Undergraduate
Program Course Curriculum

Department of Chemical Engineering

Indian Institute of Technology Jodhpur

URL :- https://www.iitj.ac.in/chemical-engineering/en/curriculum

1. Introduction

Engineering disciplines have become increasingly interdisciplinary in nature and Chemical Engineering is not an exception to that. The flexibility of opting for different specialization is ingrained in formulating the structure and curriculum of the Chemical Engineering programme. Traditionally, Chemical Engineering teaching is focused on transport phenomena, chemical engineering thermodynamics, mass transfer, fluid mechanics, heat transfer, chemical kinetics, computational systems and process control. With the advent of the era of Artificial Intelligence (AI), Machine Learning (ML), Molecular Engineering, Industry 4.0 in Chemical Plants; the discipline is being transformed by incorporation of new emerging technologies. Through this Under-Gradute (UG) programme in Chemical Engineering, IIT Jodhpur is making conscious effort to divulge from traditional path and planning to establish itself to become a leading institute in this new genre of Chemical Engineering education, which includes foundational courses, fundamental courses in chemical engineering, emerging areas in chemical engineering, and sustainability aspects for chemical engineers.

The program begins with students pursuing a common foundation in mathematics, physics, chemistry, engineering sciences, engineering design and programming. Students are expected to build on this foundation with the concentration on core chemical engineering subjects ranging from material and energy balance, chemical process technology, process control, chemical engineering thermodynamics to chemical reaction engineering, transport phenomena. Core courses are followed by a set of departmental electives that enable students to target their degree program towards in-depth knowledge of areas matching their specific interests. The program ensures that the design experience, which includes both analytical studies and experiments, is integrated throughout the curriculum in a structured manner leading to advanced work. Students can tailor their focus areas in consultation with a faculty advisor. Students can choose their departmental electives from the following thrust areas:

(i) Sustainable Chemical Processes and Materials
(ii) Interfacial and Transport Phenomena
(iii) Molecular Processes and Phenomena
(iv) Process System Engineering, Optimization and Control

Comprehensive understanding of these areas will provide graduates with the ability to adapt and maintain leadership roles through the application of fundamental principles to a rapidly changing and growing discipline. The curriculum also offers numerous options that enable students to gain practical experience, ranging from collaborative projects in industries to entrepreneurship opportunities at the institute's incubation centre.

2. Objectives of the program

The key objectives of this program are to:

I. Enable students to have fundamental understanding of the core concepts of Chemical Engineering
II. Offer opportunities to choose electives for the trust and emerging areas
III. Empower students with emerging concepts for plant design in context of chemical engineering via courses designed with AI, ML, and Industry 4.0 applications.
IV. Integrate analytical and computational ability with experimental skills to create individuals competent in professional engineering practices in the domain of Chemical Engineering.
V. Inculcate an attitude towards commitment to engineering ethics, leadership qualities entrepreneurship and professional development.

3. Expected Graduate Attributes

Graduates of B.Tech. program in Chemical Engineering will have:

I. Strong understanding of mathematics, science and engineering fundamentals of Chemical Engineering.

II. Aptitude to implement AI, ML, Molecular Engineering and Industry 4.0 relevant technologies in chemical companies.
III. Ability to use simulation and computational tools for a better understanding and designing of chemical processes/equipments.
IV. Technical competency for addressing sustainability issues and ability to provide technological solutions of sustainable nature.
V. Entrepreneurial spirit to undertake disruptive innovations.
VI. Skills to communicate engineering concepts and ideas to peers in written or oral forms.
VII. Commitment towards professional ethics and have humanitarian engineering skills.

4. Learning Outcomes

Graduates of the B.Tech. program in Chemical Engineering will:

I. Gain a strong understanding of mathematics, science and engineering fundamentals of Chemical engineering including the concepts of material and energy balance; computational methods; transport phenomena; reaction engineering; mass transfer; thermodynamics; heat transfer; fluid mechanics and process control.
II. Have the ability to design a process equipment or plant to meet desired requirements under socio-economic and environmental constraints.
III. Be equipped with knowledge of emerging domains like big data & AI applications.
IV. Have technical capability for addressing sustainability issues related to water, energy and environment.
V. Receive effective hands-on laboratory training as a part of laboratory courses and short-term research projects, and be able to design and conduct experiments as well as to analyse and interpret data.
VI. Develop their communication skills by participating in classroom presentations, entrepreneurial events, seminars and workshops.

