Department of Chemical Engineering
University of Calcutta

Course structure & Syllabi (with Objectives & Outcomes) for Semesters I to VIII of 4-Year 8-Semester B. Tech Program in Chemical Engineering (CE - Code: 407), University of Calcutta
(with effect from: Academic Year 2024-2025)
Notification No. CSR/92/2024.

(The program structure is appended in continuation of the General Regulations for B. Tech. Degree from the University of Calcutta vide Notification No.: CSR/31/2024)

UNIVERSITY OF CALCUTTA

Notification No. CSR/92/2024

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of her powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 24.09.2024, approved the Course Structure & Syllabus of 4year B.Tech. Programme in Chemical Engineering (CE-code-407), as laid down in the accompanying pamphlet.

The matter was accepted and recommended for approval in the meeting of the Faculty Council in Engineering & Technology, CU, dated. 29.07.2024, Vide Item No.2(vii)

The above shall take effect from session 2024-2025.

26.9.24

SENATE HOUSE

Kolkata-700073

26.09.2024

Prof.(Dr.) Debasis Das

Registrar

Course Structure of
4-Year B. Tech, 1st Semester

Serial No.	Name	Code	Credit	Weekly Load			Total Load
				L	T	P	
1	Communication English, Management and Social Sciences	HU101	03	2	1	0	03
2	Physics-I	PH102	03	2	1	0	03
3	Chemistry-I	CH103	03	2	1	0	03
4	Engineering Mathematics-I	MA104	03	2	1	0	03
5	Basic Electrical Engineering	EE105	03	2	1	0	03
6	Language Lab	HU106	1.5	0	0	3	03
7	Physics Lab -I	PH107	1.5	0	0	3	03
8	Chemistry Lab -I	CH108	1.5	0	0	3	03
9	Basic Electrical Engineering Lab	EE109	1.5	0	0	3	03
	TOTAL		**21**	10	5	11	27

4-Year B. Tech, 2nd Semester

Serial No.	**Name**	**Code**	**Credit**	**Weekly Load**			**Total Load**
				L	T	P	
1	Physics-II/ Chemistry-II#	PH201/CH201	03	2	1	0	03
2	Engineering Mathematics-II	MA202	03	2	1	0	03
3	Engineering Mechanics	ME203	03	2	1	0	03
4	Basic computer Science and Engineering	CS 204	03	2	1	0	03
5	Basic Electronics	BE205	03	2	1	0	03
6	Physics Lab –II/ Chemistry Lab–II#	PH206/CH206	01	0	0	2	02
7	Workshop Practice	ME 207	1.5	0	0	3	03
8	Engineering Drawing	ME 208	1.5	0	0	3	03
9	Computer Programming Lab	CS 209	1.5	0	0	3	03
10	Basic Electronics Lab	BE210	1.5	0	0	3	03
	TOTAL		**22**	10	5	14	29

Total credit in 1st Year considering both, 1st and 2nd semester is 21+22 = 43

For students of Stream CE, CT, PST, JFT will be assigned CH 201 & CH 206 and for students of Stream ECE, CSE, IE, EE, IT, OOE will be assigned PH 201 & PH 206 in 2nd Semester only.

1. **Schedule of Papers and distribution of Credits for the 4-Year B. Tech Semester III to VIII (final) Examination in Chemical Engineering are as follows:**

4-Year B. Tech, 3rd Semester

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Basic Science	BSMA 301	Mathematics III	2	1	0	3	3	100
2	Basic Science	BSTH 302	Thermodynamics	2	0	0	2	2	100
3	Professional Core	PCPT 303	Particle and Fluid Processing Technology	2	1	0	3	3	100
4	Professional Core	PCFM 304	Fluid Mechanics	2	1	0	3	3	100
5	Professional Core	PCMB 305	Material & Energy Balance Computation	2	1	0	3	3	100
6	Professional Core	PCER 306	Energy Resources and their utilization	2	1	0	3	3	100
7	Professional Core	PCFT 307	Fuel Technology Laboratory	0	0	3	3	1.5	50
8	Professional Core	PCMO 308	Mechanical Operation Laboratory	0	0	3	3	1.5	50
			Total	**11**	**6**	**6**	**23**	**20**	**700**

4-Year B. Tech, 4th Semester

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Engineering Science	ESPT 401	Process Thermodynamics	2	1	0	3	3	100
2	Engineering Science	ESSM 402	Engineering and Solid Mechanics	2	1	0	3	3	100
3	Professional Core	PCMS 403	Material Science	2	1	0	3	3	100
4	Professional Core	PCHT 404	Heat Transfer – I	2	1	0	3	3	100
5	Professional Core	PCMT 405	Mass Transfer – I	2	1	0	3	3	100
6	Professional Core	PCNM 406	Numerical Methods in Chemical Engineering	2	1	0	3	3	100
7	Professional Core	PCHL 407	Heat Transfer Laboratory	0	0	3	3	1.5	50
8	Professional Core	PCFF 408	Fluid Flow Laboratory	0	0	3	3	1.5	50
			Total	**12**	**6**	**6**	**24**	**21**	**700**

4-Year B. Tech, 5th Semester

Sl. #	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Professional Core	PCRE 501	Chemical Reaction Engineering – I	2	1	0	3	3	100
2	Professional Core	PCMT 502	Mass Transfer – II	2	1	0	3	3	100
3	Professional Core	PCCT 503	Chemical Process Technology	2	1	0	3	3	100
4	Professional Core	PCPE 504	Project Engineering	2	1	0	3	3	100
5	Professional Elective	PECE 505 / 515	Professional Elective – I	2	1	0	3	3	100
6	Open Elective	OECE 506 / 516	Open Elective – I	2	1	0	3	3	100
7	Professional Core	PCML 507	Mass Transfer Laboratory	0	0	3	3	1.5	50
8	Professional Core	PCPD 508	Process Equipment Design & Drawing	0	0	3	3	1.5	50
9	Mandatory Course (Non-Credit)	MCES 509	Environmental Science	2	0	0	2	0	100
			Total	**14**	**6**	**6**	**26**	**21**	**700***

***Excluding Mandatory (Non-Credit) Course**

4-Year B. Tech, 6th Semester

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Professional Core	PCRE 601	Chemical Reaction Engineering – II	2	1	0	3	3	100
2	Professional Core	PCRE 602	Refinery Engineering	2	1	0	3	3	100
3	Professional Core	PCIC 603	Process Instrumentation & Control	2	1	0	3	3	100
4	Professional Core	PCTP 604	Transport Phenomena	2	1	0	3	3	100
5	Professional Elective	PECE 605 / 615	Professional Elective – II	2	1	0	3	3	100
6	Open Elective	OECE 606 / 616	Open Elective – II	2	1	0	3	3	100
7	Professional Core	PCPS 607	Plant Design and Simulation Laboratory	0	0	3	3	1.5	50
8	Professional Core	PCRT 608	Reaction Engineering & Thermodynamics Lab	0	0	3	3	1.5	50
			Total	**12**	**6**	**6**	**24**	**21**	**700**

After completion of 6th Semester Examination (during the Summer), students will go for Internship/Plant Training.

4-Year B. Tech, 7th Semester

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Professional Core	PCHT 701	Heat Transfer – II	2	1	0	3	3	100
2	Professional Core	PCPC 702	Petrochemicals	2	1	0	3	3	100
3	Humanities	HUEM 703	Economics and Management	2	1	0	3	3	100
4	Professional Core	PCIC 704	Instrumentation and Process Control Lab	0	0	3	3	1.5	50
5	Professional Elective	PECE 705/ 715	Professional Elective – III	2	1	0	3	3	100
6	Open Elective	OECE 706/ 716	Open elective – III	2	1	0	3	3	100
7	Internship in Industry	PIPT 707	Internship/ Plant Training*	6-8 weeks				1.5	100
8	Project Work	PIPW 708	Project Work – I	0	0	6	6	3	100
			Total	**10**	**5**	**9**	**24**	**21**	**750**

***After completion of 6th Semester Examination (during the Summer), students will go for Internship/Plant Training.**

B. Tech, 8th Semester

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
				L	T	P	Total		
1	Professional Core	PCDS 801	Departmental Seminar	0	0	3	3	1.5	100
2	Professional Core	PCAI 802	Analytical Instrument Lab	0	0	3	3	1.5	50
3	Mandatory Course (Non-Credit)	MCIC 803	Indian Constitution	2	0	0	2	0	100
4	Project Work	PIPW 804	Project Work – II	0	0	8	8	6	200
5	Professional Elective	PECE 805/ 815	Professional Elective – IV	2	1	0	3	3	100
6	Open Elective	OECE806/816	Open Elective – IV	2	1	0	3	3	100
7	Project Internship	PIGV 807	General Viva-Voce	---				3	100
			Total	6	2	14	22	18	650*

*Excluding Mandatory (Non-Credit) Course

Elective Papers

Semester V

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
	Any one from the list			L	T	P	Total		
1	Professional Elective – I	PECE 505	Nanotechnology for Energy Harvesting	2	1	0	3	3	100
2	Professional Elective – I	PECE 515	Nanotechnology for Environmental Sustainability	2	1	0	3	3	100
	Any one from the list								
1	Open Elective – I	OECE 506	Biochemical Engineering	2	1	0	3	3	100
2	Open Elective – I	OECE 516	Biotechnology	2	1	0	3	3	100

Semester VI

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
	Any one from the list			L	T	P	Total		
1	Professional Elective – II	PECE 605	Water pollution and Wastewater Management	2	1	0	3	3	100
2	Professional Elective – II	PECE 615	Solid Waste Management	2	1	0	3	3	100
	Any one from the list								
1	Open Elective – II	OECE 606	Polymer Science and Engineering	2	1	0	3	3	100
2	Open Elective – II	OECE 616	Ceramic Materials and Engineering	2	1	0	3	3	100

Semester VII

Sl. #	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
	Any one from the list			L	T	P	Total		
1	Professional Elective – III	PECE 705	Advanced Process Control	2	1	0	3	3	100
2	Professional Elective – III	PECE 715	Computational Fluid Dynamics	2	1	0	3	3	100
	Any one from the list								
1	Open Elective – III	OECE 706	Process Plant Simulation	2	1	0	3	3	100
2	Open Elective – III	OECE 716	Process Modeling and Simulation	2	1	0	3	3	100

Semester VIII

Sl.#	Category	Paper Code	Course	Course hour/Week				Credit	Full Marks
	Any one from the list			L	T	P	Total		
1	Professional Elective – IV	PECE 805	Industrial Hazards & Plant safety	2	1	0	3	3	100
2	Professional Elective – IV	PECE 815	Air Pollution and Control	2	1	0	3	3	100
	Any one from the list								
1	Open Elective – IV	OECE 806	Advanced Separation Processes	2	1	0	3	3	100
2	Open Elective – IV	OECE 816	Interfacial Engineering	2	1	0	3	3	100

2. **Details of Course objectives, Course outcomes, Syllabi and References of the 4-Year B. Tech Semester III to VIII (final) Examination in Chemical Engineering:**

For conducting **- End Semester Examination** (applicable to all Theory papers, including Professional and Open Electives):

- The Examination will be of 3 hours duration.
- There will be at least 2 (two) paper-setters (internal) for each theoretical paper for End Semester Examination and the answer scripts will be examined by at least two Examiners (Internal).
- Each question paper shall consist of 4 (four) compulsory sections giving equal weightage to each individual module of the syllabus. Questions shall be set taking all the course outcomes specified for the paper.

Semester III

		L	T	P	Total	Credit
Paper Name: **Mathematics III**		L	T	P	Total	Credit
Paper Code: **BSMA 301**		2	1	0	3	3
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Mathematics I and II

Course Objectives: To introduce students to the statistical interpretation of data.
To understand the importance of statistical methods in to engineering.

Course outcomes:

Students completing the course will be able to:

CO1	Demonstrate the knowledge of probabilistic approaches to solve wider angel of engineering problem.
CO2	Recognize various probability distribution functions to quantify physical and engineering phenomenon.
CO3	Apply sampling methods in engineering problems.
CO4	Use correlation & regression in solving engineering problems.
CO5	Solve problems in terms of graphs and trees.
CO6	Use large flow networks.

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Importance of statistics in science and engineering, Collection and classification of data; graphic representation of data; **(1L)**

Measures of central tendency: mean, median and mode; **(1L+1T)**

Measures of dispersion: range, quartile and semi-inter quartile range, mean deviation, standard deviation, variance, coefficient of variation; **(1L+1T)**

Idea of statistical moments- skewness and kurtosis. **(1L)**

Probability theory: Definitions and basic theorems, sample points and sample space, unions, intersection & complements, independent events, Baye's theorem; random variable. **(1L+1T)**

Discrete probability distribution function, moment generating function, repeated trials, standard discrete distributions and the properties: Binomial distribution, Poisson distribution, geometric and hyper-geometric distributions. **(2L)**

Module II **(No. of classes: 10)**

Continuous probability distributions: probability density function; cumulative distribution function; **(1L)**

Normal distribution: properties and applications, probable error, normal approximation to binomial distribution; **(2L+1T)**

Rectangular, gamma, exponential and Weibull distribution; **(1L+1T)**

Two-dimensional distributions and marginal distributions; **(1L+1T)**

Functions of random variables, addition of means and variances. **(3L)**

Module III **(No. of classes: 10)**

Mathematical statistics: Introduction; random sampling point, estimation of parameters: maximum likelihood method; confidence intervals; **(2L+1T)**

Testing of hypothesis: one-sided and two-sided alternatives, errors in test, test for μ of the normal distribution with known and unknown σ^2, comparison of means & variances; **(2L)**

Quality control: control charts for mean, variance, standard deviation and range; acceptance sampling: errors and rectifications; goodness of fit: χ^2-test; nonparametric tests; **(1L+1T)**

Correlation and regression: Definition, significance and properties of correlation coefficient. **(2L+1T)**

Module IV **(No. of classes: 10)**

Graph theory: Introduction to graphs and digraphs; computer representation; **(1L)**

Shortest path problems; Bellman's principle, Dijkstra's algorithm for shortest path; **(1L+1T)**

Shortest spanning trees: Greedy- Krushkal's and Prim's algorithm; **(2L+1T)**

Flows in a networks, flow augmenting paths, cut sets; maximum flow: Ford-Fulkerson algorithm; **(2L+1T)**

Bipartite graphs :maximum cardinality matching, augmenting path theorem. **(1L)**

Suggested Text/Reference Books:

1. E. Kreyszig, Advanced Engineering Mathematics, Wiley-India.
2. Yuri A.W.Shardt, Statistics for Chemical and Process Engineers- A Modern Approach, Springer.
3. B.S.Grewal and J.S.Grewal, Higher Engineering Mathematics, Khanna Publishers.
4. J.Bird, Higher Engineering Mathematics, Elsevier.
5. N.Deo, Graph Theory with Applications to Engineering and Computer Science, PHI.
6. J.Morrison, Statistics for Engineers,Wiley.

Paper Name: Thermodynamics		L	T	P	Total	Credit
Paper Code: BSTH 302		2	0	0	2	2
	Total Contact Hour = 28					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Mathematics I & II, Chemistry I & II

Course Objectives: Principles and application of first and second law of thermodynamics, and phase equilibria. Calculation of work output from different types of power cycles, Discussion of liquefaction, refrigeration systems

Course outcomes:

Students completing the course will be able to

CO1	Explain different type of refrigeration and liquefaction process
CO2	Apply mass and energy balances to closed and open systems
CO3	Brief description of phase equilibrium
CO4	Calculation work output from different thermodynamics process
CO5	Evaluate the properties of non-ideal gases
CO6	Solve problems involving liquefaction, refrigeration and different power cycles.

Course Contents:

Module I **(No. of classes: 7)**

Introduction: The scope of thermodynamics; temperature, pressure, volume, work, energy and heat; internal energy; first law of thermodynamics; state functions; path variables; enthalpy; equilibrium; Gibbs phase rule; idea of reversibility; heat capacities. Different standard thermodynamic processes: isothermal, isochoric, isobaric, adiabatic. **(4L)**

Volumetric properties of pure fluids: Representation of P-V-T behavior; ideal gas law, cubic equations of state (Van der Waals Equation, Redlich-Kwong equation, Soave Redlich-Kwong equation, Peng Robinson equation), Virial equation of state; law of corresponding states, acentric factor.

(3L)

Module II **(No. of classes: 7)**

Second law of Thermodynamics: Limitations of the first law of thermodynamics, Statements of second law; heat engine, heat pump and refrigerator with a special emphasis on Carnot cycle; Carnot theorem; entropy; entropy change calculations; Clausius inequality; mathematical statement of second law. **(4L)**

Thermodynamic properties of fluids: property relations for homogeneous phases; Maxwell's equations; canonical variables and generating function; residual property; two phase systems: Clapeyron and Clausius -Clapeyron equations; Antoine equation. **(3L)**

Module III **(No. of classes: 7)**

Thermodynamics of flow processes:

Applications of unsteady state energy equations: filling and draining of tanks; application of steady flow energy equations: duct flow of compressible fluids, flow through nozzles and diffusers; turbines and compressors; heat exchangers and throttling valve. **(4L)**

Joule-Thompson coefficient; inversion curve. **(3L)**

Module IV **(No. of classes: 7)**

Production of power from heat:

Steam power plant: introduction, process description and related calculations for: Carnot cycle; Rankine cycle. **(2L)**

Internal-combustion engines: overview; concept of air standard cycles; Otto, Diesel and Brayton cycle. **(2L)**

Refrigeration and Liquefaction:Refrigeration process: vapor-compression and absorption refrigerator cycles; comparisons of refrigeration cycles; choice of refrigerant; **(1L)**

Liquefaction process: different processes of liquefaction, description, process sequence and calculations of Linde and Claude liquefaction processes. **(2L)**

Suggested Text/Reference Books:

1. J.M. Smith, H.C. Vanness and M.M. Abbot. Introduction to Chemical Engineering Thermodynamics. 7th Edition, McGraw-Hill, 2005.
2. Y.V.C. Rao. An Introduction to Thermodynamics. Universities Press, 2004.
3. Y.A. Cengel and M.A. Boles. Thermodynamics-An Engineering Approach. McGraw-Hill, 2006.
4. B.G. Kyle. Chemical and Process Thermodynamics. Prentice-Hall of India, 1999.
5. B.F.Dodge. Chemical Engineering Thermodynamics. McGraw-Hill, 1944.
6. M J Moran, H N Shapiro, D D Boettner and M B Bailey. Principles of Engineering Thermodynamics. 8th Edition, Willey.

Paper Name: **Particle and Fluid Processing Technology**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCPT 303**	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite: Fluid Mechanics

Course Objectives: To introduce students the numerous industrial operations dealing with the particulate solids and their handling in various unit operations, particle-fluid interactions as well as mechanical operations like sedimentation, filtration, separation of solids and fluids, etc. with their respective industrial applications.

Course outcomes:

Students completing the course will be able to

CO1	Explain various equipments for size reduction used in Chemical Industries.	Understand
CO2	Explain different types of mixing and filtration processes used in Chemical Industries.	Understand
CO3	Demonstrate the principles of liquid-solid, gas-solid, and solid-solid separators	Understand
CO4	Demonstrate the different solid conveying equipment's	Apply
CO5	Calculate the power requirements and crushing efficiencies of different crushers	Apply
CO6	Calculate pertinent parameters for mixing and filtration equipments.	Apply

Course Contents:

Module I **(No. of classes: 10)**

Particulate Solids

Characterization of solid particles, particle shape, particle size, mixed particle sizes and size analysis, specific surface of mixture, average particle size; **(2L+1T)**

Screen analysis: Types, screen effectiveness, differential/cumulative analysis, material balance over screen, screen capacity; Screening equipment. **(2L+1T)**

Size Reduction: Principles, power requirements & crushing efficiency; Empirical relationships: Kick's, Rittinger's & Bond's law with their limitations, Work index; **(2L+1T)**

Equipment: Operating principles, constructional features, capacity & application of crushers & grinder **(1L)**

Module II **(No. of classes: 10)**

Transportation and storage of solids: Overview of conveyors, elevators, storage bin; **(1L)**

Separation based on motion of particles through fluids: Free and hindered settling; Stoke's law & Newton's law regimes of settling; Gravity classifiers; **(2L+1T)**

Sorting classifiers: sink-and-float method, differential settling. **(1L+1T)**

Clarification, flocculation, batch and continuous sedimentation, rate of sedimentation, sedimentation zones; Description and design of Clarifier & Thickener. **(3L+1T)**

Module III **(No. of Classes = 10)**

Mixing: Principles of agitation, agitation equipment; **(1L)**

Flow patterns: prevention of swirling/ vortex, standard turbine design, power consumption, power correlation, significance of dimensionless groups, effect of system geometry, calculation of power consumption in Newtonian liquids. **(3L+2T)**

Solid-solid mixing equipment, Mixing effectiveness & mixing index; Agitator scale up. **(2L+1T)**

Froth Flotation: Theory, operation, types, flotation agents. **(1L)**

Module IV **(No. of Classes = 10)**

Filtration: Theory & principle of solid-liquid filtration, industrial filters, type of filtration; Discontinuous pressure filter: principle and working of filter press, compressible and incompressible filter cakes, **(2L+1T)**

Discontinuous pressure filter: filter medium resistance, constant pressure & constant rate filtration, principles of cake filtration, pressure drop through filter cake, cake washing and filtration cycle; **(2L+1T)**

Continuous filtration, Filter media/aids: Theory & working principle of Continuous vacuum filter (e.g. rotary drum filters); Filter media; Filter aids. Centrifugal Separators: Cyclones, centrifugal decanter. **(3L+1T)**

Suggested Text/Reference Books:

1. J.M.Coulson and J.F.Richardson. Chemical Engineering. Vol 2. Pergamon Press. 3e 1977.
2. C.J.Geankoplis. Transport Processes and Unit Operations. Prentice-Hall India. New Delhi. 3e1997.
3. G.G.Brown and Associates. Unit Operations. John Wiley & Sons, New York. 1950
4. A.S.Foust, L.A.Wenzel, C.W.Clump, L.Maus and L.B.Andersen. Principles of Unit Operations. John Wiley & Sons, New York. 2e 1980.
5. W.L.Badger and J.T.Banchero. Introduction to Chemical Engineering. McGraw-Hill, 1955
6. W.L.McCabe, J.C.Smith and P.Harriot. Unit Operations in Chemical Engineering. McGraw Hill.4e, 1984.
7. M. J. Rhodes. Introduction to Particle Technology. 2nd Edition, John Wiley, Chichester; New York, 2008.
8. T.Allen. Powder Sampling and Particle Size Determination. Elsevier, 2003.
9. H.Masuda, K.Higashitani and H.Yoshida. Powder Technology Handbook. CRC, Taylor and Francis, 2006.

Paper Name: **Fluid Mechanics**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCFM 304**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Mathematics, Engineering Mechanics

Course Objectives: To introduce the mechanics of fluids (fluid statics and fluid dynamics), relevant to Chemical Engineering operations.

