerical Methods and Modelling for Chemical Engineers", John Wiley & Sons, 1984.*
5. *S. K. Gupta, "Numerical Techniques for Engineers", Wiley Eastern Ltd., New York, 1995*

COURSE OUTCOMES

On completion of the course, the student can

CO1	apply mathematical concepts and principles for perform the computations
CO2	create, use and analyze graphical representations of mathematical relationships.
CO3	apply mathematics to solve the chemical engineering problems.
CO4	develop mathematical representation for chemical process system

Mapping of Course Outcomes with Programme Outcomes

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

Course Code	**:**	**CLHO15**
Course Title	**:**	**ADVANCES IN HEAT TRANSFER**
Number of Credits	**:**	**3**
Prerequisites	**:**	**CLPC21**
Course Type	**:**	**HONORS**

COURSE LEARNING OBJECTIVES

1. Understanding on the concept of thermal conduction; should be able to get analytical solutions for 2-D steady heat conduction problems by using variable separation method.
2. Understanding of the heat conduction with phase change, and knowing how to solve it.
3. Deep understanding on the governing equations for convection heat transfer; knowing thedimensionless parameters
4. Awareness of the boundary layer theory; Be able to solve the external and internal laminar boundary flow and heat transfer.
5. Understanding of the boiling and condensation mechanism; Thermal performance analysis for a heat pipe.

COURSE CONTENT

Transient Heat conduction, Extended surfaces and generalized expressions for fins or spines. Effectiveness of fins and spines, Temperature - time response of thermocouples and use of transient heat conduction charts.

Convection - Theory and practice. Energy equation for thermal boundary layer over a flat plate. Data analysis for forced and free convection problems, Analogy between heat, mass and momentum transfer.

Heat Transfer with phase change, Boiling and condensation, Boiling Regimes and types of condensation processes, effect of pressure, turbulence and other factors on boiling and condensation heat transfer.

Advances in heat exchanger design: and compact heat exchangers, Heat transfer in liquid metals. Heat transfer in packed and fluidised beds and Heat transfer process in nuclear reactors

REFERENCE BOOKS

1. *James G. Knudsen and Donald L. Katz, "Fluid Dynamics and Heat Transfer", McGraw HillBook Company, 1958.*
2. *Antony F. Mills, “Heat Transfer”, Richard D. Irwin, Inc., 1992, Homewood, IL60430 and Boston, MA021163.*
3. *W. M. Rohsenow and H.Y. Choi,"Heat Mass and Momentum Transfer", Prentice Hall, Inc.,1961.*
4. *W .H. Mc Adams," Heat Transmission", McGraw Hill, New York,1995*

COURSE OUTCOMES

On completion of the course, the student can

CO1	able to solve the 2-D transient heat conduction problems by using variable separation method.
CO2	able to understand and solve conduction, convection and radiation problems
CO3	able to design and analyze reactor heating and cooling systems.
CO4	able to design and analyze the performance of heat exchangers and evaporators.

Mapping of Course Outcomes with Programme Outcomes

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