5. New skillsets targeted

Graduates of UG programme in Chemical Engineering at IIT Jodhpur will have,

I. Capability to design and develop process equipment and plants using computer-aided design and modelling software.
II. Advanced technical capability to work with AI/ ML and Industry 4.0 aspects in chemical plants and project management
III. Latest industrial aptitude in the areas of Recycle and Reuse, Zero Liquid Discharge (ZLD), Wealth from Waste, AI in Process Engineering, Molecular Engineering, Complex fluids and Interfacial Engineering.
IV. Fluency with scientific computing techniques via courses including Material and Energy Balance, Scientific Computations and Data Analytics in Process Modelling and Simulation.

Department of Chemical Engineering

Table 1: B.Tech Curriculum Structure

S.N.	Course Type	Course Category	Credits	Minimum Total
1	Institute Core (I)	Engineering (IE)	16	39 (27.6%)
		Science (IS)	17	
		HSS (IH)	06	
2	Programme Core (P)	Programme Compulsory (PC)	66	**90 (63.8%)**
		Programme Electives (PE)	18	
		(B.Tech.) Project (PP)	6	
3	Open (O)	Electives (OE)	12	12 (8.5%)
			Total (Graded)	**141 (100%)**
4	Essential Audit (Non-taught)	Humanities (NH)	3	**12**
		Engineering (NE)	3	
		Industry-Academia Summer Internship outside IIT Jodhpur (two summers, minimum 45 days)	4	
		Design Credit	2	
			Total for award of Degree (Graded + Non-Graded)	**153**

Institute-wide Engineering (IE) Courses (16 credits):

1. Engineering Mechanics [3-0-0]
2. Introduction to Computer Science [3-0-2]
3. Introduction to Machine Learning [3-0-2]
4. Engineering Workshop [0-0-2]
5. Engineering Drawing [0-0-2]
6. Environment and Sustainability [3-0-0]

Institute-wide Science (IS) courses (17 credits):

1. Physics [3-0-0]
2. Physics Lab [0-0-2]
3. Chemistry [3-0-0]
4. Chemistry Lab [0-0-2]
5. Mathematics I [2-1-0]
6. Mathematics II [2-1-0]
7. Introduction to Bioengineering [2-0-2]

Institute-wide NH courses (3 credits):

1. Communication Skill [0-0-2]
2. Introduction to Professional Ethics [1-0-0]
3. Performing Arts /Sports [0-0-1]
4. Social Connect and Responsibilities [0-0-1]

Institute-wide NE courses (3 credits):

1. Engineering Design I [0-0-2]
2. Engineering Design II [0-0-2]
3. Introduction to Profession I [0-0-1]
4. Introduction to Profession II [0-0-2]

Table 2. Semester-wise plan for B.Tech in Chemical Engineering

Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	NC	GC
	I Semester / II Semester						**II Semester / I Semester**				
IE	Engineering Mechanics	3-0-0	3	-	3	IE	Introduction to Machine Learning	3-0-2	5	-	4
IE	Introduction to Computer Science	3-0-2	5	-	4	IS	Chemistry	3-0-0	3	-	3
IS	Physics	3-0-0	3	-	3	IS	Introduction to Bioengineering	2-0-2	4	-	3
IH	HSS I	3-0-0	3		3	IS	Chemistry Lab	0-0-2	2	-	1
IS	Physics Lab	0-0-2	2	-	1						
IS	Mathematics I	2-1-0	3	-	3	IS	Mathematics II	2-1-0	3	-	3
IE	Engineering Drawing	0-0-2	2	-	1	IE	Engineering Workshop	0-0-2	2	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill	0-0-2	2	1	-	IH	HSS II	3-0-0	3		3
NH	Social Connect and responsibilities	0-0-1	1	0.5	-	NE	Introduction to Profession	0-0-2	2	1	
NH	Performing Arts /Sports	0-0-1	1	0.5	-						-
	Total		**27**	**03**	**18**		**Total**		**26**	**02**	**18**
	III Semester						**IV Semester**				
PC	Chemical Process Technology	3-0-0	3	-	3	PC	Chemical Engineering Thermodynamics	3-0-0	3	-	3
PC	Material and Energy Balances	3-0-0	3	-	3	PC	Process Heat Transfer	3-0-0	3	-	3
PC	Momentum Transfer Operations	3-1-0	4	-	4	PC	Chemical Reaction Engineering	3-1-0	4	-	4
PC	Mechanical Unit Operations	3-0-0	3	-	3	PC	Mass Transfer – I	3-1-0	4	-	4
PC	Scientific Computations	3-0-0	3	-	3	PC	Fuel and Energy Technology	3-0-0	3	-	3
IE	Environment and Sustainability	3-0-0		-	3	PC	Chemical Engineering Lab I	0-0-6	6	-	3
	Total		**16**	**00**	**19**		**Total**		**23**	**00**	**20**
Summer Semester Internship (Minimum 45 days, Outside IIT Jodhpur)											
	V Semester						**VI Semester**				
PC	Mass Transfer – II	3-1-0	4	-	4	PC	Transport Phenomena	3-1-0	4	-	4
PC	Process Dynamics and Control	3-1-0	4	-	4	PC	Project Management and Process Economics	3-0-0	3	-	3
PC	Data Analytics in Chemical Engineering	3-0-0	3	-	3	PC	Applications of AI in Chemical Engineering	3-0-0	3	-	3
PC	Chemical Enginerring Lab II	0-0-6	6	-	3	PC	Process Equipment Design	3-0-0	3	-	3
						PC	Chemical Engineering Lab III	0-0-6	6	-	3
PE	Programme Elective	3-0-0	3	-	3	PE	Programme Elective	3-0-0	3	-	3