Course outcomes:

Students completing the course will be able to:

CO1	Understand Boundary layer separation and properties	Understand
CO2	Understand Packed bed void fraction, sphericity and drag	Understand
CO3	Calculate pressure drop and frictional loss during flow of fluid	Apply
CO4	Correlate flow rate and pressure drop in different Flow meters	Apply
CO5	Calculate Static and Fluidized bed pressure drops and fluid velocity	Apply
CO6	Apply relevant equations for Pump head and power calculations	Apply

Course Contents:

Module I **(No. of classes: 10)**

Fundamentals: Definition of fluid and scope of the subject; assumptions; approaches of fluid mechanics: Lagrangian and Eulerian; concept of field variables, dimensionality of flow; flow visualization. **(2L+1T)**

Stress as second order tensor; concept of viscosity: Newtonian and non-Newtonian fluids; flow classifications: viscous and inviscid, laminar and turbulent, compressible and incompressible, internal and external; idea of boundary layer flow. **(2L+1T)**

Fluid Statics: Fundamental equation of fluid statics; manometer calculation; force on submerged objects; fluid in rigid body motion. **(3L+1T)**

Module II **(No. of classes: 10)**

Internal flow: Introduction to differential control volume; continuity equation; kinematics of fluid: acceleration, rotation, linear deformation, angular deformation; force balance over differential control volume. **(2L+1T)**

Navier-Stokes equation; introduction to internal incompressible flow; concept of entrance length; laminar flow between parallel plates and circular pipe, Hagen-Poiseuille equation, relation between average and maximum velocity. **(2L+1T)**

Introduction to turbulent flow in a pipe,-; energy consideration in pipe flow, , Bernoulli's equation, kinetic energy correction factor; head loss; friction factor, Moody diagram, major and minor losses, pipe fittings and valves, equivalent diameter. **(3L+1T)**

Module III **(No of Classes = 10)**

Flow measurement: Introduction; general equation for internal flow meters; Orifice meter; Venturimeter; Weirs, concept of area meters: rotameter; Local velocity measurement: Pitot tube. **(3L+1T)**

Hot wire anemometer, mass flow meter.

Resistance of immersed bodies-concept of drag and lift; variation of drag coefficient with Reynolds number; stream-lined body and bluff body **(2L+1T)**

Packed bed; concept of sphericity; Ergun equation, modified friction factor. **(2L+1T)**

Module IV **(No of Classes = 10)**

Fluidization: Introduction; different types of fluidization; minimum fluidization velocity; governing equation; pneumatic conveying and other industrial uses. **(2L+1T)**

Fluid moving machines- Basic classification of pumps: Non-Mechanical Pumps—acid egg, steam jet ejector, air lift pump; Mechanical pump: Centrifugal pumps-cavitation, NPSH, Positive displacement pumps (rotary, piston, plunger, diaphragm pumps). **(3L+1T)**

Pump specification; basic characteristics curves for centrifugal pumps; Fan, blower and compressor. **(2L+1T)**

Suggested Text/Reference Books:

1. M. White, Fluid Mechanics, 8th Edition, Tata-McGraw Hill, 2016.
2. V. Gupta and S. K. Gupta, Fundamentals of Fluid Mechanics, 2nd Edition, New Age International 2011.
3. W. L. McCabe, J. C. Smith and P. Harriot, Unit Operations of Chemical Engineering, 7th Edition, McGraw-Hill International Edition 2005.
4. O. Wilkes, Fluid Mechanics for Chemical Engineers, Prentice Hall of India, 2005.
5. R. W. Fox, P. J. Pritchard and A. T. McDonald, Introduction to Fluid Mechanics, 7th Edition, Wiley-India 2010.
6. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat and Mass Transfer, 4th Ed.,Wiley (2007).
7. B. R. Munson, D. F. Young, T. H. Okiishi and W. W. Huebsch, 6th Edition, Wiley-India 2010.
8. R. L. Panton, Incompressible Flow, 3rd Edition, Wiley-India 2005.
9. R. B. Bird, W. E. Stewart and E. N. Lightfoot, Transport Phenomena, 2nd Edition, Wiley-India 2002.

Paper Name: **Material & Energy Balance Computation**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCMB 305**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry -I & II

Course Objectives: The course will serve as a basis for all further chemical engineering courses where the conservation of materials and energy are manifested.

Course outcomes:

Students completing the course will be able to

CO1	Recapitulate fundamentals of units and dimension, memorize the mole and molecular weight of gases, vapours and liquids. State the gas laws, partial pressure, vapour pressure, Raoults law, saturation and psychometric	Understand
CO2	Explain and classify the material balance without chemical reaction and explain the material balance of different unit operations.	Understand
CO3	Apply, develop the material balance equation for different unit operations	Apply
CO4	Understanding of mass and energy balance with chemical reaction involved in various chemical processes	Understand
CO5	Solve problems using mass and energy balances for steady and unsteady state conditions	Apply
CO6	Prepare flow-sheet and calculate relevant heat and mass associated with chemical reactions, and involving concepts like recycle, bypass and purge.	Understand

Course Contents:

Module I **(No. of classes: 10)**

Introduction to Chemical Engineering calculations, units and dimensions. **(1L)**

Conversion of Equations, Systems of Units, Mole Fraction and Mole Percent, Mass Fraction and Mass Percent, Volume Fraction and Volume Percent, Basis, Equation of Ideal Gas Law. **(2L+1T)**

Partial Pressure, Raoult's Law, Definition of Psychometric, Humidity, Relative Humidity/Saturation, Molal Humidity/Saturation, Absolute Saturation/Humidity, Percent Saturation/Humidity, Dry-bulb Temperature, Dew Point. **(2L+1T)**

Mathematical Requisites: Use of log-log and semi-log graph paper, Triangular Diagram, Least Square Method, Curve Fitting, Method of Regression. **(2L+1T)**

Module II **(No. of classes: 10)**

Process Flow Sheet/Flow Diagram, General Material Balance Equation, Classification Material Balance Equation. **(1L)**

Material Balance Equation involving no Chemical Reaction for the following Unit Operations Systems: Distillation, Evaporation, Drying, Absorption, Extraction (Liquid-Liquid and Liquid-Solid), Filtration, Mixing/Blending, Crystallization **(3L+2T)**
Definition of Recycle, Bypass, Purge along with Material Balance alongwith Process Flow Sheet/Diagram. **(2L+2T)**

Module III **(No. of classes: 10)**
Material Balance with Chemical Reaction: Single Reaction, Multiple Reactions **(2L+1T)**
Simple oxidation reaction, Calculation of Excess Air **(1L+1T)**
Calculations involving combustion Reaction of gaseous, liquid and solid fuels **(2L+1T)**
Material Balance of Unsteady State Reaction systems **(2L)**

Module IV **(No. of classes: 10)**
Energy Balance: Enthalpy calculation for systems (single component and multi components) without Chemical Reaction with Mean and Temperature dependent Heat Capacity **(1L+1T)**
Enthalpy calculation for systems with Chemical Reactions **(2L)**
Heat of Reaction from Heat of Formation and Heat of Combustion Data **(2L+1T)**
Hess's Law, Adiabatic Flame Temperature, Theoretical Flame Temperature **(2L+1T)**

Suggested Text/Reference Books:

1. Himmelblau, D. M., Riggs, J. B. "Basic Principles and Calculations in ChemicalEngineering", Eighth Ed., Pearson India Education Services, 2015.
2. Bhatt, B. I., Vora, S. M., "Stoichiometry", Fourth Edition, Tata McGraw Hill PublishingCompany Ltd, 2004.
3. Felder, R. M.; Rousseau, R. W., "Elementary Principles of Chemical Processes", ThirdEdition, John Wiley & Sons, 2000.
4. Hougen, O. A., Watson, K. M., Ragatz, R. A., "Chemical Process Principles, Part-I Material& Energy Balances", Second Edition, CBS Publishers & Distributors, 2004
5. Venkataramani, V., Anantharaman, N., Begum, K. M. MeeraSheriffa, "ProcessCalculations", Second Edition, Prentice Hall of India.
6. Sikdar, D. C., "Chemical Process Calculations", Prentice Hall of India.

Paper Name: Energy Resources and their utilization	L	T	P	Total	Credit
Paper Code: PCER 306	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			Marks
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Basic of Physics, Chemistry, Energy, and Geology
Course Objectives: To make the students aware about different sources of primary energy and their occurrences, discoveries, extraction and processing technologies. Also provide some ideas on future of energy, process technology and their uses. This will enable the students to gain

understanding of general engineering knowledge and how these may be applicable to the alternative energy systems.

Course outcomes:

Students completing the course will be able to

CO1	Understand different sources of energy and recent- Worldwide and Indian energy scenario
CO2	Learn different sources of energy, basic terminology, and characteristic properties of fuels
CO3	Gain knowledge about energy processing technology like coal, crude Oil, nuclear energy, and other renewable energy systems
CO4	Solve mathematical problems of different difficulty levels through tutorials
CO5	Complete design of a fuel processing equipment through assignments/ group task
CO6	Learn industrial and domestic applications of different energy sources

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Primary Energy resources, reserves, production and consumption pattern in India and in the World. **(2L)**

Coal: Origin and formation of coal; **(1L)**

Composition of coal; Properties and testing; Classification of coal, **(1L+1T)**

Coal preparation- washing and blending; Storage of coal; **(1L+1T)**

Coal carbonization; Coal Gasification; Liquid fuels from Coal and Coal Tar Fractions; **(1L+1T)**

Coke Ovens: product and by-product recovery, metallurgical and other uses; **(1L)**

Module II **(No. of classes: 10)**

Crude Oil: Crude oil reservoir and refinery status in India. **(2L)**

Origin, formation, occurrence, and recovery of crude oil; **(2L)**

Composition, evaluation and characterization of crude; **(1L+1T)**

Overview of crude oil refining operation; primary and secondary refining process: basic refinery operation: **(1L+1T)**

Testing of different petroleum products–ASTM test techniques, Octane Number, Cetane Number, Aniline Point and Diesel Index etc. **(1L+1T)**

Module III **(No. of classes: 10)**

Solar Energy: Solar radiation, solar collectors and their utilization, solar thermal systems: Operating principle, applications; Solar Photovoltaic system. **(2L+1T)**

Geothermal Energy: Preliminary ideas of geo thermal energy; type and utilization. **(1L)**

Wind Energy: Operating principles of different types of wind energy mills and utilization. **(1L)**

Tidal energy: Energy from Ocean; type, principle and utilization. Fuel cells: Introduction; different types of fuel cells- construction; operating principles and utilization. **(1L+1T)**

Nuclear Energy: Nuclear fission principles, sources and purification of nuclear fuels, power generation by nuclear reactors, reaction and operation, radioactive waste disposal. **(2L+1T)**

Module IV **(No. of classes: 10)**

Biomass: Classification of biomass; Energy from biomass: combustion, gasification, and Pyrolysis of biomass; Further thermo-chemical processes; Anaerobic/ aerobic digestors for biogas generation; **(3L+1T)**

Biouels- Biodiesels and bio-ethanol production and characteristics; Social and environmental aspects. **(2L)**

Other sources of energy: Coal Bed Methane (CBM); Shale gas; Gas-hydrate; Gasohol sources and synthesis. **(1L+1T)**

Waste to Energy: Classification and Energy recovery from waste. **(1L+1T)**

Suggested Text/Reference Books:

1. Samir Sarkar; "Fuels and Combustion" University Press (India) Private Limited, 3e, 2009.
2. O. P. Gupta; "Elements of Fuels, Furnace and Refractories" Khanna Publishers. 2013
3. D. S. Chauhan and S. K. Srivastava; "Non-Conventional Energy Resources" New Age International (P) Publishers.3e, 2013.
4. John Twidell and Tony Weir; "Renewable Energy Resources" 2nd edition; Taylor & Francis; 2006.
5. Modern Petroleum Refining; B. K. B. Rao Suggested Reference Books
6. S. P. Sharma and Chander Mohan; "Fuels and Combustion" Tata McGraw-Hill, New Delhi, 1987.
7. G. D. Rai; "Non-conventional Energy Sources" Khanna Publishers. 2011.
8. D. Mukherjee and S.Chakrabarti; "Fundamentals of Renewable Energy Systems" New Age International (P) Publishers.1e, 2011.
9. S. A. Kalogirou; "Solar Energy Engineering Processes and Systems" Elsevier.
10. S. P. Sukhatme; "Solar Energy" Tata McGraw-Hill.
11. S. T. Revankar and P. Majumdar, "Fuel Cells: Principles, Design, and Analysis" CRC Press.
12. Ghosh, Tushar, Prelas, Mark; "Energy Resources and Systems" Volume 1: Fundamentals and Non-Renewable Resources; Springer Netherlands; 2009
13. Charles F. Kutscher, Jana B. Milford, Frank Kreith; "Principles of Sustainable Energy Systems" Third Edition, CRC Press, 2018
14. James G. Speight, "The Chemistry and Technology of Petroleum", 4th Edition; First Published 2006, CRC Press

Paper Name: **Fuel Technology Laboratory**		L	T	P	Total	Credit
Paper Code: **PCFT 307**		0	0	3	3	1.5
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total			**50**

Pre-requisite: Basic of Physics, Chemistry, Energy resources and their utilization and knowledge of basic properties and standard of fuels

Course Objectives:
To make the students aware about the specification and characterization required for each type of fuels and to introduce them to the working principles and standard test method of the sophisticated analytical instruments.

Course outcomes:
Students completing the course will be able to:

CO1	Analyze the operation and performance of equipment through group tasks
CO2	Understand the principles and conduct the experiments for determination of properties of different fuels
CO3	Learn basic analytical techniques useful for fuel properties testing, analysis, and calculate characteristic parameter
CO4	Identify the difficulties associated with experimental set through group tasks
CO5	Identify functional groups and the calibration curve of organic/ inorganic compounds
CO6	Analyze the performance of equipment through group tasks

Course Contents:

List of Laboratory Experiments:
[At least six Experiments shall be conducted]

Experiment No.	Name of the Experiment
Experiment No. 01:	Determination of moisture content, volatile matter, fixed carbon and ash content of a coal sample by Proximate Analysis
Experiment No. 02:	Ultimate Analysis of coal and estimation of combustor efficiency based on Orsat Analysis of flue gases
Experiment No. 03:	Determination of ASTM Distillation of Petroleum Products - ASTM D 86
Experiment No. 04:	Determination of Smoke Point of Kerosene - ASTM D 1322
Experiment No. 05:	Determination of Aniline Point of Diesel - ASTM D 611
Experiment No. 06:	Determination of Flash and Fire Point of Petroleum Products by Cleveland Open Cup method - ASTM D56
Experiment No. 07:	Determination of Flash and Fire Point by Petroleum Products by Pensky Martin Closed Cup method - ASTM D56
Experiment No. 08:	Determination of Cloud & Pour Point of Petroleum Products - ASTM D97
Experiment No. 09:	Measurement of consistency of Lubricating Grease by Cone Penetration method - ASTM D217
Experiment No. 10:	Determination of Viscosity Index from Kinematic Viscosity at 40 and 100°C - ASTM D 2270
Experiment No. 11:	Determination of Vapor Pressure of Petroleum Products (Reid Method) - ASTM D 323 99a
Experiment No. 12:	Determination of Dropping Point of Lubricating Grease - ASTM D 556
Experiment No. 13:	Testing and Analysis of solar concentrating collector.
Experiment No. 14:	Preparation and analysis of biodiesel (from vegetable oil).

Suggested Text/Reference Books:

1. Modern Petroleum Refining: B. K. B. Rao
2. Fuels & Combustion: Samir Sarkar
3. Petroleum Refining Engineering: W. L. Nelson
4. Laboratory Manual

Paper Name: Mechanical Operation Laboratory	L	T	P	Total	Credit
Paper Code: PCMO 308	0	0	3	3	1.5
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total		**50**	

Pre-requisite: Process Instrumentation & Control, Particle & Fluid ProcessingTechnology.
Course Objectives: To check and verify some of the basic principles of the two coursesstudiedin respective theoretical papers.

Course outcomes:
Students completing the course will be able to

CO1	Explain the fundamental principles underlying mechanical operation through practical experimentation	Understand
CO2	Explain the fundamental principles underlying process control through practical experimentation	Understand
CO3	Apply various instruments for industrial applications	Apply
CO4	Assess inherent characteristics of control valve	Apply
CO5	Estimate the performances of mechanical operation equipment	Apply
CO6	Assess size reduction equipment for industrial applications	Apply

Course Contents:
List of Laboratory Experiments: [At least 6 (Six) Experiments shall be conducted]

Experiment No	Title of the Experiment
Experiment 01	Determination of 'reduction ratio', 'capacity' and 'energy required' for a Blake Jaw Crusher to crush a solid sample and verification of Kick's Law.
Experiment 02	Determination of 'angle of nip' and 'capacity' of a Roll Crusher.
Experiment 03	Determination of 'specific surface generated', 'energy required', verification of Rittinger's Law and 'critical speed' of a Ball Mill.
Experiment 04	Determination of overall effectiveness of a Sieve Shaker for a given solid sample of unknown size.
Experiment 05	Determination of average particle size of a given solid sample using a Sieve Shaker by (i) random sampling method and (ii) coning and quartering method.
Experiment 06	Determination of the settling and sedimentation characteristics of given slurry and to calculate the area of the thickener.
Experiment 07	Determination of the power number and power consumption for a given liquid in an agitated vessel with baffle.
Experiment 08	Determination of the power number and power consumption for a given liquid in an agitated vessel without baffle.
Experiment 09	Determination of overall efficiency of a Cyclone Separator.

Experiment 10	Determination of the lost quantity of calcium carbonate after filtration of calcium carbonate slurry in a Plate and Frame Filter Press.

End of Semester III

Semester IV

Paper Name: Process Thermodynamics	L	T	P	Total	Credit
Paper Code: ESPT 401	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			Marks
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Thermodynamics-I, Chemistry

Course Objectives: Introduction of the concepts of fugacity, activity coefficient, vapour-Liquid equilibrium and reaction equilibrium.

Course outcomes:
Students completing the course will be able to

CO1	Understanding of fugacity, excess properties, activity coefficient, different thermodynamics model
CO2	Understanding of phase equlibria, chemical reaction equilibria
CO3	Application of residual properties for real gas problem
CO4	Application of Excess properties for real solution problem
CO5	Application of different thermodynamics model
CO6	Application of chemical reaction equilibria

Course Contents:

Module I **(No. of classes: 10)**

Introduction to Solution thermodynamics: fundamental property relations for closed and open systems. **(1L)**

Chemical potential and phase equilibria. **(1L)**

Partial properties: introduction, summability and Gibbs-Duhem equation, graphical interpretation for binary solutions, ideal gas mixture and Gibb's theorem. **(2L+1T)**

Determination of fugacity and fugacity coefficients for pure species from equations of state, determination of residual enthalpy and entropy. **(2L+1T)**

Determination of fugacity & fugacity coefficients for component species in solution. **(1L+1T)**

Module II **(No. of classes: 10)**

Excess properties: standard state and ideal solution; excess properties and activity coefficients; fundamental excess property relation. **(2L+1T)**

Lewis-Radall rule and Henry's law, trends of excess Gibbs energy. **(2L+1T)**

Activity coefficient models for liquid mixtures: semi-empirical models: Margules models, Redlich-Kister model, van Laar model. **(2L)**

Local composition models: Wilson equation, NRTL, UNIQUAC and UNIFAC models; theories for electrolyte solutions. **(1L+1T)**

Module III **(No. of classes: 10)**

Property changes on mixing: property changes on mixing for ideal and non-ideal solutions, heat effects of mixing processes. **(1L+1T)**

Vapor-Liquid equilibrium: introduction; qualitative behavior: P-x-y, T-x-y, P-T and P-T-x-y diagrams, retrograde condensation. **(2L+1T)**

Roult's law and modified Roult's law. **(2L)**

VLE calculations: BUBL-P, DEW-P, BUBL-T and DEW-T; P-T flash calculations: Rashford-Rice function. **(2L+1T)**

Module IV **(No. of classes: 10)**

General phase equilibria: criterion of phase stability: convexity of ΔGmix; Liquid-liquid equilibrium: equilibrium relation, solubility diagram and critical solution temperatures. **(2L)**

Vapor-liquid-liquid equilibrium: VLLE for miscible and immiscible liquids; Solid-liquid equilibrium: equilibrium relation, ideal liquid state, immiscible solid state: eutectic point. **(2L+1T)**

Chemical reaction equilibrium: Estimation of equilibrium constant. Homogeneous reactions. Heterogeneous reactions. **(3L+2T)**

Suggested Text/Reference Books:

1. J.M. Smith, H.C. Van ness and M.M. Abbot. Introduction to Chemical Engineering Thermodynamics. 7th Edn. McGraw-Hill, 2005.
2. Y.V.C. Rao. An Introduction to Thermodynamics. Universities Press, 2004.
3. E. G. de Azevedo and J. Prausnitz. Molecular Thermodynamics of Fluid-phase Equilibria, Prentice-Hall.
4. Ismail Tosun. The Thermodynamics of Phase and Reaction Equilibria. Elsevier.
5. K.V. Narayanan. A textbook of Chemical Engineering Thermodynamics.PHI.
6. S. Sandler. Chemical, Biochemical and Engineering Thermodynamics. 4th Edition, Wiley, India.

Paper Name: **Engineering and Solid Mechanics**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **ESSM 402**	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Physics and Mathematics

Course Objectives: To teach students about the nature of stresses developed in simple geometries such as bars, cantilevers, beams, shafts, cylinders and spheres for various types of simple loads.

Course outcomes:

Students completing the course will be able to

CO1	Explain the basic concepts of resolution and composition of forces
CO2	Identify the condition of equilibrium for beams, truss, or any engineering component
CO3	Demonstrate the advantages and disadvantages of various geometric sections used in engineering design

CO4	Calculate the different stresses and strains occurring in components of the structure
CO5	Demonstrate the deformations such as axial, normal deflections under different loading conditions
CO6	Illustrate the changes required for the higher factor of safety to prevent deformation

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Application of Engineering and Solid Mechanics in chemical industries. **(1L)**

Tension and Compression: Stress, Strain, Elasticity, Elastic limit, Hooke's Law, Young's Modulus, Stress Strain diagram: Working stress. **(2L+1T)**

Classification of materials: Elastic, Plastic, Ductile, Brittle; Stresses and Strains in bars of varying cross sections. Stresses and Strains in statically indeterminate structures, Limit design, Strain energy in tension and compression. Stress concentration in tension and compression members, Thermal stresses and strains. **(2L+1T)**

Tests for mechanical properties of materials: Tensile test, Compression test, Impact test, Fatigue test; Fatigue and stress concentration; Fatigue under compressive stress, Physical properties of materials at high temperature. **(2L+1T)**

Module II **(No. of classes: 10)**

Biaxial Tension & Compression: Biaxial stress, Stresses in thin-walled pressure vessels. Mohr's circle, Riveted and welded joints. **(3L+1T)**

Shear and Torsion: Stress, Modulus of Rigidity, Torsion of a circular shaft, Strain energy in Shear and Torsion. **(2L+1T)**

Torsion of thin-walled tubes: Shaft of rectangular section, Stresses in shaft due to combined bending and torsion, Strain energy and impact loading. **(2L+1T)**

Module III **(No. of classes: 10)**

Stresses in beams: Shear force and bending moment, Relationship between S.F. & B. M; Shear force and bending moment diagrams, Principal stresses in beams; **(2L+1T)**

Bending stresses in beams, Shear stress in bending, Plastic bending of beams. **(1L)**

Beams of two materials: Reinforce concrete beam, Bending of beams of arbitrary cross section, Bending stresses in curved beams, Bending stresses in composite beams. **(2L+1T)**

Deflection of beams: Cantilever: Cantilever with a point load at its free end, Cantilever with a uniformly distributed load, Cantilever with a gradually varying load. **(2L+1T)**

Module IV **(No. of classes: 10)**

Column and Strut: Eccentric loading, Euler's column formula and its limitations, Empirical formula. Representation of imperfection by equivalent eccentricity. **(2L+1T)**

Thin cylindrical and Spherical Shells: Stresses, Change in dimension and volume due to internal pressure, failure, Design; **(2L+1T)**

Thin Spherical Shells: Change in diameter and volume due to internal pressure; **(1L)**

Thick Cylindrical & Spherical Shells: Stresses in single shell & in compound shells **(2L+1T)**

Selected Text/Reference Books

1. S. Timoshenko and D. H. Young. Elements of Strength of Materials, van Nostrand.
2. R. S. Khurmi. Strength of Materials.S.Chand.