NH	Professional Ethics I	1-0-0	1	1	-						
	Total		**21**	**1**	**17**		**Total**		**22**	**00**	**19**
Summer Semester Internship (Minimum 45 days, Outside IIT Jodhpur)											
	VII Semester						**VIII Semester**				
PP	B.Tech Project 1	0-0-3	-		3	PP	B.Tech Project 2	0-0-3	-		3
PE	Programme Elective	3-0-0	3	-	3	PE	Programme Elective	3-0-0	3	-	3
PE	Programme Elective	3-0-0	3	-	3	OE	Open Elective	3-0-0	3	-	3
PE	Programme Elective	3-0-0	3	-	3	OE	Open Elective	3-0-0	3	-	3
OE	Open Elective	3-0-0	3	-	3	OE	Open Elective	3-0-0	3	-	3
	Total		**12**	**-**	**15**		**Total**		**12**	**-**	**15**
									Total of Graded and Non-Graded Credit	**6**	**141**
									Industry-Academia Summer Internship	**4**	**-**
									Non-Graded Design Credits	**2**	
									Grand Total	**12**	**153**

Table 3: Curriculum Structure B.Tech with Minor

S.N.	Course Type	Course Category	B.Tech. Regular	Dual Degree (B.Tech +PhD)	B.Tech. With Minor
1	Institute Core (I)	Engineering (IE)	16	16	16
		Science (IS)	17	17	17
		Humanities (IH)	06	06	06
3	Programme Core (P)	Programme Compulsory (PC)	66	66	66
		Programme Electives (PE)	18	18	18
		B.Tech. Project (PP)	6	6	6
4	Open (O)	Electives (OE)	12	12	0
5	Additional Credits	Programme Compulsory (PC) (Fixed Courses Prescribed by the offering Academic Unit.)	0		18
6	PhD	Compulsory (DC)		12	0
		Electives (DE)		12	
		PhD. Thesis (MP)		64	
		Total Graded	**141**	**229**	**147**
7	Essential Audit (Non-taught)	Humanities (NH)	3	3	3
		Engineering (NE)	3	3	3
		Design/Practical Experience (ND)	2	2	2
		Industry-Academia Summer Internship outside IIT Jodhpur (two summers, minimum 45 days)	4	4	4
		Total Graded+Essential Audit	**153**	**241**	**159**

Table 4: List of Core Courses for Minor in Chemical engineering

Cat	***Course***	***LTP***	***CH***	***NC***	***GC***	***Cat***	***Course***	***LTP***	***CH***	***NC***	***GC***
PC	Chemical Process Technology	3-0-0	3		3	PC	Process Heat Transfer	3-0-0	3		3
PC	Material and Energy balances	3-0-0	3		3	PC	Chemical Reaction engineering	3-1-0	4		4
PC	Momentum Transfer Operations	3-1-0	4		4	PC	Mass transfer – I	3-1-0	4		4

Table 5: List of Programme Compulsory Courses:

S. No.	Course Name	
1	Chemical Process Technology	CHL2XXX
2	Material and Energy Balances	CHL2XXX
3	Momentum Transfer Operations	CHL2XXX
4	Mechanical Unit Operations	CHL2XXX
5	Scientific Computing	MAL2XXX
6	Chemical Engineering Thermodynamics	CHL2XXX
7	Process Heat Transfer	CHL2XXX
8	Chemical Reaction Engineering	CHL2XXX
9	Mass Transfer – I	CHL2XXX
10	Fuel and Energy Technology	CHL2XXX
11	Chemical Engineering Lab I	CHL2XXX
12	Mass Transfer – II	CHL3XXX
13	Process Dynamics and Control	CHL3XXX
14	Data Analytics in Chemical Engineering	CHL3XXX
15	Chemical Engineering Lab II	CHL3XXX
16	Transport Phenomena	CHL3XXX
17	Project Management and Process Economics	CHL3XXX
18	Applications of AI in Chemical Engineering	CHL3XXX
19	Process Equipment Design	CHL3XXX
20	Chemical Engineering Lab III	CHL3XXX

Table 6: List of Programme Elective Courses:

S. No.	Course Name	
1	Petroleum and Petrochemical Engineering	CHL4XXX
2	Biochemical and Bioprocess Engineering Fundamentals	CHL4XXX
3	Introduction to Complex Fluids	CHL4XXX
4	Interfacial Engineering in Soft Matter	CHL4XXX
5	Solid Waste Management	CHL4XXX
6	Air Pollution Control Technology	CHL4XXX
7	Process Modelling and Simulation	CHL4XXX
8	Artificial Intelligence in Chemical Reactor Control	CHL4XXX
9	Advanced Wastewater Treatment	CHL7XXX
10	Chemometrics	CHL7XXX
11	Computational Fluid Dynamics	CHL7XXX
12	Heterogeneous Catalysis and Catalytic Reactors	CHL7XXX
13	Modelling of Atoms, Molecules and Surfaces	CHL7XXX
14	Molecular Simulations	CHL7XXX
15	Membrane Technology	CHL7XXX
16	Novel Separation Processes	CHL7XXX
17	Principles of Electrochemical Engineering	CHL7XXX
18	Process Optimization	CHL7XXX
19	Process Safety & Hazards	CHL7XXX
20	Structure and Property for Polymers	CHL7XXX

Detailed Course Content of Programme Compulsory Courses

Title	**Chemical Process Technology**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The instructor will introduce the basic concepts of the Chemical Process Industry and give a fundamental background of innovative chemical process technology and process development.

Learning Outcomes
The students are expected to:
1. Develop a vision of the processes involved in the chemical process industries.
2. Develop a vision for the process development for chemical plants at different scales.

Contents
Introduction:
Structure of Chemical Industry, Types of Chemical Industries (Organic, Inorganic, Natural Product), Schematic representation of processes, process flow diagram, equipment and plant - flow sheet, block flow diagram, Pipe color codes, General principles of development of chemical industry, Raw materials and energy sources, base chemicals [4 lectures]
Recent trends in the chemical industry; Introduction of green chemistry, Life cycle analysis, impact on carbon credits and pollution control [2 lectures]

Inorganic Chemical Industries:
Sulfur and Sulfuric acid: Elemental sulfur production from (waste) SO2 and H2S rich gases; sulfuric acid: Reactions and thermodynamics, Reactor for SO2 conversion, sulfuric acid production process, catalyst deactivation; sulfur pollution [3 lectures]

Fertilizer Industries: Nitrogen, phosphorus and potassium-based fertilizers; Ammonia production – catalyst, reactions, thermodynamics and reactor features, manufacturing process, storage of ammonia; Urea manufacture – process, major equipment, engineering challenges. Production of nitric acid – process details, Ammonium nitrate manufacture – process, equipment; Ammonium sulphate manufacture as a byproduct from steel plants; NPK [4 Lectures]

Chlor-alkali industries: Manufacture of chlorine and caustic: process and engineering challenges in modern plants. Soda ash manufacture - Solvay process. [2 Lectures]

Cement and lime industries: Types of cement, reactions involved in cement manufacture, setting of cement; production of cement clinker – reactions thermodynamics and equipment, production of finished cement from clinker. [2 Lectures]

Organic Chemical Industries:
C1 chemicals: Products through C1 chemicals, Production of synthesis gases; Methanol manufacture from synthesis gas / others - reactions, thermodynamics and catalysts [3 lectures]
C2 chemicals: Consumption pattern of C2 chemicals, production of ethylene and acetylene using steam cracking of hydrocarbons, synthesis of ethylene oxide and acetaldehyde [3 lectures]
Polymer manufacturing processes: Physico-chemical structure of polymers, Manufacturing processes for polyethylene, polypropylene, polyvinyl chloride, ; Types of rubber and manufacture of synthetic rubber. [3 lectures]

Natural product industries:

Soaps and detergents: Classification of cleansing compounds, Methods of soap and detergent production [3 lectures]
Pulp and paper industries: Raw materials and their effect on the finished product quality, production of pulp, sulfate process, major engineering issues; Production of paper from pulp [2 lectures]
Carbohydrates and fermentation industries: Sugar industries: Methods of production, major engineering problems; Starch derivatives: Starch synthesis from different sources; production of

starch derivatives; Challenges with fermentation industries, Production and purification of ethanol [3 lectures]
Air separation: Production of liquid air, nitrogen, oxygen, argon in an air-separation industry. [2 Lectures]

Biorefineries and bio-based chemicals: Biorefinery concepts, biorefinery design criteria, Production of bio-based chemicals: biobutanol, glycerol, succinic acid, hydroxymethyl furfural, Bio ethylene, BioCNG, aviation turbine fuel from waste cooking oil [3 lectures]

Textbook

1. DRYDEN'S Outlines of Chemical Technology (3rd edition); by Marshall Sitting (Author), Charles Dryden (Author), M. Gopala Rao (Author); East-West press
2. Shreves Chemical Process Industries, (5th Edition); George T. Austin; McGraw Hill Education

Reference Book

1. Chemical Process Technology (2nd edition); Jacob A. Moulijn (Author), Michiel Makkee (Author), Annelies E. Van Diepen (Author); John Wiley & Sons Inc

Online Course Material

Prof. Tamal Banerjee; Chemical Process Technology, NPTEL Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/103103217

Title	**Material and Energy Balances**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The Instructor will:
Provide the basics of material and energy balances for Chemical Engineers.

Learning Outcomes
The students are expected to:
1. Gain basic understanding of material and energy balances.
2. Gain knowledge of applying the material and energy balances to Chemical Engineering Systems.

Contents
Introduction: Units and dimensions in chemical engineering (1 lecture), stoichiometric and composition relations (1.5 lectures), concept of degrees of freedom and linear dependence of a set of equations (1.5 lectures). [4 lectures]

Material Balance: Selection of a basis, conservation of mass/atom material balance for systems with and without chemical reactions, material balance involving gases (5 lectures), vapors, liquids and solids and uses of real gas relationships, vapor-liquid equilibrium and concept of humidity and saturation (5 lectures); Analysis of systems with bypass, recycle and purge; Analysis of processes involving condensation, crystallization and vaporization (4 lectures). [14 lectures]

Energy Balance : Conservation of energy with reference to general energy balance with and without chemical reactions, chemical engineering problems involving reversible processes and mechanical energy balance (5 lectures), calculations of heat of change of phase (solid – liquid and liquid – vapor), heat of reaction, heat of combustion, heat of solutions and mixing (5 lectures), determination of temperatures for adiabatic and non-adiabatic reactions (3 lectures). [13 lectures]

Simultaneous Material and Energy Balances: Degrees of freedom analysis for multicomponent systems (2 lectures), combined steady state material and energy balances for units with multiple sub-systems (2 lectures). [4 lectures]

Unsteady State Material and Energy Balances: Transient material and energy balances with and without chemical reactions. [4 lectures]

Textbook
1. Himmelblau D.M., Riggs, J.B. (2015), Basic Principles and Calculations in Chemical Engineering, 8th Ed., Prentice India Education Services.
2. Bhat, B.I., Vora, S.M., (2004), Stoichiometry, 4th Ed., Tata McGraw Hill Publishing Company Ltd.

Reference Books
1. Narayanan K.V. and Lakshmikutty B., (2006), Stoichiometry and Process Calculations, Prentice Hall of India.
2. Felder R.M. and Rousseau R.W., (2005), Elementary Principles of Chemical Processes, 3rd Ed., John Wiley & Sons.
3. O.A. Hougen, K.M. Watson and R.A. Ragatz, 2004, Chemical Process Principles Part 1, 2nd Edition, CBS Publishers and Distributors.

Online Course Material
Majumdar S.K., Basic Principles and Calculations in Chemical Engineering, SWAYAM Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://swayam.gov.in/nd1_noc20_ch20

Title	**Momentum Transfer Operations**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The instructor will
1. To inculcate the fundamental laws governing fluid flow
2. Help the students to understand the importance and application of fluid mechanics.
3. To exemplify concepts of similarity and model testing

Learning Outcomes
The students are expected to have the ability to:
1. Apply fundamental knowledge in modelling and analysis of fluid flow problems in engineering
2. Interpret data from experiments of fluid flows and solve using differential equations and charts

Contents
Introduction [2 Lecture]: Definition and properties, continuum approach, types of fluids, basics of vector calculus, and index notations.

Dimensional analysis and similarity [2 Lectures]: Buckingham Pi theorem and examples.
Fluid statics [4 Lectures]: Basic equations, Manometry, hydrostatic force on submerged bodies, rigid body motion.

Integral analysis of fluid flow [4 Lectures]: Reynolds transport theorem, conservation equations.

Differential analysis [6 Lectures]: Kinematics of fluids - Deformations in fluid particle, strain rate, vorticity, stream function, potential function, streamlines, path lines, streak lines, derivation of Navier-Stokes equations.

Incompressible Inviscid flow [6 Lectures]: Euler's equation, Bernoulli's equation, elementary potential flows, superposition of elementary flows. Vorticity and vortex flows
Internal Incompressible Viscous flow [4 Lectures]: Hagen-Poiseuille and Couette flows, skin friction and loss coefficients, venturi meter, orifice meter, and Pitot tube.

External Incompressible Viscous flow [5 Lecture]: Boundary layer over flat plate, boundary layer thickness, Prandtl-boundary layer equations, momentum integral equation, adverse pressure gradient & separation, drag coefficients.

Few Industrial Applications [6 Lectures]: Pipe networks, Flow past immersed objects, pumps and compressors, fluidization, and different types of fluidization methods.

Textbook
1. Fox, R. W., Pitchard, P. J., and McDonald, A. T., (2010), Introduction to Fluid Mechanics, 7th Edition, John Wiley & Sons Inc.
2. Munson, B. R., Rothmayer, A. P., Okiishi, T'H., and Huebsch, W. W. Fundamentals of Fluid Mechanics, 7th Edition, John Wiley and Sons.
3. Kundu, P. K, Cohen, I. M and Dowling, D. R, Fluid Mechanics, 6th Edition, Associated Press.
4. McCabe, W.L., Smith, J.C., Harriott, P., (2005), Unit Operations of Chemical Engineering, 7th Edition, McGraw-Hill International edition.

Reference Book
1. White, F. M. (2003), Fluid Mechanics, 5th Edition, McGraw-Hill.
2. Cimbala, J.M. and Cengel, Y.A., (2010), Fluid Mechanics: Fundamentals and Applications, McGraw-Hill.
3. Bird, R. B., Stewart, W. E., and Lightfoot, E. N., 2006, Transport Phenomena, 2nd edition, John Wiley & Sons.

Self-Learning Material
1. S. Chakrabarty, Introduction to Fluid Mechanics, NPTEL Course Material, Mechanical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/112/105/112105269/

2. V.Shankar, Fluid Mechanics, NPTEL Course Material, Chemical Engineering, IIT Kanpur, https://nptel.ac.in/courses/103/104/103104044/#

Title	**Mechanical Unit Operations**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The Instructor will:
1. Provide general principle and mechanism of different chemical engineering processes

Learning Outcomes
The students are expected to have the ability to:
1. Understand and correlate the principles of different processes and suggest design solutions to engineering problems related to separation.

Contents
Particulate matter: Introduction, Particulate matter, size reduction (2 lectures), enlargement and separation, Crushers and Grinders (3 lectures), Sieve, Mixing, Agitation (2 lectures). [7 lectures]

Packed Columns and Granular Beds: Motion of Particles in a Fluid, flow through beds and columns 4 lectures), Single Fluid flow through Granular Beds, Specific Surface and Voidage (5 lectures), Packings, pressure drop in packed column (5 lectures). [14 lectures]

Filtration and Membrane Separation: Theory, filtration equipment, membrane processes (7 lectures), general equation, microfiltration, fouling, pervaporation (6 lectures). [13 lectures]

Flotation and sedimentation: Fundamental concept, froth flotation (2 lectures), gravity settling, centrifugation, design criteria (3 lectures). [5 lectures]

Textbook
1. Harker, J. H., Backhurst, J. R., Richardson, J.F., 2013, Coulson and Richardson's Chemical Engineering, 2nd Volume, Particle Technology and Separation Processes, 5th Edition, Butterworth-Heinemann.
2. W.L. McCabe, J. Smith, P. Harriot, 2005, Unit Operations of Chemical Engineering, 7th Edition, McGraw Hill.

Reference Book
1. E. Ortega-Rivas, 2012, Unit Operations of Particulate Solids: Theory and Practice, CRC Press, FL, 2012.

Online Course Material
1. Kishore N, Mechanical Unit Operations, NPTEL course material, Department of Chemical Engineering, IITGuwahati, https://nptel.ac.in/courses/103/103/103103155/

Title	**Scientific Computations**	Number	MAL2XXX
Department	Mathematics	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

1. Demonstrate the validity and error in the numerical results
2. Explain numerical techniques for a variety of problems
3. Introduce how to solve numerically algebraic equations, linear systems of equations, approximation and ordinary differential equations.