Paper Name: Materials Science	L	T	P	Total	Credit
Paper Code: PCMS 403	2	1	0	3	3
Total Contact Hour =40					

Evaluation:

Typeof Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Physics and Chemistry, Basic Electronics

Course Objectives: To familiarize students with different classes of materials, molecular structure of the materials to their physical and chemical properties, and their processing and performance characteristics.

Course outcomes:

Students completing the course will be able to

CO1	Acquire knowledge about classes and structure of materials
CO2	Understand the behavior of materials
CO3	Understand the phases of materials
CO4	Acquire knowledge about characterization, properties, and use in engineering applications of materials.
CO5	Understand fundamentals of Phase rules
CO6	Application of materials selection

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Historic perspective and Materials Science, Properties of materials, Classification of materials. **(1L)**

Structure of materials:

Various types of bonds, crystal geometry, ray diffraction for determining crystal structure: Bragg'slaw **(2L+1T)**

Structure of solid: crystalline and non-crystalline states;

Structures of inorganic solids: ionic and covalent solid, metals and alloys; **(2L+1T)**

Structures of polymers; Defects in crystalline materials **(2L+1T)**

Module II **(No. of classes: 10)**

Thermodynamics, Kinetics and Phase Transformations

Extensive and intensive thermodynamic properties, laws of thermodynamics, **(1L+1T)**

Reaction kinetics, fundamentals of diffusion, phase rule, single-component systems **(1L)**

Phase diagrams of binary systems, Lever rule; phase diagrams of ternary systems, iron-carbon diagram; heat treatment: introduction and purposes; T-T-T Curve. **(3L+1T)**

Phase transformations: Nucleation and growth; applications, precipitation, solidification and crystallization, recovery, re-crystallization and grain growth. **(2L+1T)**

Module III **(No. of classes: 10)**

Corrosion and Degradation of Materials: Mechanisms, classification, Corrosion of metals, Corrosion of ceramics; Degradation of polymers, prevention. **(2L+1T)**

Diffusion: Diffusion Mechanisms and steady state and non-steady state diffusion, Factors that influence diffusion. **(2L+1T)**

Processing of Materials: Heat treatment of ferrous and aluminium alloys; preparation of ceramic powders, sintering; thin film deposition: evaporation and sputtering techniques, and chemical vapour deposition, thin film growth phenomena. **(3L+1T)**

Module IV **(No. of classes: 10)**

Materials characterization and measurements of properties: Different instruments and their principles. Measurements of properties. **(2L+1T)**

Properties of materials with featured applications: Mechanical properties, Electronic properties, Magnetic properties, Thermal properties and Optical properties of materials. **(3L+1T)**

Material Selection, Synthesis & Design. Testing and application of materials for specific purpose **(2L+1T)**

Suggested Text/Reference Books:

1. V. Raghavan, Materials Science and Engineering: A First Course, 5th Edition Prentice Hall India, 2004.
2. S. Upadhyaya and A. Upadhyaya, Material Science and Engineering, Anshan Publications, 2007. R.A.L Jones, Soft Condensed Matter, Oxford University Press, 2002.
3. William D. Callister, David G. Rethwisch, Materials Science and Engineering: An Introduction, Wiley Publisher.
4. B.S. Mitchell, An Introduction to Materials Engineering and Science for Chemical and Materials Engineers, John Wiley & Sons, 2004.

Paper Name: **Heat Transfer – I**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCHT 404**	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Material and Energy Balance Computation, Fluid Mechanics

Course Objectives: Basic Concepts of Heat Transfer
Design and Rating of Heat exchangers.

Course outcomes:

Students completing the course will be able to:

CO1	Understand different heat transfer resistances and coefficients	Understand
CO2	Understand overall heat transfer coefficient, dirt factor, caloric temperature, pressure drops	Understand
CO3	Identify and select type of shell and tube exchanger based on TEMA classification	Apply
CO4	Apply knowledge to calculate LMTD, dirt factor, overall heat transfer coefficient and thermal loads	Apply
CO5	Selection of Shell and Tube passes, calculation of area and pressure drops and verification of selection	Apply
CO6	Preparation of Data Sheet after designing a Shell and Tube heat exchanger	Apply

Course Contents:

Module I **(No. of classes: 10)**

Basic modes of heat transfer; Heat transfer by conduction: One dimensional steady state heat conduction, Fourier's Law, Thermal conductivity **(2L+1T)**

Compound resistance in series; Steady state heat transfer analysis through extended surface; Unsteady state heat conduction with and without heat generation, Concept of thermal diffusivity; **(3L+1T)**

Critical thickness of insulation; One dimensional unsteady state heat conduction- semi -infinite solid: Lumped system analysis; Use of transient – temperature charts. **(2L+1T)**

Module II **(No. of classes: 10)**

Heat transfer by convection: Convection heat transfer mechanism; Forced convection in systems of simple geometrics (plate, cylinder etc.). **(2L+1T)**

Thermal boundary layer; Correlation for heat transfer coefficient: internal flow & external flow, Momentum & heat transfer analogies. **(2L+1T)**

Free convection: concept; Analysis of free convection in hot vertical plate, Corrections of free convection over simple cylinder, sphere etc. **(3L+1T)**

Module III **(No. of classes: 10)**

Heat transfer of fluids with phase change: Introduction; Dropwise and film-type condensation; Film condensation on vertical surface, Nusselt equation; **(1L+1T)**

Condensation outside horizontal and vertical tube bank; Heat transfer to boiling liquid, Analysis of boiling curve, Nucleate boiling mechanism. **(2L+1T)**

Radiation heat transfer: Introduction; Black body radiation, Plank's distribution law, Monochromatic emissive power; Wein's displacement law; **(2L)**

Kirchoff's Law; Emissivity of Solids, Concept of gray body; Radiation exchange between surfaces, Concept of View Factor, Radiation shield; Absorption and emission in a gaseous medium. **(2L+1T)**

Module IV **(No. of classes: 10)**

Heat Exchanger: Classification; Construction of double pipe heat exchanger, shell and tube heat exchanger; **(2L)**

LMTD, LMTD correction factor, Dirt factor, Individual and overall heat transfer coefficient; **(2L+1T)**

Introduction to compact heat exchangers like plate heat exchangers, spiral heat exchangers, finned tube. **(1L)**

Design procedure of shell and tube heat exchanger. **(2L+2T)**

Suggested Text/Reference Books:

1. B. K. Dutta, Heat Transfer Principles and Application, PHI.
2. D. Q. Kern, Process Heat Transfer: MGH
3. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat and Mass Transfer, 4th Ed.,Wiley (2007).
4. McCabe & Smith and Harriot, Units Operations of Chemical Engineering: MGH
5. M. Necati Ozisik, Heat Transfer – A Basic Approach: McGraw-Hill International Edition, Singapore.
6. Holman, J. P., S. Bhattacharya, Heat Transfer, 10th Ed., Tata McGraw-Hill (2011).
7. Bejan, A., A. D. Kraus, Heat Transfer Handbook, John Wiley (2003).

Paper Name: Mass Transfer – I	L	T	P	Total	Credit
Paper Code: PCMT 405	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Material and Energy Balance Computation, Mathematics I, II, III

Course Objectives: To learn the basic concepts of molecular diffusion, convective and inter-phase mass transfer, design of staged and continuous contact equipment, gas-liquid absorption and distillation.

Course outcomes:

Students completing the course will be able to

CO1	Explain the principles of molecular diffusion and convective mass transfer,, theories of inter-phase mass transfer with overall mass transfer
CO2	Explain gas-liquid absorption & stripping, flash & batch distillation, feed quality in binary distillation
CO3	Calculate diffusion coefficients for liquids and gases, analyze the similarity of mass, heat and momentum transfer, estimate individual/ overall mass transfer coefficients, estimate mass transfer rates (with/without reaction)
CO4	Demonstrate the constructional features of various gas-liquid contacting equipment, Hydrodynamic characteristics of stage-wise and continuous equipment
CO5	Calculate the extent of separation achieved and number of theoretical stages required for a given extent of separation using different techniques for packed bed absorber & plate Tower as required for their design
CO6	Calculate the extent of separation achieved and number of theoretical stages required for a binary distillation using McCabe-Thiele and Ponchon-Savarit methods as required for Distillation column design

Course Contents:

Module I **(No. of classes: 10)**

Introduction to mass transfer, concept of concentration, velocity, flux and reference frame; Fick's law and diffusivity; Steady state molecular diffusion through constant area for binary mixture of gases – preliminary idea, Diffusion of A through non diffusing B, Equimolar counter diffusion.

Steady state molecular diffusion through variable area – spherical and cylindrical geometry, tapered tube. **(2L+1T)**

Determination of gas phase diffusivity by Stefan tube method; Liquid phase diffusivity; Determination of liquid phase diffusivity by diaphragm cell method; Correlations for prediction of diffusivities.

Diffusion in solids – porous, crystalline, amorphous, polymers; concept of Knudsen, surface and self- diffusion, permeability. **(3L+1T)**

One dimensional steady and unsteady state molecular diffusion in constant (slab), variable

(sphere and cylinder) area; three dimensional general equation– concept of equation of continuity; multi-component diffusion.
Introduction to convective mass transfer, eddy diffusion and basic concept of mass transfer coefficient. **(2L+1T)**

Module II **(No. of classes: 10)**
Expressions of mass transfer coefficient and their inter-conversion; Dimensionless Numbers in mass transfer and their heat transfer analogues; Determination of mass transfer coefficient–wetted wall column. **(2L+1T)**
Theories for prediction of mass transfer coefficient – Models.- Film theory, Penetration theory, Surface renewal theory, Boundary layer theory; Correlations for prediction of mass transfer coefficient; Analogy of heat, mass and momentum transfer. **(2L+1T)**
Concept of inter-phase mass transfer, Film Theory with chemical reaction; necessity of overall mass transfer coefficient. overall driving forces and overall mass transfer coefficients. **(2L+1T)**
Constructional features of gas-liquid contacting equipment; comparison of plate and packed column; hydrodynamic characteristics of stage-wise and continuous equipment. **(1L)**

Module III **(No. of classes = 10)**
Gas-Liquid absorption and stripping; Concept of equilibrium line and operating line; Limiting solvent rates; Counter-current and Co-current gas-liquid absorption and stripping. **(1L)**
Design of Packed Bed Absorber: Determination of height of packed bed absorber based on individual/overall MTC as well as based on EMCD and DANB; HTU & NTU – development, significance, differences; Determination of number of stages by graphical / numerical integration methods; Determination of NTU – log mean driving force for dilute gases, dilute gases obeying Henry's Law & concentrated gases; Graphical determination of N_{tOG} and N_{tOL} (Baker's Plot); Overall heights of transfer units; Determination of diameter of packed bed absorber. **(3L+2T)**
Design of Plate Tower: Determination of height of plate tower by graphical method, HETP, Pseudo-equilibrium line for determining actual trays graphically. Desirable absorbent properties; Determination of number of stages by Algebraic method: Absorption and Stripping Factors, Kremser Equation, Souders-Brown Equation, determination of number of theoretical stages using Sauders-Brown equation. **(3L+1T)**

Module IV **(No. of classes = 10)**
Basic concept of distillation; Vapour-liquid equilibria, Relative volatility, Ideal solutions: positive and negative deviations from ideality. Differential or Batch distillation, Rayleigh equation, Enthalpy-concentration diagram; Flash or equilibrium distillation; **(2L+1T)**
Continuous rectification of binary systems without heat effects: McCabe-Thiele method for determination of number of plates in a distillation column by graphical method; Introduction to feed quality–q-line, q-lines for different thermal states of feed; Reflux ratio (minimum /total /cold) with importance, Fenske-Underwood methods: determination of minimum reflux ratio and minimum number of plates; Selection of economic / optimum reflux ratio. **(3L+1T)**
Continuous rectification of binary systems with heat effects: Ponchon-Savarit method for determination of number of plates in a distillation column by graphical method. **(2L+1T)**

Suggested Text/Reference Books:

1. B.K.Dutta. Principles of Mass Transfer and Separation Processes.2nd Edition, Prentice Hall of India,2007.
2. R.E.Treybal. Mass Transfer Operations.3rdEdition, McGraw Hill, New Delhi, 1983.
3. E.D.Cussler. Diffusion-Mass Transfer in Fluid Systems. Cambridge University Press,

Cambridge, 1984.
4. A.S.Foust,L.A.Wenzel,C.W.Clump,L.MausandL.B.Andersen. Principles of Unit Operations. 2nd Edition. Wiley, New York, 1980.
5. C.J.Geankoplis. Transport Processes and Unit Operations.3rd Edition.PrenticeHall,India, 1993.
6. B.D.Smith. Design of Equilibrium Stage Processes. McGraw-Hill Inc., US, 1963.
7. W.L.McCabe, J.C.Smith and P.Harriott,Unit Operations of Chemical Engineering,7th Ed., McGraw Hill, 2014

Paper Name: Numerical Methods in Chemical Engineering	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCNM 406	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisite: Mathematics I and II

Course: To introduce students to numerical methods used to solve engineering problems, in particular chemical engineering problems, using numerical methods and computer programming.

Course outcomes:
Students completing the course will be able to

CO1	Explain the outline of different types of equation	Understand
CO2	Explain the different types of equation associated with the different Chemical Engineering fields.	Understand
CO3	Understanding the utility of numerical methods in chemical Engineering	Understand
CO4	Distinguish the different types of equation of numerical methods associated with the different Chemical Engineering fields.	Apply
CO5	Application of different types of equation to find out the solution of Chemical Engineering problems numerically.	Apply
CO6	Demonstrate the application of mathematical methods to solve the Chemical Engineering problems.	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Approximation and Concept of Error & Error Analysis. **(2L)**

Linear Algebraic Equations:

Methods like Gauss elimination, Gauss-Jordon **(2L+1T)**

Matrix inversion, Gauss-Siedel method **(1L+1T)**

Jacobi iteration, Chemical engineering problems involving solution of linear algebraic equations **(2L+1T)**

Module II **(No. of classes: 10)**

Root finding methods for solution on Non-linear algebraic equations: Bisection, Newton-Raphson and Secant methods, Chemical engineering problems involving solution of nonlinear equations **(2L)**

Interpolation and Approximation: Lagrange interpolation, Newton's backward and forward interpolation, linear regression, polynomial regression, least square regression. **(3L+1T)**

Numerical integration: Trapezoidal rule, Simpson's rule, integration with unequal segments, quadrature methods, Chemical engineering problems involving numerical differentiation and integration. **(2L+2T)**

Module III **(No of Classes = 10)**

Numerical Solution of Ordinary and Partial Differential Equations (ODEs and PDEs):

1. Euler method, Modified Euler /Euler's Predictor-Corrector Method. **(2L+1T)**
2. Initial and Boundary Value Problems (ODE-IVPs and BVPs). **(1L)**
3. Runge-Kutta Methods (2nd, 3rd, and 4th order). **(2L+1T)**
4. Finite difference method (Forward, Backward and Central Difference); Solution of a set of ODEs, application in Chemical Engineering systems. **(2L+1T)**

Module IV **(No of Classes = 10)**

1. Characterization of Partial Differential Equations (PDEs). **(1L)**
2. Explicit method for solution of elliptical and parabolic equations **(2L+1T)**
3. Implicit method for solution of elliptical and parabolic equations. **(2L+1T)**
4. Crank-Nicholson method for solution of elliptical and parabolic equations. **(1L+1T)**
5. Convergence and stability criteria. **(1L)**

Suggested Text/Reference Books:

1. S.K.Gupta. Numerical Methods for Engineers. New Academic Science. 2012
2. B.S.Grewal. Higher Engineering Mathematics.
3. S.C.Chapra and R.P.Canale. Numerical Methods for Engineers with Personal Computer Applications. McGraw Hill Book Company. 1985.
4. R.L.Burden and J.D.Faires. Numerical Analysis. 7th Edition, Brooks Coles. 2000.
5. K.E.Atkinson. An Introduction to Numerical Analysis. John Wiley & Sons. 1978.
6. 4. W.H.Press, et al., Numerical Recipes in C: The Art of Scientific Computing, 3rd Edition, Cambridge University Press. 2007.

Paper Name: Heat Transfer Laboratory	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCHL 407	**0**	**0**	**3**	**3**	**1.5**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total		**50**	

Pre-requisite: Heat Transfer -I (PCHT404)

Course Objectives: To verify experimentally some of the fundamental concepts studied in Heat Transfer-I course and to get the feeling of heat exchangers used in process industries.

Course outcomes:

Students completing the course will be able to:

CO1	Experimentally determine the thermal conductivities of materials in different configurations.
CO2	Experimentally determine the heat transfer coefficient under forced convection
CO3	Study heat transfer in a pin-fin and experimentally determine the efficiency of fin
CO4	Study the boiling heat transfer and determine the critical heat flux
CO5	Experimentally determine the parameters of radiation heat transfer
CO6	Be familiar with the heat transfer process in double pipe, shell and tube and plate type heat exchangers

Course Contents:

List of Laboratory Experiments:

[At least six Experiments shall be conducted]

Experiment number	Title
Experiment No.01:	Determination of thermal conductivity and thermal resistance in steady state heat transfer through a composite wall
Experiment No.02:	Determination of thermal conductivity of an insulating powder using conductive heat transfer in spherical geometry
Experiment No.03:	Determination of thermal conductivity of the lagging material of a lagged pipe using steady state heat conduction in cylindrical geometry
Experiment No.04:	Determination of the heat transfer coefficient under forced convection
Experiment No.05:	Study of heat transfer from a pin-fin
Experiment No.06:	Study of boiling heat transfer and determination of critical heat flux in pool boiling
Experiment No.07:	Determination of emissivity of a test plate
Experiment No.08:	Determination of the Stefan-Boltzman constant
Experiment No.09:	Study of parallel and counterflow in a double pipe heat exchanger
Experiment No.10:	Determination of the overall heat transfer coefficient in a 1-2 pass shell and tube heat exchanger
Experiment No.11:	Determination of overall heat transfer coefficient in a plate-type heat exchanger

Paper Name: Fluid Flow Laboratory		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCFF 408		**0**	**0**	**3**	**3**	**1.5**
	Total Contact Hour = 40					

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td rowspan="3">Continuous Assessment</td><td>Assessment of all Practical sessions</td><td>15</td><td rowspan="3">25</td></tr>
<tr><td>Active participation in routine practical classes</td><td>05</td></tr>
<tr><td>Overall conduct, attendance, manners, skills etc.</td><td>05</td></tr>
<tr><td rowspan="4">End Semester Examination</td><td>Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.</td><td></td><td rowspan="4">25</td></tr>
<tr><td>Practical Notebook</td><td>05</td></tr>
<tr><td>Experimental Study</td><td>10</td></tr>
<tr><td>Viva-Voce</td><td>10</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">50</td></tr>
</table>

Pre-requisite: Fluid mechanics
Course Objectives: To check and verify some of the theories in Fluid mechanics experimentally
Course outcomes:
Students completing the course will be able to:

CO1	Analyze the performance of equipment through group tasks	Understand
CO2	Conduct the experiments for determination of fluid behaviours	Apply
CO3	Understand the principles of flow through testing instruments	Understand
CO4	Explain the fundamental principles underlying fluid mechanics through practical experimentation	Apply
CO5	Apply various measuring device for industrial applications	Apply
CO6	To be able to understand the characteristics of pump	Understand

Course Contents:
List of Laboratory Experiments:
[At least six Experiments shall be conducted]

Experiment No.	Title of the Experiment
Experiment No. 01:	Calibration of orifice meter and determination of orifice co-efficient (Co)
Experiment No. 02:	Calibration of venture meter and determination of venturi co-efficient (Cv)
Experiment No.03:	Calibration of v-notch and determination of discharge co-efficient (C_d)
Experiment No. 04:	Determination of combined efficiency of a pump and a motor
Experiment No. 05:	Determination of co-efficient of viscosity of a liquid by capillary flow method
Experiment No. 06:	Determination of viscosity of liquid by falling sphere method
Experiment No. 07:	Determination of loss co-efficient due to losses in pipe fittings, sudden enlargement and contraction
Experiment No. 08:	Studies of pressure drop in packed bed for single phase flow
Experiment No. 09:	Verification of Bernoulli's equation experimentally
Experiment No. 10:	Determination of losses due to pipe friction
Experiment No. 11:	Studies of pipe fittings and valves

Suggested Text/Reference Books:

1. Laboratory Manual

End of Semester IV

Semester V

Paper Name: Chemical Reaction Engineering - I	L	T	P	Total	Credit
Paper Code: PCRE 501	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Material and Energy Balance Computation, Mathematics I, II, III

Course Objectives: This course will discuss kinetics of chemical reactions and give overview of various kinds of reactors. This course will teach students design of multiple reactions, handling of reactions coupled with mass and heat transfer. This course will also teach applications of reactor combinations in order to achieve desired quality and quantity of products.

Course outcomes:

Students completing the course will be able to

CO1	Memorize different rate of reactions and their classifications of elementary and non-elementary reactions, single and multiple reactions.
CO2	Explain how to find the rate equation using integral as well as differential method of analys is for constant and variable volume batch reactors.
CO3	Demonstrate how to apply the design equation in case of different types of reactors.
CO4	Design multiple reactions
CO5	Use reactors or their combinations to achieve optimum quality and quantity of products

Course Contents:

Module I **(No. of classes: 10)**

Fundamentals: Definition of reaction rate; kinetics of homogeneous reaction: concentration-dependent term of a rate equation; reaction classifications: single and multiple reactions, elementary and non-elementary reactions; molecularity and order of reaction. **(1L)**

Non-elementary reactions: classification and kinetics, idea of active intermediates, formulating the rate equation for enzymatic and chain reactions. **(1L)**

Temperature dependent rate equation: Arrhenius law, collision theory, transition- state theory. **(1L)**

Batch reactor analysis: Constant-volume reactor, integral method of analysis: general procedure, zero-order reactions, irreversible first and second order reactions. **(2L+1T)**

Irreversible reactions in parallel, homogeneous and autocatalytic reactions, reversible reactions. **(1L+1T)**

Variable volume batch reactor: Integral method of analysis for zero, first and second-order reactions. **(1L+1T)**

Module II **(No. of classes: 10)**

Flow reactors: Introduction; space-time and space-velocity, ideal flow reactors: continuous stirred tank and plug flow reactors (CSTR and PFR); **(1L)**
Design equations of CSTR, PFR; **(1L+1T)**
Graphical representations of design equations of CSTR, PFR & comparison. **(1L+1T)**
Multiple-reactor systems for single reactions: Series-parallel combinations of PFRs, Identical and different CSTRs in series; infinite nos. of CSTRs in series; **(2L+1T)**
Jone's method; Series-parallel combinations of reactors: optimum sequence; **(1L)**
Recycle reactor: definition of recycle ratio, design equation & the optimum recycle ratio. **(1L)**

Module III **(No. of classes: 10)**

Design for multiple reactions
Reactions in parallel: product distribution, instantaneous and overall fractional yield, point selectivity, overall selectivity; **(1L)**
Product distribution: point selectivity maximization in parallel reactions; **(1L)**
Irreversible first order reactions in series: in batch, PFR and CSTR; **(1L+1T)**
First order followed by zero order reaction & the reverse: in batch, PFR & CSTR; **(1L+1T)**
Irreversible series-parallel reactions: applications; **(1L)**
Denbigh reactions: in batch, PFR and CSTR. **(2L+1T)**

Module IV **(No. of classes: 10)**

Non-isothermal reactor
General energy balance in a reacting system, heat of reaction; **(2L)**
Cases of constant and variable heat capacities; **(1L+1T)**
Non-isothermal continuous flow reactors at steady state: CSTR, adiabatic tubular flow reactor; **(1L+1T)**
CSTR, PFR and batch reactors in unsteady state; **(1L)**
Non-adiabatic reactors: case study; **(1L)**
Multiple steady state: ignition-extinction curve, steady state bifurcation analysis; **(1L+1T)**

Suggested Text/Reference Books:

1. O.Levenspiel, Chemical Reaction Engineering, 3rd Ed., Wiley, 2006.
2. H.S.Fogler, Elements of Chemical Reaction Engineering, 3rd Ed., PHI Learning.
3. J.M.Smith, Chemical Engineering Kinetics, 3rd Ed., McGraw Hill, 1981.
4. L.D.Schmidt, Engineering of Chemical Reactions, 2nd Ed., Oxford University Press, 1998.
5. M.E.Davis and R.J.Davis, Fundamentals of Chemical Reaction Engineering, 1st Ed., McGraw Hill, 2013.

Paper Name: **Mass Transfer – II**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCMT 502**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Mass Transfer - I, Process Thermodynamics

Course Objectives: To introduce complex mass transfer processes and to understand their applications in chemical process industries.

Course outcomes:

Students completing the course will be able to:

CO1	Explain the principles of adsorption, crystallization, chromatography, humidification, extraction and basics of membrane separation processes	Understand
CO2	Explain continuous adsorption, membrane modules, types of chromatographic processes, binary and ternary diagrams of systems	Understand
CO3	Calculate maximum adsorption capacity of an adsorbent and rate of adsorption	Apply
CO4	Solve problems of Leaching operation in single and multiple stages	Apply
CO5	Solve problems of Liquid-Liquid Extraction operation for partially miscible and completely immiscible systems	Apply
CO6	Demonstrate the constructional features and working principles of crystallizers and fixed bed adsorption column in industry	Apply

Course Contents:

Module I **(No. of classes: 10)**

Adsorption: Introduction; commercial adsorbents (activated carbon, molecular sieves, silica gel, activated alumina etc) and their applications; characteristics and properties of adsorbents; adsorbent selection; batch adsorption; adsorption isotherms: Langmuir, Freundlich, BET; heat of adsorption; adsorption equipment, mass transfer zones and breakthrough curves, length of unused bed, design of fixed bed adsorption column; other adsorption equipment; thermal regeneration of adsorbents; pressure swing and temperature swing adsorption; introduction to ion-exchange. **(4L+2T)**

Crystallization: Introduction, solid-liquid phase equilibria, nucleation, growth and distribution of crystals, batch crystallization, crystallizer and its design considerations. **(3L+1T)**

Module II **(No. of classes: 10)**

Humidification and dehumidification processes: Introduction, characteristics of saturated and unsaturated vapor gas mixtures, definitions of Humidities, dry and wet bulb thermometry, Preparation of psychometric chart. **(2L+1T)**

Adiabatic saturation curves, wet-bulb temperature curve, psychrometric ratio and correlations.

Gas-liquid contact, design of humidifiers, dehumidification operation.

Classification of cooling towers, relative advantages and disadvantages; Cooling range and approach; blow down. **(2L+1T)**

Drying: Introduction, drying rate curve, drying mechanism, time of drying from drying rate data, the mechanism of moisture movement during drying.

Classification and selection of dryer.Direct and indirect-heat batch and continuous dryers.

(3L+1T)

Module III **(No of Classes: 10)**

Solid-liquid extraction (Leaching): Introduction, classification of solid-liquid extraction system; solid-liquid contacting equipments; equilibrium relations.

Batch, crosscurrent and counter-current leaching calculations **(3L+1T)**

Liquid-liquid extraction: Introduction, liquid-liquid equilibria, triangular diagram, selectivity and choice of solvents, industrial applications. Crosscurrent and counter-current extractor with miscible and immiscible solvents **(2L+1T)**

Determination of number of equilibrium stages by graphical method; Classification and selection of industrial liquid-liquid extraction equipment **(2L+1T)**

Module IV **(No of Classes: 10)**

Fundamentals of Chromatography: Introduction, Types- Affinity chromatography, Gel permeation chromatography or size exclusion chromatography, Supercritical fluid chromatography, Countercurrent chromatography, Lipid separation by chromatography

Combination of two chromatographic methods, Antibiotic separation by TLC Applications, Instrument and detectors; Performance parameters like selectivity, resolution. Retention Theory, HETP, selectivity, parts of chromatograph instrument, Normal and reversed phase chromatography, Isocratic and gradient modes, **(3L+2T)**

Fundamentals of Membrane separation processes: Introduction, types of membranes and membrane processes, mechanism of membrane transport, modules, Dialysis and haemodialysis, reverse osmosis, ultrafiltration and microfiltration, idea of concentration polarization, gel polarization, membrane fouling and cleaning. **(3L+2T)**

Suggested Text/References Books:

1. B K.Dutta, Principles of Mass Transfer and Separation Processes,2nd edition, Prentice Hall of India,2007
2. R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi, 1983.
3. J. M. Coulson and J. M. Richardson, J. R. Backhurst and J. H. Harker, Chemical Engineering, Vol. 2, 5th Ed., Butterworth-Heinemann.
4. C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, Prentice Hall, India, 1993
5. B.D. Smith, Design of Equilibrium Stage Processes: MGH
6. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, 7thEd., McGraw Hill.
7. J. D. Seader & Ernest J. Henley; Separation process principles, 2nd Edn., Wiley.
8. Baker, R. W., Membrane Technology & Applications, John Wiley and Sons Ltd.

Paper Name: Chemical Process Technology		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCCT 503		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Fluid Mechanics, Mass Transfer-I, Chemical Reaction Engineering – I

Course Objectives: To familiarize students with manufacturing aspects of industrially relevant chemicals

Course outcomes:

Students completing the course will be able to

CO1	Identify different unit operations and unit processes in a given process flow diagram
CO2	Explain manufacturing of various process industries (inorganic acids, glass & ceramics, artificial abrasives, nuclear, petrochemicals & polymer)

CO3	Explain the Indian industrial scenario of above mentioned industries.
CO4	Demonstrate process operations of above mentioned industries.
CO5	Illustrate raw material requirements, process conditions, construction material and operational aspects for the above mentioned industries.
CO6	Assess the potential of above mentioned industries.

Course Contents:

Module I **(No. of classes: 10)**

Inorganic Chemical Industries: Indian scenario, raw materials, principles, process description with process flow diagram, advancement of process technology, major engineering problems and uses with reference to manufacturing of

(a) Sulfuric Acid (Contact & DCDA processes) **(2L+1T)**
(b) Phosphoric acid **(1L)**
(c) Ammonia (Haber and Bosch &Killogg processes) **(2L+1T)**
(d) Caustic Soda (Electrolytic & Membrane) **(1L)**
(e) Soda Ash (Solvay Process) **(1L+1T)**

Module II **(No. of classes: 10)**

Fertilizers: Indian scenario, raw materials, principles, process description with process flow diagram, advancement of process technology, major engineering problems and uses with reference to manufacturing of (a) Urea, NPK and (b) Di Ammonium Phosphate, Single & Triple Super Phosphates **(2L+1T)**

Glass**:-** Introduction, types of commercial glasses, raw materials, chemical reactions, Methods of manufacture (melting, shaping or forming of different variety of glasses, annealing & finishing). **(1L+1T)**

Ceramics & Refractories**:** Introduction, Properties, raw materials, manufacture and variety). **(2L)**

Cement**:** Composition, Raw materials, Dry and Wet processes for manufacturing cement clinker, setting and hardening of cement. **(2L+1T)**

Module III **(No. of classes: 10)**

Oil & Fats: Chemical composition, Consumption pattern, Methods of extracting vegetable oils & animal fats; Process description with process flow diagram for processing of oils (Refining, Bleaching, Hydrogenation & Deodorization); Major engineering problems **(2L+1T)**

Sugar & Starch: Sugar:– Introduction, Different type of raw materials, manufacturing of raw cane-sugar, cane-sugar refining, decolonization-char filtration; Starch:– Introduction, different types of starches, Manufacture of starch, dextrin & dextrose form corn. **(1L+1T)**

Pulp and Paper: Pulp – Definition, Methods of production, details of Sulfate (Kraft) Pulp process, Major engineering problems; Paper – Definition, Types of paper products, Raw Materials, details of methods of production of paper. **(2L)**

Paints & Pigments: Paints**:** Introduction, Constituents, Manufacturing procedures, flowchart with different unit operations, Applications of Paints. Pigments: Introduction, Manufacturing procedures of different Pigments (White, Red, Blue, Yellow, Green, Black & Brown); Applications of Pigments. **(2L+1T)**

Module IV **(No. of classes: 10)**

Fermentation: Industrial Alcohol (ethyl alcohol) – Consumption, Methods of production, details of production of ethyl alcohol from molasses, major engineering problems, economic aspects; CO_2 recovery; Production of absolute alcohol from industrial alcohol. **(2L)**

Petrochemicals: Petrochemical industry feedstocks; Different routes of ethylene production; Manufacturing details of ethylene from steam cracking of naphtha and separation/purification of co-products. **(1L)**
Manufacture of petrochemical products: Formaldehyde, Methanol, Ethylene Oxide, Ethylene glycol; Ethanolamines, Cumene, Ethyl Benzene. **(1L+1T)**
Polymerization: Indian scenario, details of classification, modes of polymerization. Description, raw material and consumptions, operating conditions, catalysts, simplified process flow diagram for manufacture and uses of polymer products:
(a) Polyethylene, HDPE, LDPE, LLDPE; **(2L+1T)**
(b) Polypropylene, SBR, Phenol-Formaldehyde resin, PET Resin. **(1L+1T)**

Suggested Text/Reference Books:

1. M. Gopala Rao and Marshall Sittig. Dryden's Outlines of Chemical Technology. East West Press, 1997.
2. George T. Austin. Shreve's Chemical Process Industries. McGraw-Hill International Editions Series, 1984.
3. P. H. Groggins. Unit Processes in Organic Synthesis. 5th Edition, McGraw-Hill Book Co., NY.1958.
4. S.D.Shukla and G.N.Pandey. A Textbook of Chemical Technology. Vol. 1 (Inorganic). Vikas Publishing House Pvt. Ltd. 1978.
5. S.Venkateswarlu (Ed.). CHEMTECH, Vols. 1 & 2, Chemical Engineering Education Development Centre, IIT, Madras.
6. Jacob A. Moulijn, Michiel Makkee and Annelies E. van Diepen. Chemical Process Technology. 2nd Edition, Wiley, 2013.
7. Kirk – Othmer (Editor). Encyclopedia of Chemical Technology. Wiley. 2004.

Paper Name: **Project Engineering**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCPE 504**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Materials and Energy Balance, General Heat and Mass Transfer, Economics, Management, Process Control

Course Objectives: This course will deliver overview on all stages of process plant construction: from feasibility study to plant commissioning and start-up. It will also teach students different aspects of cost estimation and profitability analysis

Course outcomes:

Students completing the course will be able to

CO1	Explain the life cycle of a project from conceptualization to commissioning via process design engineering, documents and drawings
CO2	Explain the economic, management and financial aspects of chemical process plants with planning, cost estimation, financing and monitoring
CO3	Explaining feasibility and profitability study, design, safety and other design aspects of chemical process plants.
CO4	Construct process flow diagram (PFD), piping and instrumentation (P&ID) and layout drawing; generate equipment and utility specifications
CO5	Prepare feasibility and profitability report for a proposed project
CO6	Construct suitable network diagram for project monitoring

Course Contents:

Module I **(No. of classes: 10)**

Concept of project: Engineering ethics, Concept of project, project development: scale-up and scale-down techniques, role of a project engineer; brief overview of feasibility study: site selection and its various governing factors. **(2L)**

Pre-design costestimation **(1L+1T)**

Basic engineering and process drawing: process description and flow diagram (PFD), P&I diagram **(2L+1T)**

Plant layout, equipment specification, utilities; detailed engineering: specification, drawing, codes and standards, checking and incorporating vendor's information, procurement of equipment and materials, plant Commissioning and start-up. **(2L+1L)**

Module II **(No. of classes: 10)**

Capital cost estimation and control: equity and debt, concept of fixed cost and working cost, calculation of fixed capital investment and working capital investment; gross and net profit, PBT, PAT. Introduction to costing tools. **(3L+1T)**

Simple interest, nominal and effective interest rates, continuous interest, annuities, perpetuity; depreciation, concepts of service life, salvage value and book value, depreciation calculation methods: straight line, multiple straight line, declining balance method, sum-of-the-years digit method and sinking fund method. **(4L+2T)**

Module III **(No. of classes: 10)**

Profitability analysis: Rate of return on investment, internal rate of return, discounted cash flow method, payout period (with and without interest), present worth method, capitalized cost, effect of inflation on profitability. **(4L+1T)**

Alternative investment: Choices among various alternatives, replacements, methods of profitability evaluation for replacements. **(3L+2T)**

Module IV **(No. of classes: 10)**

Optimum design: Analytical and graphical methods, break-even point, optimum production rates, optimum conditions in cyclic operations, optimum economic pipe diameters, optimum flow rate of cooling water. **(2L)**

Basic steps of project: planning, scheduling, allocation, control; project scheduling: bar chart, Gantt chart, milestone chart. **(2L+1T)**

Concepts of network analysis: Critical path method (CPM), calculation of critical path, float, project evaluation and review technique (PERT), statistical distribution associated with PERT. Introduction to planning tools like MS-Project. **(3L+2T)**

Suggested Text/Reference Books:

1. M.S.Peters, K.D.Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw-Hill Inc.
2. R.K.Sinnot, Chemical Engineering Design, Coulson and Richardson's Chemical Engineering Series, Volume 6, Elsevier (Butterworth-Heinemann).
3. E. D. Ludwig, Applied Process Design for Chemical and Petrochemical Plants, Vols. 1, 2, 3, Gulf Publishing.
4. R. Paneerselvam, P.Semthilkumar; Project Management; 2009; PHI Learning Pvt. Ltd. New Delhi; ISBN 978-81-203-3817-3
5. PeterWatermeyer; Handbook for Process Plant Project Engineers; Professional Engineering Publishing Limited; London and Bury St Edmunds, UK; 2002.

Paper Name: **Nanotechnology for Energy Harvesting**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PECE 505** (Professional Elective – I)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry, Physics, Energy Resources

Course Objectives: To impart the knowledge on applications of nanotechnology in the field of energy harvesting applications

Course outcomes:

Students completing the course will be able to

CO1	Comprehend the fundamental principles of nanotechnology and its applications in energy harvesting.
CO2	Know the methods of synthesis of nanomaterials
CO3	Understand the characteristics of nanomaterials
CO4	**Identify** suitable nanomaterials and their properties for various energy harvesting applications
CO5	Analyze the performance and efficiency of nanomaterial-based energy harvesting devices
CO6	Evaluate the design and performance of flexible and wearable energy devices.

Course Contents:

Module I **(No. of classes: 10)**

Fundamentals of Nanotechnology and Energy Harvesting **(1L)**

Basic concepts, properties, and characterization of nanomaterials **(1L+1T)**

Synthesis and fabrication techniques **(1L+1T)**

Principles of energy harvesting: Different forms of energy, Conversion mechanisms and efficiency, Energy storage concepts **(4L+1T)**

Module II **(No. of classes: 10)**
Nanomaterials for Energy Harvesting
Nanomaterials for solar energy harvesting: **(1L)**
Nanostructured semiconductors, Dye-sensitized solar cells, Perovskite solar cells **(2L+1T)**
Nanomaterials for thermal energy harvesting:
Thermoelectric materials and devices, Pyroelectric materials and devices **(2L+1L)**
Nanomaterials for mechanical energy harvesting:
Piezoelectric and triboelectric nanogenerators **(2L+1T)**

Module III **(No. of classes: 10)**
Nanotechnology for Energy Storage
Nanomaterials for batteries:
Lithium-ion batteries, Sodium-ion batteries, Other emerging battery technologies **(2L+1T)**
Nanomaterials for supercapacitors:
Electrode materials and electrolytes. Hybrid energy storage devices **(2L+1T)**
Nanomaterials for hydrogen storage:
Metal hydrides and carbon-based materials **(3L+1T)**

Module IV **(No. of classes: 10)**
Emerging Nanotechnologies for Energy Harvesting **(1L)**
Flexible and wearable energy devices **(1L)**
Energy harvesting from the environment **(2L+1T)**
Nanotechnology for energy efficiency **(2L+1T)**
Environmental and societal impacts of nanotechnology in energy **(1L+1T)**

Suggested Text/Reference Books:

1. Encyclopedia of Nanoscience and Nanotechnology, Nalwa, H.S. (Ed.), American Scientific Publisher (2004)
2. K.K. Chattopadhyay and A.N. Banerjee, Introduction to Nanoscience and Nonotechnology, PHI, 2010.
3. Nanotechnology for Energy Sustainability: Prof. Baldev Raj, Prof. Marcel Van de Voorde, Yashwant Mahajan Dr., 2017, Wiley
4. Energy Harvesting and Storage, Fundamentals and Materials, M. K. Jayaraj, Aldrin Antony, P. P. Subha, 2022, Springer.

Paper Name: **Nanotechnology for Environmental Sustainability**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PECE 515 (Professional Elective – I)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry, Physics, Reaction Engineering

Course Objectives: To impart the knowledge on applications of nanotechnology in the field of Environmental Science and Technology

Course outcomes:
Students completing the course will be able to

CO1	Understand the various types of nanomaterials and their properties
CO2	Know the methods of synthesis of nanomaterials
CO3	Understand the characteristics of nanomaterials
CO4	Analyze the characteristics of nanomaterials
CO5	Explain and estimate the environmental impacts of nanomaterials
CO6	Apply the nanomaterials for environmental remediation and explain related case studies

Course Contents:

Module I **(No. of classes: 10)**

Introduction of nanomaterials; Classification and Nomenclature of Nanomaterials- Nanosized metals and alloys, semiconductors, ceramics - a comparison with respective bulk materials. **(2L)**

Organic semiconductors, carbon nanotubes; Zero-, one-, two-, and three dimensional nanostructures – quantum dots, quantum rods **(1L+1T)**

Size Effect in Nanomaterials: Quantum confinement in semiconductors – particle in a box like model for quantum dots **(1L+1T)**

Origin of charge on colloidal sols, zeta potential, Implications of colloids in making building blocks **(1L+1T)**

Catalytic and photocatalytic properties, Mechanical properties **(2L)**

Module II **(No. of classes: 10)**

Synthesis and characterization of nanomaterials by physical and chemical methods - Physical methods – (like mechanical milling, laser ablation, sputtering, microwave plasma and ultrasonication) **(2L)**

Chemical methods (like reduction and oxidation, hydrothermal, micelles, sol-gel processes, photolysis, radiolysis, and metallo-organic chemical vapor deposition) **(2L+1T)**

Characterization of Nanomaterials: Structural Characterization - XRD, SAXS, SEM, TEM, SPM/AFM; Chemical Characterization – Optical spectroscopy, Electron spectroscopy, Ionic spectrometry **(1L+1T)**

Physical properties – Melting point, Lattice constant, Electrical and magnetic characterization; Mechanical properties – nanoindentaion, nanotribology **(2L+1T)**

Module III **(No. of classes: 10)**

Environmental impacts of nanomaterials - Exposure and risk assessment **(1L)**

Dose-response, mechanisms, toxicity; ecotoxicological impacts of nanomaterials - bioavailability and uptake; assessment of life cycle risk of nanomaterials **(2L+1T)**

Analytical methodologies for studying impact of nanomaterials in environment – atomic absorption spectrometry, inductively coupled plasma spectrometry, hyphenated techniques chromatography, thermal methods **(3L+3T)**

Module IV **(No. of classes: 10)**
Environmental applications of nanomaterials **(1L)**
Mechanism for remediation of aqueous contaminants, photocatalysis **(3L+1T)**
membranes incorporating nanomaterials, transport processes in membrane technology **(2L+1T)**
nanomaterial based adsorbents for water and wastewater treatment – adsorption at metal oxide surfaces, hybrid adsorbents, Case studies **(1L+1T)**

Suggested Text/Reference Books:

1. Nalwa, H.S. (Ed.), "Encyclopedia of Nanoscience and Nanotechnology" Americal Scientific Publisher (2004)
2. Wiesner, M.R., and Bottero, J.Y. (Ed.) "Environmental Nanotechnology: Applications and Impacts of Nanomaterials"; McGraw-Hill, New York. (2007)
3. Lead J., and Smith, E. "Environmental and Human Health Impacts of Nanotechnology" ;John Wiley & Sons. (2009)

Paper Name: Biochemical Engineering		L	T	P	Total	Credit
Paper Code: OECE 506 (Open Elective – I)		2	1	0	3	3
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry, Mass Transfer, Reaction Engineering

Course Objectives: To apply the knowledge of chemistry and reaction engineering in biological domain and develop equipment for biochemical process plant

Course outcomes:
Students completing the course will be able to

CO1	Understand kinetics of microbial cell growth	Understand
CO2	Understand sterilization methods	Understand
CO3	Apply knowledge of mass transfer in bioprocesses	Apply
CO4	Evaluate energy requirement in bioprocesses	Evaluate
CO5	Apply knowledge of various forms of enzyme and its kinetics in industries	Apply
CO6	Design bioreactors for different types of bioprocesses	Create

Course Contents:
Module I **(No. of classes: 10)**

Introduction: Definition and scope of biochemical engineering. Unit operations in biochemical processes, mass and energy balance in microbial processes. **(1L+1T)**
Metabolic stoichiometry, metabolites. Microbial growth kinetics: phase of cell growth, estimation of cell mass **(1L+1T)**

Kinetics of balanced cell growth: Monod growth model, other forms of growth model, concept of limiting nutrient and effect of its concentration on cell growth **(3L+1T)**
Study of growth inhibition kinetics, structured kinetic rate models. **(2L)**

Module II **(No. of classes: 10)**

Aeration and agitation: transport phenomena in bioprocess systems, gas-liquid mass transfer in cellular systems, measurement of $k_l a'$ using gas-liquid reactions, parameters affecting $k_l a'$. **(3L+1T)**
Bubble aeration and mechanical agitation, power consumption, correlation between oxygen transfer coefficient and process parameters, rheology of fermentation fluids. **(2L+1T)**
Methods of media and air sterilization, aseptic operation, thermal death kinetics of microorganisms, batch and continuous sterilization. **(2L+1T)**

Module III **(No. of classes: 10)**

Kinetics of reaction catalyzed by free enzyme. **(2L)**
Enzyme immobilization and its various techniques, kinetics of reaction catalyzed by immobilized enzyme, effect of external mass transfer and intra-particle diffusion, limitations and applications of immobilized enzymes. **(3L+2T)**
Applied enzyme catalysis: medical and analytical applications of enzymes, applications of enzymes in industry: food, pharmaceutical, leather, detergent. **(2L+1T)**

Module IV **(No. of classes: 10)**

Bioreactor design: ideal and non-ideal reactors, design of ideal reactors: batch and fed-batch reactors, CSTR, PFR. **(2L+1T)**
Reactor dynamics: dynamic model and stability. **(1L)**
Non-ideal reactors: residence time distribution, non-ideal reactor models: dispersion model, tanks-in-series model. **(1L+1T)**
Multiphase bioreactors: packed bed, bubble column, fluidized bed, trickle bed. Nonconventional bioreactors: membrane reactors, perfusion reactor. Control of bioreactors. **(3L+1T)**

Suggested Text/Reference Books:

1. J. E. Bailey and D. F. Ollis, Biochemical Engineering Fundamentals, McGrew- Hill, Second Edition, 1986.
2. M. L. Shuler and F. Kargi, Bioprocess Engineering, Prentice Hall,Second Edition, 2002.
3. O. Levenspiel, Chemical Reaction Engineering, Wiley, Third Edition, 2005.
4. S. Aiba, A. E. Humphrey and N. F. Millis, Biochemical Engineering, Academic Press, 1973.
5. P. M. Doran. Bioprocess Engineering Principles, Academic Press, Second Edition, 2013.
6. T. Palmer, Enzymes: Biochemistry, Biotechnology and Clinical Chemistry, Horwood Publishing, 2001.
7. J. M. Smith, Chemical Engineering Kinetics, McGraw Hill, Third Edition, 1981.
8. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall of India, Third Edition, 1998.