Learning Outcomes

The students will have the ability to:

1. Develop an understanding of numerical error and applicability of a particular method.
2. Solve numerically algebraic equations, linear systems of equations and ordinary differential equations.
3. Carry out numerical interpolation, differentiation and integration.

Contents

Errors in computation [Lectures 2]: Numerical Algorithms and errors, source and types of errors, error propagation, floating point representation, rounding error and floating point arithmetic.

Roots of equation [Lectures 7]: Iterative methods, order of convergence, Iterative methods for roots of nonlinear system of equations.

Linear systems of equations [Lectures 7]: Direct and iterative methods (Jacobi, Gauss Seidel), rate of convergence of iterative methods, Condition number, Power and inverse power methods for eigenvalue problems, matrix factorization schemes (LU, QR, spectral, Schur, polar, SVD).

Interpolation [Lectures 7]: Lagrange, Newton divided difference formula, Newton's interpolations, errors in interpolation.

Differentiation and Integration [Lectures 8]: differentiation using interpolation formulas, Integration using interpolation, Newton-Cotes formulas, Gauss quadrature rules, and Method of Undetermined Coefficients.

Ordinary differential equations [Lectures 8]: Taylor series method, Euler's Method, Modified Euler's Methods, multistep methods, Runge-Kutta Methods, adaptive methods, BVP finite difference methods, introduction to parallel computation.

Textbook

1. S.S. Sastry, (2012) Introductory Methods of Numerical Analysis, PHI Learning.
2. E. Kreyszig, (2010) Advanced Engineering Mathematics, Wiley.
3. S.C. Chapra, (2008) Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw-Hill.

Reference Books

1. R.L. Burden and J.D. Faires, (2011) Numerical Analysis, Cengage Learning.
2. J.H Mathews and K.D. Fink, (2006) Numerical Methods using Matlab, Pearson Education.
3. R. Süli and D.F. Mayers, (2003) Introduction to Numerical Analysis, Cambridge University Press.

Self-Learning Material

1. Lal, R. and Banerjee S., Numerical Analysis, NPTEL Course Material, Department of Mathematics, IIT Roorkee, https://nptel.ac.in/courses/111107062/
2. Usha, R., Numerical Analysis, NPTEL Course Material, Department of Mathematics, IIT Madras, https://nptel.ac.in/courses/111106101/

Title	**Chemical Engineering Thermodynamics**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The Instructor will:
1. Provide background of basic concepts in thermodynamics for chemical engineers such as fugacity, activity coefficient, vapor-liquid equilibrium and reaction equilibrium while focusing on thermodynamics of fluids, equilibria and processes.

Learning Outcomes
The students are expected to:
1. Gain understanding of thermodynamic aspects relevant to chemical engineering
2. Learn about the importance of thermodynamics for mixing, equilibria and processes

Contents
Thermodynamic systems (open, closed, isolated), State and path functions, Intensive and extensive properties with examples. (2 lectures) Laws of thermodynamics, PVT behaviour of fluids, Gibb's phase rule, cubic equations of state and generalized correlations with numerical solving. [5 lectures]

Vapor-liquid equilibrium (VLE): Phase rule, simple models for VLE, VLE by modified Raoult's law(3 lectures), VLE from K-value correlations, Flash calculations (2 lectures) with examples. [5 lectures]

Solution Thermodynamics: Fundamental property relationships (1 lecture), free energy and chemical potential (1 lecture), partial properties, definition of fugacity and fugacity coefficient of pure species and species in solution (3 lectures), the ideal solution and excess properties (3 lectures) with numerical solving. [8 lectures]

Liquid phase properties from VLE: Models for excess Gibbs energy, heat effects and property change on mixing with examples, UNIFAC and UNIQUAC models. [3 lectures]

Liquid-Liquid Equilibria: Vapor-Liquid-Liquid Equilibria (2 lectures); Solid-Liquid Equilibria (2 lectures); Solid-Gas Equilibria (2 lectures) [6 lectures]

Chemical reaction equilibria: Equilibrium criterion, equilibrium constant, evaluation of equilibrium constant at different temperatures (3 lectures), equilibrium conversion of single reactions, multireaction equilibria (4 lectures) with numerical solving. [7 lectures]

Thermodynamic Analysis of Processes: Work and free energy, availability (2 lectures), analysis of mixing, separation processes (3 lectures). [5 lectures]