Paper Name: **Biotechnology**	L	T	P	Total	Credit
Paper Code: **OECE 516** (Open Elective – I)	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			Marks
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Chemistry, Unit operations, Reaction Engineering

Course Objectives: To inter-relate chemistry and unit operations with the biological life processes for understanding the basis of bio-based chemical process plants.

Course outcomes:

Students completing the course will be able to

CO1	Explain the basis of biotechnology to correlate chemistry and biology for industrial biotechnology.
CO2	Gain knowledge about kinetics of biochemical reactions.
CO3	Demonstrate bio-based separation and kinetic processes for solving the application of chemical engineering processes.
CO4	Learn about cell growth kinetics
CO5	Learn about performance of large scale bioreactor.
CO6	Apply to develop bio-process

Course Contents:

Module I **(No. of classes: 10)**

Basic biochemistry and microbiology:

Introduction (role of chemical engineers in biotechnology); cell structure and chemistry. **(1L)**

Cell construction: amino acids and proteins, carbohydrates: mono and polysaccharides, lipids, fats and steroids, nucleic acids, RNA and DNA. **(2L+1T)**

Cell nutrients: macro and micro nutrients, growth media, morphological and biochemical characteristics of microorganisms. **(2L+2T)**

Basics of genetic engineering and tissue culture: recombinant DNA technology. **(2L)**

Module II **(No. of classes: 10)**

Enzyme and its kinetics

Enzyme kinetics – mechanistic models, Michaelis-Menten equation **(2L+2T)**

Determination of rate parameters, kinetics of inhibited enzyme - competitive, uncompetitive and noncompetitive. **(2L+1T)**

Effect of pH and temperature on enzymatic action; **(1L)**

Immobilization of enzymes, applications of enzymes in industry. **(2L)**

Module III **(No. of classes = 10)**

Bio-separation processes

Separation of insoluble biomolecules and products – filtration, centrifugation, coagulation and flocculation. **(2L+1T)**

Separation of soluble products – precipitation, salt precipitation, isoelectric precipitation. Application of chemical engineering principles in bio-separation; **(2L+1T)**

Two-phase extraction, adsorption, dialysis, microfiltration and ultrafiltration, reverse osmosis, electrophoresis. **(3L+1T)**

Module IV **(No. of classes = 10)**

Bioprocess development

Fermentation – fundamentals, principles and mechanism of sterilization techniques, sterilization equipment; **(2L)**

Kinetics of microbial batch growth, models to predict specific growth rate, models of cell growth inhibitors. **(2L+1T)**

Bioreactor design and its scale up, type of bioreactors; **(2L+2T)**

Industrial application of bioprocesses - production of alcohols, acids, antibiotics, etc. **(1L)**

Suggested Text/Reference Books:

1. J.E.Bailey and D.F.Ollis. Biochemical Engineering Fundamentals. McGraw Hill, New York. 1986.
2. M.L.Shuler and L.F.Kargi. Bioprocess Engineering-Basic Concepts. Prentice Hall. 2001.
3. M.J.Pelczar, R.D.Reid and E.C.S. Chan. Microbiology. Vol 1, McGraw Hill, New York. 2012.
4. K.Wilson and J.Walker. Principles and Techniques of Biochemistry and Molecular Biology.Cambridge University Press, Cambridge. 2010.

Paper Name: Mass Transfer Laboratory	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCML 507	**0**	**0**	**3**	**3**	**1.5**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total		**50**	

Pre-requisite: Mass Transfer –I & II

Course Objectives:

Application of the knowledge of different Mass transfer operations

Course outcomes:

Students completing the course will be able to:

CO1	Have the real life feeling of the theoretical knowledge on Mass Transfer Process by performing experiments
CO2	Understanding of different types of packing materials
CO3	Application of knowledge to study distillation column and pipings
CO4	Calculate different parameters of the theories related to molecular diffusion

CO5	Understanding of PVT relationship of water
CO6	Application of convective mass transfer and other separation processes by performing experiments.
	Application of humidification operations

Course Contents:

List of Laboratory Experiments:

[At least six Experiments shall be conducted]

Experiment 01:	Determination of diffusivity of volatile liquid in air using Stefan tube.
Experiment 02:	Determination of mass transfer coefficient of a single solid sphere of Naphthalene ball under forced convection and verification of Froessling correlation.
Experiment 03:	Determination of the diffusivity of a volatile solid in stagnant air.
Experiment 04:	Study of adsorption isotherm for batch adsorption of acetic acid-active carbon system.
Experiment 05:	Verification of Rayleigh's equation for differential distillation.
Experiment 06:	Study of the internals of a tray – type distillation column.
Experiment 07:	Study of packing materials used in packed tower.
Experiment 08:	Construction of rate of drying curve for drying of a granular solid under constant drying conditions.
Experiment 09:	Construction of boiling point diagram and equilibrium diagram of a binary system using Othmer still.

Suggested Text/Reference Books:

1. Laboratory Manual

Paper Name: **Process Equipment Design and Drawing**	L	T	P	Total	Credit
Paper Code: **PCPD 508**	0	0	3	3	1.5
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	A design problem will be given to the student at the beginning of the Semester V. Evaluation throughout the session	15	20
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Two copies of the Report along with Equipment Drawing should be submitted 10 days before the examination.		30
	Design Report with drawing	10	
	Viva-Voce will be conducted by a panel of 2 (two) Examiners including the Teacher(s) In-Charge and one External Examiner	20	
Total		**50**	

Pre-requisite: Mathematics, Process Calculation, Fluid Mechanics, Mass Transfer, Heat Transfer, Chemical Reaction Engineering

Course Objectives: To have basic idea of process equipment design and drawing applying the principles previously studied.

Course outcomes:

Students completing the course will be able to:

CO1	Explain the general arrangement drawings of an equipment
CO2	Explain the principles of design of an equipment
CO3	Solve design problems of an equipment
CO4	Apply the theoretical knowledge for process calculations for the design
CO5	Apply the theoretical knowledge for mechanical calculations for the design
CO6	Use 3D drawing tools for engineering drawing of equipment as per design

Course Contents:

List of Design Problems:
[At least one from the following]

Design Problem 01:	Design of a Pressure Vessel
Design Problem 02:	Design of a Shell and Tube Heat Exchanger
Design Problem 03:	Design of an Evaporator
Design Problem 04:	Design of a Plate type Distillation Column
Design Problem 05:	Design of an Absorption Column

Suggested Text/Reference Books:

1. L. E. Brownell and E. H. Young, Process Equipment Design, John Wiley and Sons, Inc., New York, 2010.
2. E. Ludwig, Chemical Process Equipment Design, Gulf Pub., 3rd Ed., 2002.
3. M. V. Joshi & V. V.Mahajani, Process Equipment Design, Macmillan India Ltd., 2009, CAD
4. J. M. Coulson, J. F.Richardson and R. K. Sinnot, Coulson and Richardson's Chemical Engineering: Chemical Engineering Design (vol. 6), 3rd. Ed., Butterworth - Heinemann, (Indian Print) 2004.
5. D. Q. Kern, Process Heat Transfer, McGraw Hill Book Company, 2010.
6. Chemical Engineers Handbook by R. H. Perry and C. H. Chilton.
7. B. C. Bhattacharyya, Introduction to Chemical Equipment Design, CBS Publishers &Distributors, New Delhi, 2009.
8. B. K. Dutta, Heat transfer, Principles and Application, PHI Pvt. Ltd., 2006.
9. R. Smith, Chemical Process Design and Integration, Authorized reprint by Wiley India (P) Ltd., New Delhi, 2012.
10. Backhurst, J. R. and Harker J. H.,"Coulson and Richardson Chemical Engineering", Vol. II, 5th Ed., 2002, Butterworth-Heinemann.
11. Serth, R.W., "Process Heat Transfer: Principles and Applications" 2007, Elsevier Ltd.
12. S. M. Walas, Chemical Process Equipment Selection and Design, Butterworth-Heinemann, 2010.
13. J. Douglas, Conceptual Design of Chemical Processes, McGraw-Hill, 1988.

Paper Name: **Environmental Science**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **MCES 509** (Mandatory Course – I, Non-Credit)	**2**	**0**	**0**	**2**	**0**
Total Contact Hour = 28					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Basic Science
Course Objectives: To learn the basics of environment and human-environment interaction
Course outcomes:
Students completing the course will be able to

CO1	Clarify the importance of earth, environment and ecosystem
CO2	Explain the various segments of Environment
CO3	Explain & interpret the natural resources
CO4	Demonstrate the impact of human population on environment
CO5	Illustrate environmental pollution and disaster management
CO6	Interpret environmental ethics

Course Contents:

Module I **(No. of classes: 7)**
Earth, Environment & Eco-System:
Introduction to Environmental Science and need for studying Environmental Science. **(1L)**
Segments of Environment: Atmosphere (Layers, Characteristics); Hydrosphere (Constituents, Oceans, Groundwater, Surface Water); Lithosphere (constituents of lithosphere, Rock and Mineral resources) and Biosphere (its components, Ecosystems and Ecology). **(3L)**
Bio-geo chemical cycles: Hydrologic or Water cycle, Gaseous cycles (Oxygen, Carbon & Nitrogen cycles) and Sedimentary cycles (Phosphorus & Sulphur cycles) **(2L)**
Structure and function of ecosystem; Energy flow in an ecosystem. **(1L)**

Module II **(No. of classes: 7)**
Natural Resources
Renewable and non-renewable resources, land resources and land-use change; land degradation, soil erosion and desertification. **(2L)**
Deforestation: Causes and impacts due to mining, dam building on environment. **(1L)**
Water: Use and over-exploitation of surface and ground water, floods, droughts; Water Conservation, Rainwater Harvesting. **(2L)**
Energy: Renewable and non-renewable energy sources, use of alternate energy sources. **(2L)**

Module III **(No. of classes: 7)**
Human population growth: Global population growth, Impacts on environment, human health and welfare; Climate & health, Risks due to chemicals in food, health and human rights. **(2L)**
Gender and Environment, Environmental tradition and values in ancient India. **(1L)**
Environmental & social impacts of natural resource exploitation; Food & Water security. **(1L)**

Nature reserves, tribal populations and rights, human wildlife conflicts in Indian context. **(2L)**
Environmental movements: Chipko, Silent valley, Bishnois of Rajasthan. **(1L)**

Module IV **(No. of classes: 7)**
Environmental Pollution: Definition, causes, effects and remedies of environmental pollution (air, water, soil, noise); Brief overview of solid waste management. **(2L)**
Disaster Management: floods, earthquake, cyclones and landslides. **(1L)**
Environmental Laws; Climate Change, Global Warming, Ozone Layer Depletion; International Agreements: Montreal and Kyoto Protocols, Stockholm Convention. **(2L)**
Environmental Ethics, Environmental communication and public awareness. **(2L)**

Suggested Text/Reference Books

1. S.Baskar and R.Baskar. Environmental Studies for Undergraduate Courses. 1st Edition, Unicorn Books. 2010.
2. E.Bharucha. Textbook of Environmental Studies for Undergraduate Courses. Universities Press. 2013
3. P.D. Sharma. Ecology and Environment. Rastogi Publications. 13th Edition. 2017.
4. S.C.Santra. Environmental Science. New Central Book Agency. (5th Reprint) 3rd Edition.2017.

Note: Indian Environmental Acts & Rules are available at www.moef.gov.in

End of Semester V

Semester VI

Paper Name: Chemical Reaction Engineering - II		L	T	P	Total	Credit
Paper Code: PCRE 601		2	1	0	3	3
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			Marks
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Chemical Reaction Engineering -I

Course Objectives: Basic Concepts of Catalysis, Kinetics and Mechanistic aspects of Catalysts, Design and Rating of Catalytic Reactors, Design Aspects of Gas-Liquid Reactors

Course outcomes:
Students completing the course will be able to

CO1	Identify the inter-relation of mass transfer and catalytic reaction.
CO2	Explain how stoichiometric coefficient of a reaction is related with material and energy balance with rate equation.
CO3	Application of catalytic reactor. Be aware about microreactor
CO4	Knowledge of real and ideal conditions
CO5	Flow behavior of fluids in reactors
CO6	Designing latest experimental reactors

Course Contents:

Module I **(No. of classes: 10)**

Catalysis: Catalysts, their preparation and properties, catalyst promoter and inhibitor **(1L)**
Steps in a catalytic reaction: adsorption, surface reaction, desorption; **(1L+1T)**
Mechanism, rate limiting step and rate law of a catalytic reaction; **(2L+1T)**
Catalyst deactivation and determination of its order. **(1L)**
Catalytic reactor: design for gas-solid reactions, heterogeneous data analysis for reactor design. **(2L+1T)**

Module II **(No. of classes: 10)**

Steady state non-isothermal continuous flow reactors:
General steady state energy balance equation for a reactor; **(1L)**
Adiabatic operation: tubular reactor and tank reactors; **(1L+1T)**
Non-adiabatic Reactors: Steady state tubular reactors and tank reactors with heat exchange; Case study; multiple steady states; non-isothermal multiple reactions in CSTR and PFR. **(2L)**
Unsteady state non-isothermal reactors: Unsteady state energy balance: batch, semi-batch, CSTR, PFR **(2L+1T**
Transient reactors with heat exchanger; multiple reactions; reactor safety. **(1L+1T)**

Module III **(No. of. classes: 10)**

Residence time for chemical reactor:

General characteristics of distribution; residence-time distribution (RTD) function; measurement of the RTD: pulse and step input; characteristics of RTD: integral relationships, mean residence time; **(2L+1T)**

RTD in ideal reactor; concept of macromixing & micromixing; **(2L+1T)**

Zero parameter model: segregation model and maximum mixedness model; Models for non-ideal reactors: introduction; one-parameter models: tanks in series model, dispersion model. **(3L+1T)**

Module IV **(No. of classes: 10)**

Multiphase reactors: Fluidized bed reactor and its two-phase modeling; **(2L+1T)**

Slurry reactor and its modeling, Trickle bed reactor and its modeling. **(3L+1T)**

Microreactor: Physical characteristics, flow regime, fabrication, applications in homogeneous, liquid-liquid biphasic, gas-liquid, bioorganic and biocatalytic reaction. **(2L+1T)**

Suggested Text/Reference Books:

1. H.S. Fogler, Elements of Chemical Reaction Engineering, 3rd Ed., PHI Learning.
2. Octave Levenspiel, Chemical Reaction Engineering, 3rd ED.
3. J. M. Smith, Chemical Engineering Kinetics, 3rd Ed., McGraw Hill.
4. T. Wirth (Ed.), Microreactors in Organic Chemistry and Catalysis,Wiley-VCH.

Paper Name: **Refinery Engineering**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCRF 602**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Energy Resources, Chemical Process Technology

Course Objectives: Studying this subject the students will learn about the present status of crude oil and their extraction, production, characterization, as well as refining of crude oil for a wide spectrum of useful products such as transportation fuel, petrochemicals, and Chemicals. This course intends to form the foundation of the chemical engineers on all the above mentioned basic fields of petroleum from extraction to the safe end use where refining is the most challenging. The course puts major thrust on all the techniques/processes of petroleum refining encompassing selection of the mass/heat transfer devices, their operation, basic design, safety, and waste treatment.

Course outcomes:

Students completing the course will be able to

CO1	Explain the role of petroleum as energy source amidst world and India's scenario
CO2	Explain the chemical and physical principles of the refining of crude oil
CO3	Illustrate various feed and product properties & test methods
CO4	Demonstrate various petroleum refining processes and safe practice in operation
CO5	Demonstrate various operations with techno-economic analysis & trouble shooting aspect
CO6	Building foundation for process intensification and motivation towards innovation

Course Contents:

Module I **(No. of classes: 10)**

Indian & World crude oil reserve and production. Petroleum economy: national and global scenarios. **(2L)**

Indian Petroleum Refinery Industry: Present status & future prospects. **(1L+1T)**

Petroleum - Origin and Occurrence, Exploration, Estimation and recovery. **(3L+1T)**

Evaluation of crude composition – elemental, chemical nature of components, category of components – PONA etc. Classification, evaluation of petroleum. **(1L+1T)**

Module II **(No. of classes: 10)**

Major Product- specification, properties - test methods and quality control: **(1L+1T)**

Pre-treatment of Crude Petroleum - Desalting of crude **(1L)**

Fractionation (distillation)- Atmospheric Distillation Unit (ADU) and Vacuum Distillation Unit (VDU) - column control schemes, design aspects **(2L+1T)**

Conversion Processes: Decomposition (dividing) by thermal - Vis-breaking, Coking and catalytic cracking - FCC; **(3L+1T)**

Module III **(No. of classes: 10)**

Unification (combining) through alkylation and polymerization; **(2L)**

Alteration (rearranging) with isomerization and catalytic reforming **(1L+1T)**

Treatment Process (finished product): like desalting, drying, hydrodesulfurizing, solvent refining, sweetening, solvent extraction, and solvent de-waxing. **(3L+1T)**

Other Refining operations- light-ends recovery; sour water striping; hydrogen production; acid and tail-gas treatment; sulphur recover, cooling, storage and handling and product movement. **(1L+1T)**

Module IV **(No. of classes: 10)**

Refinery Product blending **(1L)**

Lubes and waxes – treating, finishing, and blending. **(2L+1T)**

Asphalt/ Bitumen processing. **(1L)**

Refinery safety procedure and Environmental aspects. **(1L+1T)**

Waste generation in petroleum oil refineries; Environmental Standards & Regulations; Waste water treatment, Disposal of solids in reference to Petroleum Oil Refining. **(2L+1T)**

Suggested Text/Reference Books:

1. B.K. Bhaskara Rao, "Modern Petroleum Refining Processes", 2nd Edn., Oxfordand IBH Publishing Company, New Delhi, 1990.
2. U. Raychaudhuri, Fundamentals of Petroleum and Petrochemical Engineering, CRC Press, 2010.
3. James G. Speight, "The Chemistry and Technology of Petroleum", 4th Edition; First Published 2006, CRC Press
4. W.L.Nelson,." Petroleum Refinery Engineering", 4th Edn., McGraw Hill, New York, 1985
5. Robert. A. Meyers, "Handbook of Petroleum Refining Processes", McGraw Hill, 1986.
6. G.D.Hobson and W.Phol, "Modern Petroleum Technology", Applied science Publishers, IV Edition, 1975.

Paper Name: Process Instrumentation & Control	L	T	P	Total	Credit
Paper Code: PCIC 603	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Mathematics, Fluid Mechanics, Heat Transfer, Mass Transfer, Chemical, Reaction Engineering.

Course Objectives: To introduce the basic theories of Process Instrumentation & Control relevant to Chemical Engineering operations.

Course outcomes:

Students completing the course will be able to:

CO1	Understanding the basic principles of process modelling	Understand
CO2	Understanding the approach of control theory	Understand
CO3	Designing the basic control blocks for a chemical process	Apply
CO4	Designing the controller for a chemical process	Apply
CO5	Investigating the stability of a process	Apply
CO6	Updating the feedback scheme to advanced control schemes	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Need for process control, Industrial control strategies: feedback, feed forward and inferential; Mathematical model of simple lumped parameter models in Flow, Level, Pressure and Thermal processes **(3L+1T)**

Distributed parameter models: Heat exchanger, CSTR; Degrees of freedom–Continuous and batch processes; Linearization, Input-output relation in Laplace domain, Concept of transfer function, block diagram **(1L+1T)**

First and Second order systems: Transfer function and dynamic responses to different input functions, Concept of process gain, time constant for first order systems; Concept of natural period of oscillation and damping factor for second order system; Interacting and non-interacting systems; Examples of first and second order processes. **(3L+1T)**

Module II **(No. of classes: 10)**

Basic idea of feedback loop; Different elements of feedback control loop; Characteristic of on-off, P, PI, PID and PD controllers, Final control elements **(2L+1T)**

Block diagram formulation of feedback control systems; transient response analysis of feedback loops. **(2L+1T)**

Stability Analysis: Concept of stability, definition of stability, stability criterion. Stability for linear system: Routh-Hurwitz stability criterion. Root locus diagram. **(3L+1T)**

Module III **(No of Classes = 10)**

Design of control system using frequency response: Bode and Nyquist plots; Bode stability criterion, phase and gain margins. **(2L+1T)**

Tuning of controller settings: Ziegler Nichols controller settings. **(2L+1T)**

Advanced Control system: cascade control, feed forward control, ratio control, selective control and split-range control with examples; advanced industrial applications including PLC, DCS and smart instrumentation **(3L+1T)**

Module IV **(No of Classes = 10)**

Principles of measurements and classification of process control instruments. Temperature measuring instruments, Liquid-level measuring instruments, Pressure measuring instruments. **(3L+1T)**

Composition measuring instruments. Measurements of viscosity, pH, concentration, thermal conductivity and humidity of gases **(3L+1T)**

Process instrumentation, instrumentation diagram, P&ID, application of P&ID, examples. **(1L+1T)**

Suggested Text/Reference Books:

1. Stephanopoulos, G., "Chemical Process Control – An Introduction to Theory and Practice", Prentice Hall of India, 2005.
2. Coughanowr, D.R., "Process Systems Analysis and Control", McGraw – Hill International Edition, 2004.
3. Bequette, B.W., "Process Control Modeling, Design and Simulation", Prentice Hall of India, 2004.
4. Seborg, D.E., Edgar, T.F. and Mellichamp, D.A., "Process Dynamics and Control", Wiley John and Sons, 2nd Edition, 2003.
5. D. P. Eckman, "Automatic Process control", 7th Edition, John Wiley, New York, 1990.
6. Considine, D.M., Process Instruments and Controls Handbook, Second Edition, McGraw, 1999.
7. Bela.G.Liptak., "Process Control and Optimization"., Instrument Engineers' Handbook., volume 2,CRC press and ISA, 2005.
8. Curtis D. Johnson Process Control Instrumentation Technology, 8th Edition, Pearson, 2006.

Paper Name: **Transport Phenomena**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCTP 604**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Fluid Mechanics, Mass Transfer, Heat Transfer

Course Objectives: To learn the coupling between three transport phenomena with applications in various disciplines in engineering for demonstrating the common mathematical structure of transport problems involving Newtonian and non-Newtonian fluids, solid-state heat conduction, forced and free convection, binary diffusion with or without chemical reaction.

Course outcomes:

Students completing the course will be able to

CO1	Explain overall balances for conservation of momentum, energy and mass.	Understand
CO2	Recognize different analogies among momentum, heat and mass transfer for industrial application.	Understand
CO3	Develop appropriate macroscopic balances for solving conservation of momentum, energy and mass.	Apply
CO4	Demonstrate the appropriate equations of change to obtain desired profiles for velocity, temperature and concentration for industrial application.	Apply
CO5	Examine the information obtained from solutions of the balance equations	Apply
CO6	Develop the models required for the key components of the Engineering quantities of interest application.	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction to Transport Phenomenon: Classification of Transport Processes, Conservation Laws **(2L+1T)**

Vector and Tensor Calculus **(3L+1T)**

Principles of Transport, Shell Balance **(2L+1T)**

Module II **(No. of classes: 10)**

Principles of Momentum Transport: Concept of Viscosity, Newton's Law of Viscosity, Shell Momentum Balance **(2L)**

Application of Shell Momentum Balance: Flow of Falling Film, Flow Through Circular Pipe, Flow Through annulus, Flow Over Moving Plate, Couette Viscometer **(3L+1T)**

Equation of Changes: Continuity Equation, Equation Motion, Navier-Stokes Equation in Cartesian Co-ordinate's and Cylindrical Co-ordinate, Basics of Velocity Distribution **(2L+2T)**

Module III **(No. of classes: 10)**

Energy Transport: Basic energy transport equations, derivation using elementary volume concept and conservation theorems in different coordinate system **(2L)**

Analysis of energy transport using shell balance techniques: Conduction with energy sources in fixed bed catalytic reactors and in cooling fins, mechanical energy conservation with viscous dissipation, forced convection in circular tubes, natural convection from a heated plate **(3L+2T)**

Unsteady state conduction of finite slab **(2L+1T)**

Module IV **(No. of classes: 10)**

Mass Transport: Type of fluxes i.e. mass flux and molar flux and their relation, continuity equation for a binary mixture, boundary conditions **(2L)**

Analysis of mass transport using shell balance techniques and equation of continuity for different coordinate systems, diffusion with a homogeneous and heterogeneous chemical reaction, diffusion into a falling liquid film **(3L+2T)**

Unsteady state mass transport **(2L+1T)**

Suggested Text/Reference Books

1. R.B. Bird, W.E. Stewart, E.N. Lightfoot, D.J. Klingenberg, Introductory Transport Phenomena, Wiley, 2013.
2. J.C.Slattery, Advanced Transport Phenomena, Cambridge University Press, 1999.

3. P.K. Kundu and I.M. Cohen, Fluid Mechanics, Academic Press.
4. W.M.Deen, Analysis of Transport Phenomena (Topics in Chemical Engineering), Oxford University Press.

Paper Name: **Water Pollution and Wastewater Management**	L	T	P	Total	Credit
Paper Code: **PECE 605** (Professional Elective - II)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisites: Particle and Fluid Processing Technology, Mass Transfer I & II, Chemical Reaction Engineering

Course Objectives: To learn the essential principles used for environmental pollution and to understand the remedial measures for pollutions generated from industries and other sources in accordance with appropriate Indian environmental regulations.

Course outcomes:

Students completing the course will be able to

CO1	Explain various types of pollution from chemical industries and various regulations
CO2	To understand the treatments practiced for water treatment to make it portable
CO3	Disinfection techniques used for making drinking water supply to public
CO4	Demonstrate physico-chemical and biological treatment systems for waste water
CO5	To understand designing of Settling tanks, Filtration units, Biological treatment systems
CO6	Find ways to dispose, minimize or utilize solid wastes generated from sludge

Course Contents:

Module I **(No. of classes: 10)**

Water Pollution Control

Source of water, hydrological cycle, available source of water for utilization **(1L)**

Different water pollutants, Primary and secondary pollutants, maximum contaminant limits and goals. **(1L+1T)**

Primary Treatment: pre-treatment, coagulation, flocculation, sedimentation, design of sedimentation tank. **(3L+1T)**

Polishing of water, disinfection, distribution and storage of public water distribution system **(2L+1T)**

Module II **(No. of classes: 10)**

Measurement of BOD and COD, CBOD, NBOD, Streeter-Phelps oxygen sag-curve. **(2L+1T)**

Waste water, characterization of wastewater, treatment procedure – Primary and Secondary wastewater treatments **(2L)**

Clarifier, design and practice **(1L+1T)**

Trickling Filter, Rotating Disc Contactor, Activated Sludge Treatment (operation, design etc.) **(2L+1T)**

Module III **(No. of classes: 10)**

Oxidation ponds (Lagoons), Anaerobic Treatment (UASB) **(1L+1T)**
Tertiary (advanced) Treatment: Adsorption, Advanced Oxidation Process. **(2L+1T)**
Sludge treatment, incineration, disposal of reduced solids **(2L+1T)**
Disposal of Sewage on land, Sewage farming, Sewage sickness, **(2L)**

Module IV **(No .of classes: 10)**

Types of Industrial Wastewater, basis of classification, Standards for treatments (ISO:22447, 2019), tannery wastewater **(2L+1T)**
Oil field wastewater treatment **(2L+1T)**
DAF, Circular economy for water reuse in Oil & Gas, **(1L+1T)**
Biomedical Waste and e-waste **(2L)**

Suggested Text/Reference Books:

1. M.L.Davisand, D.A.Cornwell. Introduction to Environmental Engineering. McGraw Hill Education (India) Private Limited, New Delhi. 4th Edition. 2010.
2. Gilbert M. Masters, Introduction to Environmental Engineering and Science.
3. Metcalf & Eddy, Wastewater Engineering-Treatment and Reuse, Revised by G. Tchobanoglous, F.L. Burton and H.D.Stensel, 4th Edition. Tata McGraw-Hill, 2003.
4. Industrial Wastewater Classification, https://www.iso.org/obp/ui/en/#!iso:std:73237:en
5. J.Pichtel. Waste Management Practices: Municipal, Hazardous and Industrial. 2ndEdition. CRC Press. 2014.
6. W.W.Eckenfelder. Industrial Water Pollution Control. 2ndEdition. McGraw Hill. 1989.

		L	T	P	Total	Credit
Paper Name: Solid Waste Management						
Paper Code: PECE 615 (Professional Elective – II)		2	1	0	3	3
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through ClassTest/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Physics and Chemistry

Course Objectives: To understand different types of solid wastes followed by respective management practices and integrated solid waste management

Course outcomes:

Students completing the course will be able to

CO1	Explain various types of solid wastes and various waste management rules of India.
CO2	Explain treatment technologies for the management of various solid wastes.
CO3	Explain the ethical issues and societal impact of releasing pollutants in the environment.
CO4	Select technologies for managing different waste streams
CO5	Demonstrate industrial waste management systems
CO6	Find ways to dispose, minimize or utilize solid wastes from different sources.

Course Contents:

Module I **(No. of classes: 10)**

Introduction; Types and classification of solid wastes; rate of generation; concept of integrated solid waste management (ISWM); **(1L+1T)**

Municipal Solid Waste (MSW);

(a) Separation and collection methodologies; recycling and reuse; **(2L+1T)**

(b) Characterization for treatment – physical, chemical and biological; empirical formulae; Dulong's formula for calorific value; mechanical operation in managing MSW. **(2L+1T)**

(c) Management of urban solid waste in developing countries; comparison with developed countries. **(1L)**

(d) Indian regulation for MSW management. **(1L)**

Module II **(No. of classes: 10)**

Thermal Treatment Technologies – Incineration, pyrolysis, gasification, plasma arc; rotary kiln and fluidized bed. **(2L+1T)**

Biological Treatment Technologies – compost (static pile, aerated pile, in-vessel, vermin compost) and biogas generation. **(2L)**

Sanitary Landfill – Site selection, sanitary landfill design and operation; Land fill bioreactors. **(1L+1T)**

Engineered Landfill – Waste acceptance criteria; Engineered landfill design & operation; Lining & laterals; Leachate collection & management; Gas control; Cover design; Surface drainage system; Environmental Monitoring Plan; Closure and Post-Closure Plans. **(2L+1T)**

Module III **(No. of classes: 10)**

Plastic Waste Management – problems, current practice, recommended treatment; Indian regulation of plastic waste management. **(2L)**

Construction and Demolition (C&D) Waste Management – composition, rate of generation, recycle & reuse; sustainable models; Indian regulation for C&D waste management. **(2L+1T)**

Electronic Waste (e-waste*)* Management – Definition, classification & component analysis; e-Waste Management: Generation, on-site storage, collection, transportation, separation, processing & treatment/disposal. Indian regulation for e-waste management. **(2L+1T)**

Biomedical Waste Management – composition, rate of generation; Health hazards & environmental concerns; Biomedical waste management: storage, segregation, identification, handling and transportation, treatment & disposal; Indian regulation for Biomedical Waste Management. **(1L+1T)**

Module IV **(No. of classes: 10)**

Management of Industrial Hazardous/Solid Waste

Health hazards and environmental concerns; Waste Storage, Segregation, Identification; Waste Handling and Transportation. **(2L)**

Waste Treatment and Disposal; Common Treatment/Disposal Facility; Onsite Treatment/ Disposal facility. **(2L+1T)**

Indian regulation for hazardous wastes management. **(1L+1T)**

Industrial Practices: Petroleum Oil Refinery, Petrochemical, Pesticide, Fruit Processing, Fertilizer, Paper, Sugar, Tannery etc. **(2L+1T)**

Suggested Text/Reference Books:

1. J.Pichtel. Waste Management Practices: Municipal, Hazardous and Industrial. 2^{nd} Edition. CRC Press. 2014.
2. G.Kiely. Environmental Engineering. Tata-McGrew-Hill. 1997.

3. A.P.Sincero and G.A. Sincero. Environmental Engineering. PHI Publication. 2002.
4. R.Chandrappa and D.B.Das. Solid Waste Management: Principles and Practice. Springer-Verlag, Berlin, Heidelberg, 2012.
5. T.V.Ramchandra. Management of municipal solid waste. TERI Press, 2016.
6. M.N.Rao, R.Sultana and S.H.Kota. Solid and Hazardous Waste Management: Science & Engineering. BSP Books Pvt. Ltd. Published by Elsevier Inc. 2017.

Note: Indian Environmental Acts & Rules are available at www.moef.gov.in

Paper Name: **Polymer Science and Engineering**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: OECE 606 (Open Elective – II)		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry, Reaction Engineering I , Chemical Process Technology

Course Objectives: To impart knowledge on the role of chemical engineering in polymer science and engineering and provide knowledge on synthesis, characterization, properties and applications of polymers

Course outcomes:

Students completing the course will be able to

CO1	To acquire concepts of various useful polymers and their classification
CO2	To gain knowledge on different structure of polymer
CO3	Ability to identify structure - properties relation of polymer
CO4	Acquire the concept of polymerization mechanism and kinetics
CO5	Acquire the concept of polymer synthesis and processing
CO6	To gain concept about different polymer processing and application of Engineering plastics

Course Contents:

Module I **(No. of classes: 10)**

Introduction: Historical development, Basic concepts and Definitions **(1L+1T)**

Classification of polymers- Natural vs. Synthetic **(1L)**

Polymer structure- Linear, Branched or cross-linked, amorphous or crystalline, homopolymer or Cipolymer, Fibers, Plastics, or Elastomers **(1L+1T)**

Polymerization Mechanism/ reactions: Mechanism and kinetics of step growth polymerization; **(1L+1T)**

Mechanism and kinetics of free radical chain growth polymerization; **(1L)**

Mechanism of cationic, anionic and coordination polymerizations; **(1L)**

Mechanism and kinetics of copolymerization. **(1L)**

Module II **(No. of classes: 10)**

Techniques for polymer manufacture: Polymerization in homogeneous system (bulk and solution polymerization); **(2L)**

Polymerizations in heterogeneous system (emulsion & suspension polymerization). **(2L)**

Chemical reactions of polymers: Cross linking during polymerization and cross linking after polymerization (curing and vulcanization) **(1L+1T)**

Polymer degradation - kinetics and products **(1L+1T)**

Characterization of polymers: Molecular weight and molecular weight distribution. **(1L+1T)**

Module III **(No. of classes: 10)**

Structure and properties of polymers: Morphology and order of crystalline polymers **(1L)**

Structure and physical properties of polymers **(1L+1T)**

Electrical properties of polymers **(1L)**

Mechanical properties of polymers-Stress-Strain Behavior of polymer, Creep experiment, Fracture behaviour **(1L+1T)**

Polymer Visco-elasticity- Simple Rheological Response, and Visco-elasticity **(2L)**

Polymer Additives and Reinforcements- Plasticizr, fillers, Antioxidant, Stabilizers, Flame Retardant, Colorant etc. **(1L+1T)**

Module IV **(No. of classes: 10)**

Unit operation in Polymer processing:

Extrusion: co-extrusion, film extrusion **(1L+1T)**

Molding : compression, injection, blow, reaction-injection, rotational, compression and transfer **(1L+1T)**

Calendering, casting, coating **(1L)**

Compounding/ Formulating **(1L)**

Polymer Processesing, properties and applications-Polyethylene (PE), Polypropylene (PP), Poly Vinyl Chloride (PVC), Nylons, Engineering plastics- some representative polymers **(3L+1T)**

Suggested Text/Reference Books:

1. F. W. Billmeyer, Text Book of Polymer Science, John Wiley, New York.
2. P. Ghosh, Polymer Science & Technology, Tata McGraw Hill, New Delhi.
3. R.O. Ebewele, Polymer Science and Technology, CRC Press, 2000.
4. G. Odian, Principles of Polymerization, John Wiley & Sons, New Jersey.
5. T. Whelan, Polymer Technology Dictionary, Springer Science & Business Media, 1994.

Paper Name: Ceramic Materials and Engineering	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: OECE 616 (Optional Elective – II)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Chemistry, Chemical Process Technology

Course Objectives: To impart knowledge on the role of chemical engineering in ceramic materials and provide knowledge on synthesis, characterization, properties and applications of a number of ceramic materials used in chemical industries

Course outcomes:

Students completing the course will be able to

CO1	Understand the fundamentals of ceramic materials and their types
CO2	Relate solid phase equilibrium with ceramic materials
CO3	Correlate thermodynamic properties with ceramic transformations
CO4	Analyze the characteristics of the raw materials and ceramic materials
CO5	Explain the characteristics and properties of glass
CO6	Understand the properties and applications of advanced ceramic materials

Course Contents:

Module I **(No. of classes: 10)**

Definition and scope of ceramics and ceramic materials, classification of ceramic materials – conventional and advanced ceramics. **(1L)**

Pottery & White wares: Classification and type of pottery & white wares with applications, basic properties **(1L)**

Glass: Definition of glass, glass raw materials and their functions, different types of glasses, application of glasses. **(1L+1T)**

Refractories: Definition of refractory, properties of refractories, classification of refractory, basic areas of application specially in steel plant. **(1L)**

Cement and Concrete: basic compositions, setting and hardening, concrete. **(1L)**

Advanced Ceramics: Engineering ceramics, ceramics used in advanced applications, ceramics for medical and scientific products, ceramics for electrical and electronic, aerospace. **(2L+2T)**

Module II **(No. of classes: 10)**

Phase rule, Phase equilibrium in a single component system, Clausius-Clapeyron equation **(1L+1T)**

Phase equilibrium diagrams for Water, Silica, Zirconia. Two Component systems: Cooling behaviour and phase compositions for important ceramic systems such as SiO_2-Al_2O_3, MgO-Al_2O_3, CaO-SiO_2, CaO-Al_2O_3, CaO-MgO; **(2L+1T)**

Phase Transformation:Review of Thermodynamics, Gibbs free energy-composition diagrams, stability criteria, metastability. **(1L+1T)**

Solidification: Eutectic, Peritectic. Diffusional transformations in Solid: Eutectoid, Peritectoid, Precipitation, Ordering. Diffusionless Transformations: Martensitic Transformation. Spinodal decomposition, Glass Transition; The application of phase diagrams in refractories and glass industries **(2L+1T)**

Module III **(No. of classes: 10)**

Characterization techniques for ceramic raw materials and products – powder characterization, thermochemical analysis, X-ray diffraction, spectroscopy and microscopy. **(2L+1T)**

Advanced Ceramics – Electro-ceramics-Ceramic Capacitors **(1L)**

Engineering ceramics-Fracture behaviour of ceramic materials, Toughening mechanism. Toughened materials and their engineering applications **(1L+1T)**

Bioceramics-Definition and scope of bio-materials. Classification of bio-ceramic materials; Surgical implants; Resorbable bioceramics. Characterization of bio-ceramics. **(1L+1T)**

Ceramic nanomaterials; Application of ceramic materials for energy and environment. **(2L)**

Module IV **(No. of classes: 10)**

Glassy State; Kinetic and thermodynamic criteria for glass formation, use of Na_2O-SiO_2 and Na_2O-CaO- SiO_2 phase diagrams in glass manufacture **(2L)**

Manufacture of glass, types of glasses and their chemical compositions **(1L+1T)**

Physical properties of glasses, density, refractive index and dispersion, surface tension, viscosity and its measurement, effect of temperature and composition on the physical properties of glasses. **(2L+1T)**

Manufacturing process and properties of high and low temperature insulating refractories. Application of ceramic materials in chemical process industries. **(2L+1T)**

Suggested Text/Reference Books:

1. Fundamentals of Ceramics (Series in Materials Science and Engineering)-M. Barosoum- Taylor and Francis – 2nd Edition (2022)
2. Introduction to Ceramics, W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley Series on the Science and Technology of Materials Products. 2nd Edition (1976)
3. Chemistry of Glasses - A. Paul; Springer Nature ; 1st Edition (1982)
4. Ceramic Whitewares –Their Technologies and Application; Sudhir Sen; Oxford and IBH Publications (1992)

Paper Name: Plant Design and Simulation Laboratory	L	T	P	Total	Credit
Paper Code: PCPS 607	0	0	3	3	1.5
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total			**50**

Pre-requisite: Mass Transfer, Heat Transfer, Reaction Engineering, Process Thermodynamics,

Course Objectives: Purpose of different equipment sizingbasedonindustry scale and material and energy balance.

Course outcomes:

Students completing the course will be able to

CO1	Explain the working principle of different equipments	Understand
CO2	Explain the overall layout of different equipments in a complete chemical plant	Understand
CO3	Explain material and energy balance	Understand
CO4	Explain thermodynamic model for different problem	Understand
CO5	Demonstration of different equipment based on industrial equipment	Apply
CO6	Design and simulation of a complete chemical plant	Apply

Course Contents:
List of Laboratory Tasks:
[At least six tasks shall be conducted]

Experiment 01:	Introduction of any commercial simulation package, such as ASPEN, UNISIM etc or similar products
Experiment 02:	Discussion of different thermodynamic model
Experiment 03:	Steady state simulations of different types of pumps and compressors.
Experiment 04:	Steady state simulations of different types of heat exchangers.
Experiment 05:	Steady state simulations of different types of flash drum, absorption distillation and extraction columns.
Experiment 06:	Steady state simulations of different types of reactors.
Experiment 07:	Design and simulation of a complete chemical plant.

Suggested Text/Reference Books:
1. Laboratory manual
2. Compiler: C/C++
3. MATLAB/ ASPEN PLUS/ CHEMCAD software

Paper Name: **Reaction Engineering & Thermodynamics Laboratory**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCRT 608**	**0**	**0**	**3**	**3**	**1.5**
Total Contact Hour = 40					

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td rowspan="3">Continuous Assessment</td><td>Assessment of all Practical sessions</td><td>15</td><td rowspan="3">25</td></tr>
<tr><td>Active participation in routine practical classes</td><td>05</td></tr>
<tr><td>Overall conduct, attendance, manners, skills etc.</td><td>05</td></tr>
<tr><td rowspan="4">End Semester Examination</td><td>Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.</td><td></td><td rowspan="4">25</td></tr>
<tr><td>Practical Notebook</td><td>05</td></tr>
<tr><td>Experimental Study</td><td>10</td></tr>
<tr><td>Viva-Voce</td><td>10</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">50</td></tr>
</table>

Pre-requisite: Reaction Engineering, Process Thermodynamics

Course Objectives: To check and verify some of the basic principles of the two courses studied in respective theoretical papers

Course outcomes:

Students completing the course will be able to

CO1	Verify the theoretical knowledge by performing experiments	Understand
CO2	Understanding of different types of reactor and distribution of reactant in reactor	Understand
CO3	Understanding of heat capacity ratio of Air and PVT relationship of water	Understand
CO4	Calculate different parameters of the theory	Apply
CO5	Evaluation of Residence Time Distribution (RTD)	Apply
CO6	Extend of saponification reaction in different reactor	Apply

List of Laboratory Tasks:
[At least six tasks shall be conducted]

Experiment	Study of non-catalytic homogeneous reaction in a packed bed reactor
Experiment	Study of saponification reaction in an isothermal plug flow reactor
Experiment	Study of saponification reaction in a cascade of CSTR
Experiment	Study of saponification reaction in a batch reactor
Experiment	Study of Residence Time Distribution (RTD) in a plug flow tubular
Experiment	Determination of Heat Capacity Ratio of Air
Experiment	Pressure Volume Temperature relationship of water

Suggested Text/Reference Books:

1. Laboratory Manuals

End of Semester VI

Semester VII

Paper Name: Heat Transfer – II	L	T	P	Total	Credit
Paper Code: PCHT 701	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Thermodynamics, Heat Transfer I

Course Objectives: Idea of compact Heat Exchangers, Design and economy of Evaporator, Design concept of furnace, Heat exchanger networking

Course outcomes:
Students completing the course will be able to

CO1	Understand category of heat transfer equipments based on application	Understand
CO2	Understand compactness of heat exchangers	Understand
CO3	Make calculations of fin/ plate Heat exchanger areas	Apply
CO4	Calculate steam economy in evaporators	Apply
CO5	Calculation of pipe-steel heater heat loads, surface area	Apply
CO6	Design multiple effect evaporators	Apply

Course Contents:

Module I **(No. of classes: 10)**

Compact Heat Exchangers and Their Classifications, Fin-tube (flat tubes, continuous plate fins), Fin-tube (circular tubes, continuous plate fins), Fin–tube (circular tubes, circular fins), Plate–fin (single pass).and Plate–fin (multi-pass) type heat exchangers. **(3L+2T)**

Extended surface and plate heat exchangers design and design calculations. Effectiveness-NTU Method for Heat Exchanger Design. **(3L+2T)**

Module II **(No. of classes: 10)**

Liquid-to-vapor phase-change exchangers, evaporator; processing factors, capacity, steam economy; boiling point elevation; Material and energy balance in evaporator. **(2L+1T)**

Classification of evaporator: Natural and Forced circulation, Agitated and Gasket type evaporator, steam trap, vent. **(2L+1T)**

Single and multiple effect evaporators, design procedure of triple effect evaporator andcalculations. **(3L+1T)**

Module III **(No. of classes: 10)**

Furnace: types of furnaces and usage, application of furnace in oil refinery, different heat transfer modes in furnaces. **(2L+1T)**

Simple furnace with overhead convection bank, double and multiple radiant section box type furnace; **(3L+1T)**
Design procedure of Pipe steel heater and calculations. **(2L+1T)**

Module IV **(No. of classes: 10)**

Pinch technology, Flow sheet to Pinch data, energy targets & composite curve, multiple utility targeting, process modifications and placement of heat engines & heat pumps. **(2L+1T)**
2. Heat Exchanger network design - the difference between Streams and Branches, Grid Diagram for heat exchanger network representation. **(2L+1T)**
3. Design method, heat exchanger network design for Retrofits. **(3L+1T)**

Suggested Text/Reference Books:

1. B. K. Dutta, Heat Transfer Principles and Application, PHI.
2. D. Q. Kern, Process Heat Transfer: MGH
3. Ian C. Kemp, Pinch Analysis and Process Integration, ELSEVIER
4. Holman, J. P., S. Bhattacharya, Heat Transfer, 10th Ed., Tata McGraw-Hill (2011).
5. Bejan, A., A. D. Kraus, Heat Transfer Handbook, John Wiley (2003).
6. B. K. V. Rao, Modern Petroleum Refining Process, Oxford
7. Bodo Linnhoff, A User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers (UK).

Paper Name: **Petrochemicals**		**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PCPC 702**		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisites: Petroleum refinery, Energy resources

Course Objectives: To provide a broad and fundamental knowledge of the petrochemical industry in India and World.
To introduce the processing techniques for production of petrochemicals.

Course outcomes:

Students completing the course will be able to

CO1	Understand the basic aspects of petrochemical industries.
CO2	Understand the various processing techniques and their characteristics/ Limitations of synthesis of petrochemicals.
CO3	Understand Catalytic production of petrochemicals
CO4	Understand effects of pressure & temperature on catalytic processes
CO5	Apply operating processes for production/safety aspects of petrochemicals.
CO6	Develop knowledge of safety and pollution control in the industrial process.

Course Contents:

Module I **(No. of classes: 10)**

Definition of Petrochemicals: Petrochemical industries in India. Recent trends in Petrochemical industries and its inter-relation with crude refinery. **(1L)**

Raw materials and production of C1 and C2 compounds **(2L+1T)**

Raw materials and production of C3 and C4 compounds. **(2L+1T)**

Chemicals from C1 Compounds: Manufacturing of methanol and chloromethanes. Manufacturing of perchloro ethylene. **(2L+1T)**

Module II **(No. of classes: 10)**

Chemicals from C2 compounds: Ethylene and acetylene, ethanol, polyethylene, ethylene dichloride, acetaldehyde, ethylene oxide **(3L+1T)**

Manufacturing of Ethanol amines, vinyl acetate and acetic acid **(2L)**

Chemicals from C3 Compounds: Isopropanol, acetone, lumen (isopropyl benzene), acrylonitrile, isoprene, polypropylene, epichlorohydrin, propylene oxide. **(3L+1T)**

Module III **(No. of classes: 10)**

Chemicals from C4 Compounds: Butadiene, Dehydrogenation of butane, Dehydrogenation of butylenes. Dehydrogenation-dehydration of ethanol. **(2L+1T)**

Steam cracking of hydrocarbons. Oxo synthesis (Hydroformylation) **(2L+1T)**

Chemicals from Aromatics: Primary raw material. Hydroalkylation, Manufacture of phenol, nitrobenzene, aniline, paraxylene, PTA etc. **(3L+1T)**

Module IV **(No. of classes: 10)**

Secondary Chemicals: Manufacture of vinyl chloride, styrene, extraction of butadiene from C_4 fraction. **(3L+1T)**

Manufacture of Phthalic anhydride, maleic anhydride, etc. Manufacture of industrial dyes based on petroleum feed stocks. **(3L+1T)**

Commercial productions of different monomers and respective polymers (such as elastomers, polyamides, polyesters, polyurethanes) – process and plant description, design and safety aspects. **(2L+1T)**

Suggested Text/Reference Books:

1. Petrochemicals, B.K. Bhaskar Rao, CRC Press, 1990.
2. Chemicals from Petroleum, A.L.Waddams, 2nd Edition, ELBS, London, 1970.
3. Dryden's Outlines of Chemical Technology, Gopal Rao M and Marshall Sittig, 3rd Edition, East-West Press, 1997.
4. Chemical Process Industries, 5th edition, Shreve and Austin, McGraw Hill,1984.
5. Chemical Technology, G.N.Pandey, Vikas Publishing House Pvt. Ltd.
6. Chemical Technology, Mukhlyonov, Mir Publications,1982.

Paper Name: **Economics and Management**		L	T	P	Total	Credit
Paper Code: **HUEM 703**		2	1	0	3	3
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: English, Mathematics
Course Objectives: To know about the economical and managerial aspects of design and operation of a chemical plant
Course outcomes:
Students completing the course will be able to

CO1	Explain different economic and accounting concepts
CO2	Apply the knowledge of the interplay of various economic variables and indicators in Work place.
CO3	Illustrate the methodologies involved inproject financing.
CO4	Apply knowledge about allocation, management and funding of financial resources.
CO5	Demonstrate the functions, roles and skills of management for running a cohesive business unit.
CO6	Assess the effective application of managerial practices to both economic and human Resources of a firm.

Course Contents:

Module I **(No. of classes: 10)**

Economic Activity: concept of subject to economics, Production and consumption of commodities; consumers and firm, fundamental economic problems, problem of scarcity and choice; economic systems (market economy, planned economy and mixed economy). **(2L+1T)**

Demand-Supply: Concept of demand and supply; Law of demand and supply, demand-supply interaction, elasticity of demand. **(2L+1T)**

Cost of production: production function with factors of production, cost of production (Total cost, average cost, and marginal cost), preparation of projected cost with various component of project and their estimation with working capital. **(3L+1T)**

Module II **(No. of classes: 10)**

Price: concept of classification of market, overview of price determination in different market (pure and imperfect), theory of factor-pricing; return to scale; marginal productivity theory, wages and profit. **(3L+1T)**

The macroeconomic concept: National income and product, determination of national income with Investment-Consumption theory, Inflation, time value of money, real income vs monetary income, control of inflation, banking system, industrial policies **(2L+1T)**

Project Analysis: Analysis of projected financial statement (Balance Sheet and profitability) with estimation of project financing, concept of depreciation and effect on project analysis with interest (cost of capital) burden. **(2L+1L)**

Module III **(No. of classes: 10)**

Industrial Management:

(a) Scope, brief history of industries (particularly, chemical) in India; **(1L)**

(b) Characteristics, principles and responsibilities of management, functions of management: planning, motivating, leading, controlling; **(3L+1T)**

(c) Introduction to organization, basic types of organization, levels of management, skills of management, inter relation between skills and levels of management. **(1L+1T)**

Production Management: principles & concept, various strategies: investment strategy, capacity strategy, quality strategy, customer focus strategy, product flexibility strategy, quick time delivery strategy, etc., concepts of Productivity. **(2L+1T)**

Module IV **(No. of classes: 10)**

Financial Management:

(a) Sources of capital, investment decisions; **(1L)**

(b) Budgeting and budgetary control. **(2L)**

Quality Management: Use of control charts for implementing the quality plan: X-R chart, moving average chart, p-chart, c-chart. Sampling: Acceptance sampling, AOQ, AQL, LTPD, chain sampling plan (concept only). **(1L+1T)**

Maintenance Management: Causes, costs, classifications, equipment & plant reliability and availability, management of shutdowns and turnarounds, preventive and predictive maintenance. **(1L+1T)**

Materials Management: Management of project materials and maintenance materials, purchasing and vendor development, store-keeping and inventory control. **(2L+1T)**

Suggested Text/Reference Books:

1. M.Adhikary. Business Economics. Excel Books, New Delhi. 2000.
2. C.R.Basu. Business Organization and Management. Tata McGraw Hill, New Delhi. 2000.
3. K.Ghuman and K.Aswathappa. Management Concepts and Cases. Tata McGraw Hill, New Delhi. 2017
4. R.Narayanswamy. Financial Accounting: A Managerial Perspective. PHI Learning. 2017
5. J.L.Riggs, D.D.Bedworth and S.U.Randhawa. Engineering Economics. Tata McGraw Hill, New Delhi. 2004.
6. S. Mishra. Engineering Economics and Costing. Prentice Hall of India Pvt. Ltd. New Delhi.2011.
7. S.P.Robbins.Management.14thEdition, Pearson Education, New Delhi. 2019.
8. P.Chandra. Fundamentals of Financial Management. McGraw Hill, Noida, UP. **2020.**

Paper Name: Instrumentation and Process Control Laboratory	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCIC 704	**0**	**0**	**3**	**3**	**1.5**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation			**Marks**
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total			**50**

Pre-requisite: Fluid Mechanics, Mass Transfer, Heat Transfer, Process Control, Instrumentation

Course Objectives:

1. Application of the concept of time constant
2. To know the calibration techniques for instrument
3. To know the tuning of controllers
4. Digital control through Human-machine interactions

Course outcomes:

Students completing the course will be able to:

CO1	Understand the concept of time constant of a first order process
CO2	Application of Calibration techniques for instruments
CO3	Application of dynamic response in respect of an input to a process
CO4	Application of Controller tuning parameters for Level Control
CO5	Application of Controller tuning parameters for Flow Control
CO6	Application of Controller tuning parameters for Temperature Control

Course Contents:

List of Laboratory Experiments:

[At least six Experiments shall be conducted]

Experiment 01:	Determination of time constant of a mercury in glass thermometer
Experiment 02:	Calibration of a pressure gauge using a Dead Weight Tester
Experiment 03:	Studies on valve characteristics of a process control valve
Experiment 04:	Dynamic response study of a non-interacting second order system
Experiment 05:	Studies on the Stability and tuning of a Flow Controller
Experiment 06:	Studies on the Stability and tuning of a level Controller
Experiment 07:	Studies on the Stability and tuning of a Temperature Controller
Experiment 08:	PC-PLC based level control
Experiment 09:	PC-PLC based flow control
Experiment 10:	Flow control of a pump by frequency modification

Suggested Text/Reference Books:

5. Laboratory Manual

Paper Name: **Advanced Process Control**	L	T	P	Total	Credit
Paper Code: **PECE 705** (Professional Elective – III)	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Modeling and Simulation, Process Instrumentation & Control

Course Objectives: The purpose of this course is to provide an advanced treatment of the theory and practice of chemical process control. An emphasis of this course is on model-based control system design and implementation. The SIMULINK simulation package (based on MATLAB) will be used for dynamic process simulation and control system development. Most of the homework assignments will require the use of MATLAB/SIMULINK.

Course outcomes:

Students completing the course will be able to:

CO1	Understand PID Algorithm	Understand
CO2	Understand IMC and IMC-based PID	Understand
CO3	Computer based Tuning of PID controller	Apply
CO4	Design model-based control system and its implementation	Apply
CO5	Practice simulation package(SIMULINK) for dynamic process simulation and control system	Apply
CO6	Updating advanced control schemes to digital control	Apply

Course Contents:

Module I **(No. of classes: 10)**

Review of incentives for process control, control block diagrams, designing and tuning of PID controllers. **(1L)**

MATLAB for Process Control, application through computer software **(2L+1T)**

SIMULINK Modelling for Liquid Level and Chemical Reactor, application **(2L+1T)**

Detailed comparison of PID algorithms. Derivative action on process output vs. error. Problems with proportional "kick" and reset "wind-up". **(2L+1T)**

Module II **(No. of classes: 10)**

Review of continuous-time Internal Model Control (IMC), and IMC-based PID **(2L+1T)**

Introduction to digital control, implementation of digital PID algorithms. **(2L+1T)**

Analog to digital conversion and vice-versa **(1L)**

Identification of discrete models for digital control, digital model-based control - IMC and Dahlin's method. **(2L+1T)**

Module III **(No. of classes: 10)**

Introduction to model predictive control (MPC), analysis of multivariable systems. **(1L+1T)**

Review of RGA and introduction to singular value analysis. Impact of process design on process control, reactor scale-up example. **(2L+1T)**

Analysis of the effect of recycle on chemical process dynamics and control. **(2L+1T)**

Fuzzy Logic, Application to Process Control **(2L)**

Module IV **(No. of classes: 10)**

Frequency response techniques for control system design. Bode plots for SISO systems, singular value analysis for MIMO systems. **(2L+1T)**

Nyquist plots for SISO systems, singular value analysis for MIMO systems. **(2L+1T)**

Special course project involving a detailed study of a process jointly agreed upon by the student, instructor and TA. **(3L+1T)**

Suggested Text/Reference Books:

1. Camacho E F & Bordons C, Model Predictive Control, Springer, 1999.
2. Dutton K, Thompson S & Barraclough B, The Art of Control Engineering, Addison Wesley, 1997.
3. Love J, Process Automation Handbook, Springer, 2007.
4. Marlin T, Process Control: Designing Processes and Control Systems for Dynamic Performance, 2nd Edition, McGraw Hill, 2000.
5. Ogunnaike B A & Ray W H, Process Dynamics, Modelling and Control, Oxford University Press, 1994.

6. Seborg D, Edgar T, Mellichamp, D and Doyle F, Process Dynamics and Control, 3rd Edition, Wiley, 2011.

Paper Name: Computational Fluid Dynamics	L	T	P	Total	Credit
Paper Code: PECE 715 (Professional Elective – III)	2	1	0	3	3
	Total Contact Hour = 40				

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Fluid Mechanics, Transport phenomena, Mathematics-III, Computer programming

Course Objectives: To understand and visualize various flow patterns in equipment or pipeline in different industrial or research problem.To learn the model development based on numerical approach with partial differential equations (PDEs) converting into algebraic equation and to simulate different optimized process parameter for different process.

Course outcomes:

Students completing the course will be able to

CO1	Explain the complexity and non-availability of analytical solution method	Understand
CO2	Explain different governing equation in conservative and non-conservative	Understand
CO3	Explain the necessity of CFD for turbulent flow model	Understand
CO4	Able to characterize transfer process in equipment or pipeline	Apply
CO5	Able to visualize transfer process in equipment or pipeline	Apply
CO6	Interested to use software of CFD to understand and present the transfer	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction to Computational Fluid Dynamics **(1L)**

Conservation Equations **(1L)**

Discretization, Different Numerical methods and their comparison; Finite Difference Method, Finite Volume Method, Finite Element Method, etc. **(3L+2T)**

Source terms and their linearization **(1L)**

Solution of discretized equations **(1L+1T)**

Module II **(No. of classes: 10)**

Solution of diffusive problems: Steady 1D , Steady 2D and steady 3D problems **(4L+2T)**

Unsteady1D, 2D unsteady and 3D unsteady problems **(3L+1T)**

Module III **(No. of classes: 10)**
Solution of convective-diffusion problems:
Steady and unsteady problems **(3L+1T)**
Different schemes **(4L+2T)**

Module IV **(No. of classes: 10)**
(includes practical/ demonstration)
SIMPLE algorithms **(2L)**
SIMPLER algorithms **(2L)**
Practical Demonstration **(3L+ 3 T)**

Suggested Text/Reference Books:

1. An Introduction to Computational Fluid Dynamits – H. K. Versteeg and W. Malalasekera
2. Numerical heat transfer and fluid flow – Suhas V. Patankar
3. Computational Fluid Dynamics – J. D. Anderson, McGraw-Hill
4. Computational Fluid Mechanics and Heat Transfer – J.C. Tannehill, D.A.Anderson, R.H. Pletcher, Taylor and Francis
5. Computational Fluid Dynamics – T. J. Chung, Cambridge University Press
6. P.K.Kundu and I.M.Cohen, Fluid Mechanics, Academic Press.

Paper Name: Process Plant Simulation	L	T	P	Total	Credit
Paper Code:OECE 706 (Open Elective – III)	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Thermodynamics, Reaction Engineering, Mass Transfer, Heat Transfer, Mathematics

Course Objectives:
To understand the systematic approaches for the development of conceptual chemical process designs.
To learn the advances in problem formulation and software capabilities which offer thepromise of a new generation of practical process synthesis techniques

Course outcomes:
Students completing the course will be able to

CO1	Understanding different processes and equipment	Understand
CO2	Application of chemical process parameter to produce industrial process	Understand
CO3	Explain material and energy balance	Understand
CO4	Explain thermodynamic model for different problem	Understand
CO5	Design best chemical process flow sheet for a given product	Apply

CO6	Perform economic analysis related to process design and evaluate project profitability	Apply

Course Contents

Module I **(No. of classes: 10)**

Introduction to fundamental concepts of mass and energy balance of different equipments. (1**L+1T**)

Principles of different Process Flow Sheet: Block Diagram, Process Flow Diagram(PFD) and Piping and Instrumentation Diagram (P&ID). (2**L+1T**)

Process Flow-sheeting (2L)

Introduction to commercial software such as HYSYS, Aspen plus etc. for Chemical Process (reactor, heat exchanger, distillation etc). (2**L+1T**)

Module II **(No. of classes: 10)**

Analysis of different parameters effect on efficiency of pumps, compressors. **(2L)**

Analysis of different parameters effect on efficiency of heat exchangers. **(1L+1T)**

Analysis of different parameters effect on efficiency of distillation column etc. **(2L+1T)**

Analysis of different parameters effect on efficiency of reactors. **(2L+1T)**

Module III **(No. of classes: 10)**

Different thermodynamic model for ideal: VLE, Binary VLLE. Different thermodynamic model for non-ideal: VLE, Binary VLLE. **(3L+2T)**

Different thermodynamics model available in HYSYS, Aspen plus (NRTL, SRK, Peng-Robinson, UNIQUAC, UNIFAC, modified UNIQUAC, modified UNIFAC etc) and their utility for different type of processes. **(3L+2T)**

Module IV **(No. of classes: 10)**

Simulation of different conventional chemical process plant simulation **(2L+1T)**

Process Flow-sheeting of different conventional chemical process plant simulation **(2L+1T)**

Concept of nonconventional renewable energy sources: biomass combustion, biomass gasification, methanol generation from biomass etc. **(3L+1T)**

Suggested Text/Reference Books:

1. Douglas, J. “Conceptual Design of Chemical Processes”,New York, NY: McGraw-HillScience/Engineering/Math, 1988. ISBN: 0070177627.
2. Seider, W. D., J. D. Seader, and D. R. Lewin. “Product and Process Design Principles:Synthesis, Analysis, and Evaluation”,. 2nd ed. New York, NY: Wiley, 2004. ISBN:0471216631.
3. Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., “Analysis,Synthesis, and Design of Chemical Processes”, 2nd Edition, 2002, Prentice Hall ISBN-10: 0-13-064792-6
4. Biegler L.T., Grossmann I.E. and Westerberg A.W., “Systematic Methods of ChemicalProcess Design”, Prentice Hall, 1997.

Paper Name: **Process Modelling and Simulation**		L	T	P	Total	Credit
Paper Code: **OECE 716** (Open Elective – III)		**2**	**1**	**0**	**3**	**3**
	Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Knowledge of basic chemical engineering subjects, Process calculation, Mathematics I, II & III

Course Objectives: Theoretical outcome of a system.

Course outcomes:
Students completing the course will be able to

CO1	Understanding the principle of mass, energy and momentum conservation equations	Understand
CO2	Design and solve of steady state and unsteady state model equations	Develop
CO3	Numerical techniques to solve Algebraic, ODE and PDE	Apply
CO4	Pros and cons of different systems	Understand
CO5	Designing different units of chemical plants	Develop
CO6	Simulation of a Specific Process	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction to mathematical model and simulation:
Concept of mathematical model, simulation and process analysis; **(1L)**
Lumped and distributed parameters models: hydraulic tank, mixing vessel, simultaneous mass and energy balance; **(2L+1T)**
Modelling of batch & continuous process: batch heating of multi-component flash drum; **(2L+1T)**
Steady-state flow processes involving non-reactive systems: extraction column (plate type); continuous heating in a stirred tank using jacket and coil, mixing in flow processes. **(2L+1T)**

Module II **(No. of classes: 10)**

Modelling of heat and mass transfer operations:
Concentration gradient across a bubble plate, simultaneous heat and mass transfer in packed bed; Start-up of double pipe heat and shell and tube heat exchangers; **(3L+1T)**
Simulation of multi-component multi-stage mass exchangers: formulation of MESH equations, general strategy, equation tearing procedure; **(2L+1T)**
Wang-Henke method, sum-rates method for absorption and stripping, isothermal sum-rate method for liquid-liquid extraction, Inside-out method. **(2L+1T)**

Module III **(No. of classes: 10)**

Chemical reactor simulation:

Modelling and simulation of isothermal and non-isothermal operation of batch reactor, CSTR and semi-batch reactor; **(2L+1T)**

Steady-state CSTRs in series, thermal stability analysis of CSTR, non-isothermal operation of a single-homogeneous gas phase reaction in PFR; **(3L+1T)**

Diffusion and chemical reaction-catalytic reaction in packed bed reactor. **(2L+1T)**

Module IV **(No. of classes: 10)**

Process optimization:

Concept and utility of process optimization; **(1L)**

Single variable optimization techniques: Newton's method, Secant method, dichotomous search, Fibonacci and golden search method; **(2L+1T)**

Constrained and unconstrained multivariable optimization techniques: direct search, simplex method, Rosenbrock search technique; **(3L+1T)**

Powell search, complex method of Box and gradient search techniques. **(1L+1T)**

Suggested Text/Reference Books:

1. W.L. Luyben, Process Modeling Simulation and Control, 2nd Ed., McGraw Hill, 1990.
2. B.K. Dutta, Mathematical Methods in Chemical and Biological Engineering, CRC Press, 2016.
3. B.V.Babu: Process Plant Simulation,
4. W.F.Ramirez: Computational Methods in Process Simulation
5. B.W.Bequette, Process Dynamics- Modeling, Analysis and Simulation, Prentice Hall, Englewood Cliffs, NJ, 1998.
6. A. Hussainand K. Gangaiah, Optimization Techniques for Chemical Engineering, MacMillan, Delhi, 1976.
7. T.F. Edgar, D.M. Himmelblau and L.S.Lasdon, Optimization of Chemical Processes, 2ndEd.,McGrawHill, New York, 2001.

Paper Name: Internship/Plant Training	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PIPT 707	**6 to 8 weeks**				**1.5**
Government/non-Government/ NGO/MSME/Rural Industry/ Consultancy/R&D Organization, after Semester VI					

Evaluation:

Type of Evaluation			**Marks**
End Semester Examination	A student has to present a Seminar at the Examination on the basis of Internship/Plant training and to appear in Viva-Voce. The Examination shall be conducted by a Board of Examiners consisting of the two Internal Examiners.		
	Report	50	100
	Presentation	30	
	Viva Voce.	20	
Total			**100**

Each student shall be required to undergo Internship/Plant Training, for a period of 6 (six) to 8 (eight) weeks in a chemical process industry or R&D laboratory of an industry or design/consultancy organization after Semester VI and before commencement of Semester VII. After completion of the Internship/Plant Training program, a student has to submit 2 (two) type-written bound copies of Report with certificate from respective training providers within 1 (one) month of the following semester (Semester VII).

	L	T	P	Total	Credit
Paper Name: Project Work – I	L	T	P	Total	Credit
Paper Code: PIPW 708	0	0	6	6	3

Evaluation:

Type of Evaluation		Marks	
Continuous Assessment	Sessional Work/Assessment by the Supervisor(s)	60	
End Semester Examination	A student has to present a Seminar at the Examination and appear in Viva-Voce.The Examination shall be conducted by a Board of Examiners consisting of the Supervisor(s) and one Internal Examiner.		
	Report	10	40
	Presentation	15	
	Viva Voce.	15	
Total		**100**	

- Each student will be allotted the topic of the Project Work at the beginning of the **Semester–VII**.
- Each student will have to carry out the Project Work – I, under the supervision of a faculty member /faculty members of the Department.
- A student has to submit a Report (three copies) certified and approved by the Supervisor(s) at least 10 days prior to the commencement of the End Semester Examination.

Pre-requisite:
Attended all the courses as required in the course

Course Objectives:
To familiarize the students prior to taking up Final Project in Semester - VIII.

Course outcomes:
Students completing the course will be able to:

CO1	Review a set of published literature on a given topic
CO2	Summarise the essence of the available literature on the given topic
CO3	Find out the gap in the available work on the given topic
CO4	To identify the need of research
CO5	Present the observations and summary of the reviewed literature in a report
CO6	Present the whole work in seminar

Course Contents:
Any topic related to the field of Chemical Engineering/allied subject(s) of Chemical Engineering.

End of Semester VII

Semester VIII

Paper Name: Departmental Seminar	L	T	P	Credit
Paper Code: PCDS 801	0	0	3	1.5
Total Contact Hour = NA				

Evaluation:

Type of Evaluation		Marks	
Continuous Assessment	Sessional Work/Assessment by the Supervisor(s)	50	
End Semester Examination	A student has to present an Open Seminar at the Examination. The Examination shall be conducted by a Board of Examiners consisting of three Internal Examiners including the Supervisor.		
	Report	20	50
	Presentation	15	
	Viva Voce.	15	
Total			100

- Each student will be allotted the topic of the Departmental Seminar at the beginning of the **Semester-VIII**.
- Each student will have to carry out the preparation of Seminar talks under the supervision of a faculty member of the Department.
- A student has to submit a Report (three copies) on the Seminar topic certified and approved by the Supervisor(s) at least 10 days prior to the commencement of the End Semester Examination.

Pre-requisite:
Attended all the courses as required in Semester courses

Course Objectives: Will be able to prepare presentations on specific subjects and to represent the same in front of a gathering

Course outcomes:
Students completing the course will be able to:

CO1	Knowledge to survey available literature
CO2	Knowledge to retrieve data from sources/ agencies
CO3	Able to compile all data collected
CO4	Able to prepare Report
CO5	Present the observations and summary in PowerPoint presentation
CO6	Presentation in front of a mass gathering

Contents:
Any topic related to the field of Chemical Engineering/allied subject(s) of Chemical Engineering.

Paper Name: **Analytical Instrument Laboratory**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PCAI 802	**0**	**0**	**3**	**3**	**1.5**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Continuous Assessment	Assessment of all Practical sessions	15	25
	Active participation in routine practical classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination	Examination shall be of 3 (three) hours duration and shall jointly be conducted by two Internal Examiners.		25
	Practical Notebook	05	
	Experimental Study	10	
	Viva-Voce	10	
Total		**50**	

Pre-requisite: Physics, Chemistry

Course Objectives: To introduce students to the working principles and standard test methods of the sophisticated analytical instruments

Course outcomes:

Students completing the course will be able to:

CO1	Identify unknown organic compound in a sample and quantify that compound	Understand
CO2	Identify functional groups of organic/ inorganic compounds	Understand
CO3	Determine metal ion concentration in a given sample	Evaluate
CO4	Determine specific surface area of a given solid sample	Evaluate
CO5	Develop calibration curve for an organic compound followed by estimation of its unknown concentration	Evaluate
CO6	Determine particle size distribution	Evaluate

Course Contents:

List of Laboratory Experiments:

[At least six Experiments shall be conducted]

Experiment No.	Title of the Experiment
Experiment No.01:	Identification and quantitative determination of organic compounds using High Performance Liquid Chromatography
Experiment No.02:	Identification and quantitative determination of organic compounds using Gas Chromatography
Experiment No.03:	Quantitative determination of metal ion using Atomic Absorption Spectrophotometer
Experiment No.04:	Determination of specific surface area using BET Analyzer
Experiment No.05:	Determination of 'Total Organic Carbon' of organic compounds using TOC Analyzer
Experiment No.06	Estimation of Iron content in Cement by Colorimeter Method
Experiment No.07	Development of calibration curve for an organic compound

	followed by estimation of its unknown concentration using UV-VIS Spectrophotometer
Experiment No.08	Identification of functional groups of organic/inorganic compounds using FTIR
Experiment No.09	Determination of particle size and its distribution using Malvern Particle Size Analyzer
Experiment No.10	Separation of Mixture of Lipids by Column Chromatography

Suggested Text/Reference Books:

1. Laboratory Manual

Paper Name: **Indian Constitution**	L	T	P	Total	Credit
Paper Code: **MCIC 803** (Mandatory Course –II, Non-Credit)	**2**	**0**	**0**	**2**	**0**
Total Contact Hour = 28					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Nothing specific

Course Objectives: To make students aware of the theoretical and functional aspects of the Indian Parliamentary System to channelize their thinking towards basic understanding of the legal concepts and its implications for citizens and engineers.

Course outcomes:

Students completing the course will be able to

CO1	Explain the basic features and modalities about Indian constitution
CO2	Interpret the various rights and responsibilities of an Indian citizen
CO3	Relate the functioning of Indian parliamentary system at the center and state level.
CO4	Illustrate the different aspects of Indian Legal System and its related bodies.
CO5	Apply different laws and regulations related to engineering practices.
CO6	Develop role of engineers with different organizations and governance models

Course Contents:

Module I **(No. of classes: 7)**

Meaning of the constitution law and constitutionalism. **(1L)**
Historical perspective of the Constitution of India. **(2L)**
Salient features and characteristics of the Constitution of India. **(2L)**
The scheme of the Fundamental Duties and its legal status. **(2L)**

Module II **(No. of classes: 7)**

The Directive Principles of State Policy-Its importance and implementation. **(3L)**
Federal structure and distribution of legislative and financial powers between the Union and the States. **(2L)**
Parliamentary Form of Government in India–The constitution powers and status of the President of India. **(2L)**

Module III **(No. of classes: 7)**

Amendment of the Constitutional Powers and Procedure.	**(2L)**
The historical perspectives of the constitutional amendments in India.	**(2L)**
Emergency Provisions: National Emergency, President Rule, Financial Emergency	**(2L)**
Local Self Government–Constitutional Scheme in India.	**(1L)**

Module IV **(No. of classes: 7)**

Scheme of the fundamental rights.	**(1L)**
Scheme of the Fundamental Right to Equality.	**(2L)**
Scheme of the Fundamental Right to certain Freedom under Article 19.	**(2L)**
Scope of the Right to Life and Personal Liberty under Article 21.	**(2L)**

Suggested Text/Reference Books:

1. P.M.Bakshi.TheConstitutionofIndia.17th Edition.LexisNexis.2020.
2. D.D.Basu.IntroductiontotheConstitutionofIndia.24th Edition.LexisNexis.2020

Paper Name: **Project Work – II**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **PIPW 804**	**0**	**0**	**8**	**8**	**6**

Evaluation:

<table>
<tr><th colspan="2">Type of Evaluation</th><th colspan="2">Marks</th></tr>
<tr><td>Continuous Assessment</td><td>Sessional Work/Assessment by the Supervisor(s)</td><td colspan="2">100</td></tr>
<tr><td rowspan="4">End Semester Examination</td><td>A student has to present a Seminar at the Examination and appear in Viva-Voce. The Examination shall be conducted by a Board of Examiners consisting of the Supervisor(s) and one External Examiner.</td><td colspan="2"></td></tr>
<tr><td>Project Report</td><td>20</td><td rowspan="3">100</td></tr>
<tr><td>Presentation</td><td>30</td></tr>
<tr><td>Viva Voce.</td><td>50</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">200</td></tr>
</table>

During the Project Work - II, student is expected to complete the proposed work as per the schedule. The complete report of Project Work -II should contain the Project Work presented under both Project Work – I and Project Work – II.

At the end of the Semester VIII, a student has to submit 3 (three) type-written copies of the complete report includingthrough the Supervisor(s) [at least 10 (ten) days prior to the commencement of the End Semester Examination] and defend the same through a Seminar presentation at the End Semester Examination in front of Board of Examiners duly constituted by the Post Graduate Board of Studies.

Pre-requisite: Attended all the courses as required in the course

Course Objectives:

1. Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
2. Ability to present the findings of their technical solution in a written report.
3. Presenting the work in PowerPoint presentation
4. Capable of attending International/ National conference

Course outcomes:
Students completing the course will be able to:

CO1	Work to achieve the aim and objectives
CO2	Organize the results
CO3	Comparison with other similar Works
CO4	Present the observations and summary of the Work
CO5	Present the whole work in seminar
CO6	To identify the need of further research

Course Contents:
Any topic related to the field of Chemical Engineering/allied subject(s) of Chemical Engineering.

Paper Name: Industrial Hazards and Plant Safety	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PECE 805 (Professional Elective – IV)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			**100**

Pre-requisites: Fluid Mechanics, Heat Transfer I, Mass Transfer I, Thermodynamics

Course Objectives: To understand chemical plant hazards and their remedies, risk management principles, accident analysis and safety rules

Course outcomes:
Students completing the course will be able to

CO1	Identify typical sources of risk and hazard in a process plant	Understand
CO2	**Explain the severity of the consequences of incidents**	Understand
CO3	Explain the legal framework controlling process plant safety in process plant	Understand
CO4	Demonstrate how the root cause of incidents can be investigated and analyzed and the various human and technical aspects of such causes.	Apply
CO5	**Use logic based quantitative risk analysis**	Apply
CO6	**Apply a Hazard and Operability Study (HAZOP)**	Apply

Course Contents:

Module I **(No. of classes: 10)**

Introduction to industrial hazard, Difference between risk and hazard. Classification of chemical plant accidents. Nature of accident in processes. **(2L)**

Fundamentals of Toxicology, Effect of Toxicants on Biological Systems, Dose-response relationships, Threshold limit values. **(2L+1T)**

Industrial Hygiene: Material safety data sheets (MSDS), Occupational health and hygiene; Occupational hazards and control. **(3L+2T)**

Module II **(No. of classes: 10)**

Fire: Fire Triangle; Flammability Characteristics of Liquids and Vapours–Flammability limit dependence on temperature and pressure, Autoignition, Auto-Oxidation, Adiabatic compression, Spray and Mists. **(2L+1T)**

Explosions: Detonation and Deflagration, Confined Explosions, Vapour Cloud Explosions, Boiling-Liquid Expanding-Vapor Explosions (BLEVE); Blast & Missile Damage, Energyof Mechanical and Chemical Explosions, TNT Equivalency. **(3L+2T)**

Corrective control technologies to prevent fire and explosions: Brief overview of inerting, static electricity, explosion proof equipment & instruments; ventilation; sprinkler. **(2L)**

Module III **(No. of classes: 10)**

Source Models for accidental release of pollutants from a chemical plant: Estimation of flow of liquids and vapours from hole/leak, pipe; Flashing liquids. **(3L+1T)**

Toxic Release & Dispersion Models: Brief overview of various cases of Dispersion Models; Release mitigation approaches. **(2L+1T)**

Relief System & Sizing: Introduction, Flares, Scrubbers, Condensers; Rupture discs, Deflagration venting for dust and vapour explosions. **(2L+1T)**

Module IV **(No. of classes: 10)**

Hazard Identification: Fire and Explosion index, HAZOP, Safety Reviews **(2L+2T)**

Risk Assessment: Event Trees, Fault Trees. **(2L+1T)**

Applicable Indian Regulations for Chemical Plant Safety. **(1L)**

Case Studies (Bhopal, Flixborough, Seveso, Love Canal Tragedy) **(2L)**

Suggested Text/Reference Books:

1. D.A.Crowl and J.F. Louvar. Chemical Process Safety: Fundamentals with Applications, 2nd Ed., Prentice Hall.2001.
2. Lees' Loss Prevention in the Process Industries (Fourth Edition). Volume 1, Volume 2, Volume 3. Butterworth-Heinemann, Elsevier. 2012
3. G. L.Wells. Safety in Process Plant Design, John Wiley and Sons Inc., 1980.
4. H.H. Fawcett and W.S.Wood. Safety and Accident Prevention in Chemical Operations, 2ndEdition, Wiley-Interscience, New York, 1982.
5. N.J.Hoboken. Guidelines for Chemical Process Quantitative Risk Analysis, Wiley Interscience, 2000.
6. R.W.King and J.Magid. Industrial Hazards and Safety Handbook, Butterworth, 1982

Note: Indian Environmental Acts & Rules are available at www.moef.gov.in

Paper Name: Air Pollution and Control	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: PECE 815 (Professional Elective – IV)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	5	
	Overall conduct, attendance, manners, skills etc.	5	
End Semester Examination			70
Total			100

Pre-requisites: Particle and Fluid Processing Technology, Mass Transfer I & II Chemical Reaction Engineering

Course Objectives: To learn the essential principles used for environmental pollution and to understand the remedial measures for pollutions generated from industries and other sources in accordance with appropriate Indian environmental regulations.

Course outcomes:

Students completing the course will be able to

CO1	Explain various types of pollution from chemical industries
CO2	Explain various regulations pertinent to air pollutions.
CO3	Explain the ethical issues and societal impact of releasing pollutants in the environment.
CO4	Explain air pollution control devices for industrial gaseous & particulate air pollutants
CO5	Demonstrate the performance of gravity settling chamber, cyclone, bag filter, ESP, wet scrubber and absorbers for air pollution control.
CO6	Apply the knowledge to design gravity settler, cyclone separator

Course Contents:

Module I **(No. of classes: 10)**

Nature and composition of the atmosphere; Fundamentals of atmospheric chemistry; Carbon, sulfur and nitrogen cycles **(2L+1T)**

Air pollutants and their toxicity. Applicable Acts, Rules and Regulations for the prevention and control of air pollution **(1L+1T)**

Types of Pollution, Air Emission Standards, Ambient Air Quality Standards, Brief overview of the Air (PCP) Act, 1981, The Water (PCP) Act, 1974 & The Environment (P) Act, 1986 **(2L+1T)**

Air emission standards for Process Industries; Sources and typical characteristics of industrial air pollution emphasizing categorization of Industries under Indian Regulations. **(2L)**

Module II **(No. of classes: 10)**

Air Quality Monitoring; Stack gas monitoring; Analytical and instrumental techniques for measuring various parameters specified in the Air Emission Standards. **(1L+1T)**

Atmospheric dispersion of pollutants; Application of dispersion modeling in stack design. **(1L)**

Air Pollution Control: Particulate Emission Control:

(a) Gravity Settling Chamber, Cyclone Separator and Bag Filter **(3L+1T)**

(b) Electrostatic Precipitator (ESP) and Wet Scrubber **(2L+1T)**

Module III **(No. of classes: 10)**

Air Pollution Control: Gaseous Emission Control

Absorption, Adsorption, Catalytic Oxidation/ Incineration/ Combustion **(3L+1T)**

Selection criteria of APCDs; Air and water pollution control in industries (e.g., Petroleum Oil Refinery, Petrochemical) **(2L+1T)**
Selection of APCDs in Fertilizer, Iron & Steel, Thermal Power plants **(2L+1T)**

Module IV **(No. of classes: 10)**
Fundamentals of noise pollution; Hearing damage and other health effects, Standards of noise in various work places; Monitoring of noise level; Noise control techniques. **(2L+1T)**
Global Issues: Climatic Change, GHG Emission, Kyoto Protocol **(1L)**
Emission Trading, Ozone Depletion, Montreal Protocol **(1L)**
Environmental Impact Assessment (EIA), EIA methodologies; EIA Notification in India, ISO:14000 series of international environmental management systems; Environmental Auditing; Life Cycle Analysis. **(3L+1T)**

Suggested Texts/Reference Books:

1. deNevers N., Air Pollution Control Engineering, 2nd Ed. McGraw-Hill. 2000.
2. Masters G.M., Ela W.P., Introduction to Environmental Engineering and Science, 3rd Ed. Prentice Hall of India Private Limited. 2008.
3. Davis M.L., Cornwell D.A., Introduction to Environmental Engineering, 5th Ed. McGraw-Hill, 2013.
4. Sincero A.P.,Sincero G.A., Environmental Engineering: A Design Approach. Prentice Hall of India Private Limited. 1999.
5. Mahajan S.P., Pollution Control in Process Industries, Tata McGraw Hill Publishing Company. 1985.
6. Crowl D.A., Louvar J.F., Chemical Process Safety: Fundamentals with Applications, 2nd Ed. Prentice Hall Inc. 2002.
7. Lees' Loss Prevention in the Process Industries, 4th Ed. Volume 1, Volume 2, Volume 3. Butterworth-Heinemann, Elsevier. 2012.
8. **Central Pollution Control Board, CPCB, Ministry of Environment, Forest & Climate Change, Government of India for Environmental (Protection) Acts & Environmental (Protection) Rules. https://cpcb.nic.in/**

Paper Name: Advanced Separation Processes	L	T	P	Total	Credit
Paper Code: OECE 806 (Open Elective – IV)	2	1	0	3	3
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		Marks	
Internal Assessment	Sessional Assessments through Class Test/ Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			100

Pre-requisite: Mass Transfer - I (PCMT 405) and II (PCMT 502)

Course Objectives: To know the advanced applications of the mass transfer principles studied in the basic courses.

Course outcomes:

Students completing the course will be able to

CO1	Understand the principles of separation processes more elaborately that that was done by basic courses
CO2	Apply the principles of adsorption and chromatography for complex separation
CO3	Utilize the membrane- based methods for special type of separation
CO4	Understand the role of supercritical fluid and micellar for advanced separation
CO5	Be familiar with the industrial application and economics of the advanced separation techniques
CO6	Apply special types of distillation for various industrial separations-

Course Contents:

Module I **(No. of classes: 10)**

Adsorption, Ion Exchange and Chromatography: Complex adsorption isotherms – Gibs, Sips, Toth, Dubinin-Raduskevich; **(1L+1T)**

Adsorption of ions on inorganic adsorbents and their applications in Arsenic and fluoride removal **(3L)**

Ion exchange – basics of demineralization and softening; **(2L+1T)**

Chromatography – theories, detectors, types and applications of complex chromatographic processes **(1L+1T)**

Module II **(No. of classes: 10)**

Membrane processes: Various modules of membrane, Transport across membrane, **(1L)**

Electrodialysis, pervaporation, microfiltration and Donnan dialysis, ultrafiltration; **(2L+1T)**

Liquid membrane, membrane reactor, **(1L+1T)**

Nanofiltration, ceramic membrane, biomembrane; **(2L+1T)**

Economics of membrane separation process **(1L)**

Module III **(No. of classes: 10)**

Distillation: Multicomponent distillation, Steam distillation, Enhanced distillation – introduction and types with applications, azeotropic distillation, reactive distillation – simple examples and application **(4L+3T)**

Supercritical fluid extraction- Introduction, advantages and disadvantages of supercritical fluids as solvents **(2L+1T)**

Module IV **(No. of classes: 10)**

Cross flow filtration and electrofiltration **(1L)**

External field induced membrane separation process: Colloidal particle separation. **(1L)**

Surfactant-based separation processes: Micellar-enhanced separation processes. **(2L+1T)**

Surface based solid-liquid separations involving a second liquid, Siroflocfilter. **(2L+1T)**

Adductive Crystallization **(1L)**

Industrial application of advanced separation techniques **(1L)**

Suggested Text/Reference Books:

1. King, C.J. " Separation Processes ", Tata McGraw - Hill Publishing Co., Ltd., 1982.
2. Schoew, H.M. - " New Chemical Engineering Separation Techniques ", Interscience Publishers, 1972.

3. Ronald W.Roussel - " Handbook of Separation Process Technology ", John Wiley, New York, 1987.
4. Humphrey J., Keller G., Separation Process Technology, McGraw-Hill. 1997.
5. Khoury F.M., Multistage Separation Processes, 3rd Ed., CRC Press. 2004.
6. Wankat P.C., Separation Process Engineering, 3rd Ed., Prentice Hall. 2012.
7. Seader J.D., Henley E.J., Separation Process Principles, 2nd Ed., Wiley. 2006.
8. Basmadjian D., Mass Transfer and Separation Processes: Principles and Applications, 2nd Ed., CRC Press. 2007.
9. Rousseau, R. W., Handbook of Separation Process Technology, John Wiley, New York. 2009.

Paper Name: **Interfacial Engineering**	**L**	**T**	**P**	**Total**	**Credit**
Paper Code: **OECE 816** (Open Elective - IV)	**2**	**1**	**0**	**3**	**3**
Total Contact Hour = 40					

Evaluation:

Type of Evaluation		**Marks**	
Internal Assessment	Sessional Assessments through Class Test/Assignments	20	30
	Active participation in routine classes	05	
	Overall conduct, attendance, manners, skills etc.	05	
End Semester Examination			70
Total			**100**

Pre-requisite: Thermodynamics, Fluid Mechanics

Course Objectives: To understand role of interfaces in industrial applications of mass transfer to understand physical and thermodynamic properties of interfaces

Course outcomes:

Students completing the course will be able to

CO1	Explain the difference between the bulk and interfacial aspects of a process.
CO2	Explain mass transfer and separation process from the physical and interfacial point of view.
CO3	Explain the interfacial aspects of familiar separation processes.
CO4	Illustrate colloidal chemistry, fluid-fluid and solid-fluid interface engineering in different industrial fields.
CO5	Demonstrate intermolecular forces involved in colloids and interfaces.
CO6	Use various adsorption isotherms to engineering problems.

Course Contents:

Module I **(No. of classes: 10)**

Concept and definition of interface; Physical surfaces, Surface tension; **(1L)**

Kinetics of molecules in the surface; Overview of industrial applications of various interfacial phenomena; **(1L)**

Colloidal materials; Properties of colloidal systems; Experimental characterization of colloidal dispersions; **(1L)**

Forces at interface: Introduction to intermolecular and surface forces, van der Waals forces, Hamaker constant, Derjaguin approximation, Electrostatic double layer force, Gouy- Chapman model of double layer, Stern layer, Disjoining pressure, DLVO theory, Non- DLVO forces (Born repulsion, hydrophobic interaction, hydration force, bridging interaction). **(4L+3T)**

Module II **(No. of classes: 10)**

Surface and interfacial tension; Theoretical methods for the calculation of surface and interfacial tension; Experimental techniques for the determination of equilibrium and dynamic tension; **(2L+1T)**

Shape of the surfaces: curvature and radius of curvature, Young-Laplace equation; **(1L)**

Kelvin equation; Pendant and sessile drops; Adams-Bash forth equation; **(1L+1T)**

Characterization of fluid-solid interfaces; Contact angle and wetting phenomena; Young- Dupré equation; Measurement of equilibrium and dynamic contact angles; **(1L+1T)**

Deposition of thin films; Mechanism of film nucleation; Chemical vapor deposition, molecular beam epitaxy, sputtering and atomic layer deposition techniques; **(1L)**

Applications of fluid-solid interfaces in crystallization, development of ceramic materials, catalysts, electronic products and nanomaterials. **(1L)**

Module III **(No. of classes: 10)**

Adsorption at fluid-fluid and fluid-solid interfaces; Adsorption of surfactants; Gibbs and Langmuir mono layers; **(1L)**

Gibbs adsorption equation; Surface equation of state; Surface pressure isotherm; **(1L)**

Langmuir-Blodgett films and their applications; **(1L)**

Radiotracer and neutron reflection techniques for studying adsorption at fluid-fluid interfaces; **(1L)**

Henry, Freundlich, Langmuir, Frumkin and Davies adsorption isotherms; **(2L+1T)**

Brunauer-Emmett-Teller theory of adsorption; Adsorption hysteresis; Characterization of adsorption at fluid-solid interfaces by vacuum and non-vacuum techniques. **(1L+2T)**

Module IV **(No. of classes: 10)**

Interfacial rheology and transport processes; Surface shear viscosity; Surface dilatational viscosity; Boussinesq number; **(1L)**

Interfacial tension gradient and Marangoni effect; Gibbs and Marangoni elasticity; Boussinesq-Scriven model; **(1L)**

Interfacial turbulence; Motion of drops in a liquid; **(1L)**

Properties of monolayers, Surface pressure, Surface viscosity; Compressional moduli of monolayers, Shear elastic moduli, Yield values of monolayers; **(1L+1T)**

Diffusion in monolayers; Fibers from monolayers, Reactions in monolayers and emulsions, Complex formation in monolayers, Penetration into monolayers; **(1L+1T)**

Interfacial reactions; Reactions at fluid-solid interfaces; Langmuir-Hinshelwood model; External and internal transport processes; Interfacial poly condensation reactions; Fast and instantaneous reactions at fluid-fluid interfaces; Reactions at bio-interfaces; Micellar catalysis; Phase transfer catalysis. **(2L+1T)**

Suggested Text/Reference Books:

1. Hiemenz, P.C.and Rajagopalan, R., Principles of Colloid and Surface Chemistry, Marcel Dekker, New York, 1997
2. Adamson,A.W.and Gast,A.P., Physical Chemistry of Surfaces, John Wiley, New York, 1997.
3. Israelachvili,J., Intermolecular and Surface Forces, Academic Press, London, 1992.
4. Myers,D., Interfaces and Colloids, Wiley-VCH, Inc.,(1999).
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Paper Name: **General Viva-Voce**	L	T	P	Credit
Paper Code: **PIGV 807)**	-	-	-	2

Evaluation:

Type of Evaluation		**Marks**
End Semester Examination	At the end of the Semester–VIII, General (Comprehensive) Viva-Voce Examination shall be conducted to test the student's overall grasp of the principles of Chemical Engineering and allied subjects	
	Evaluation by two Boards of Examiners consisting of at least one External Examiner and three Internal Examiners, in each Board.	
Total		**100**

End of Semester VIII

(End of the 4-Year B. Tech in Chemical Engineering Program)