Textbook
1. Smith J.M., Van Ness H.C. and Abbott M.M., (2005), Introduction to Chemical Engineering Thermodynamics, 7th Ed., McGraw Hill.
2. Rao, Y.V.C., (1997), Chemical Engineering Thermodynamics, University Press, Hyderabad

Reference Book
1. Koretsky M.D., (2004), Engineering and Chemical Thermodynamics, John Wiley & sons.
2. Kyle B.G., (1999), Chemical and Process Thermodynamics, 3rd ed., Prentice Hall.
3. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 5th edition, Wiley, 2020, India

Online Course Material
1. Ananth M.S., Chemical Engineering Thermodynamics, NPTEL Course Material, Department of Chemical Engineering, IIT Madras, https://nptel.ac.in/courses/103106070/

Title	**Process Heat Transfer**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
1. To inculcate understanding, formulation, designing and solving problems with various modes of heat transfer
2. To explain detailed design concepts of heat exchangers, evaporators

Learning Outcomes
Students will acquire the ability to understand different modes of heat transfer, be able to design and assess the performance of heat exchangers and evaporators, and be equipped with practical problem solving skills.

Contents
Introduction [1 lecture]: Different modes of heat transfer, Fourier's law and Newton's law of cooling,Thermal conductivity and diffusivity

Conduction [7 lectures]: Steady state conduction (plane wall, cylinder and sphere) with and without heat generation, Network analysis, critical thickness of insulation, Unsteady state conduction: Lumped capacitance method, transient conduction in large walls and cylinder. Numerical Simulation of Heat Transfer using COMSOL Multiphysics/MATLAB

Convection [8 lectures]: Forced convection heat transfer in laminar and turbulent boundary layer flow; empirical and practical relations for forced convection. free convection heat transfer from vertical, horizontal and inclined surfaces; combined free and forced convection heat transfer, Heat transfer in agitated vessels and packed beds

Heat Exchangers [10 lectures]: Various types of heat exchangers, The Overall Heat-Transfer Coefficient, Fouling Factors. The Log Mean Temperature Difference method, Effectiveness-NTU Method, Problems on double pipe and shell and tube heat exchanger using the LMTD approach and the effectiveness-NTU method. Basics of Compact Heat Exchangers and their importance in the chemical industry, Formulation of a design and rating problems in heat exchangers, Heat transfer analogies, Heat exchanger design and selection criteria.

Heat Transfer with Phase Change [6 lectures]:
Boiling heat transfer: Subcooled and saturated boiling, boiling curve for pool boiling, basics of burnout in flow boiling.
Condensation heat transfer: Film and Dropwise condensation, Derivation of the mathematical model of Nusselt theory for film condensation on a vertical plate, effect of non condensable gas on the rate of condensation.
Evaporation: Mass and energy balances for single and multiple effect evaporators. The concept of steam economy in multiple effect evaporators, Numerical problems on single effect evaporator and multiple effect evaporators with and without boiling point elevation.

Radiation [4 lectures]: Law of radiation, View factor, black and gray body radiation, radiation network and radiation shield.

Introduction to AI/ML in heat transfer, Aspect of process safety [2 Lectures]

Textbook
1. J.P. Holman, Heat Transfer, 10th edition, McGraw-Hill, New York, 2010.
2. Cengel, Y.A. Ghajar, A.J. Heat and Mass Transfer: Fundamentals and Applications: 2025, McGraw Hills.
3. Bergman, T. L., Lavine, A. S. Incropera, F. P. DeWitt, D.P. Fundamentals of Heat and Mass Transfer, 8th Edition, ISBN: 978-1-119-35388-1, 2018.

Reference Book
1. Geankoplis,C.J., Transport processes and Unit operations, 3rd edition, PHI,2002.
2. Kern D Q, Process Heat Transfer, Tata McGraw-Hill, New Delhi, 1997

3. McCabe W.L., Smith J.C. and Harriott P., Unit Operations in Chemical Engineering, 7th Edition, McGraw Hill,2005

Title	**Chemical Reaction Engineering**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce basic concepts of reaction kinetics and chemical reactors.

Learning Outcomes

The students are expected to have the ability to:

1. Have fair understanding of basic concepts of chemical engineering reaction kinetics and chemical reactors.
2. Design and operate a chemical reactor.

Contents

Introduction: [3 lectures] General understanding and background, Definition of rate of reaction, Concepts of rate equations, stoichiometry and rate laws, types of reactors, industrial reactions and reactors.

Reaction kinetics: [10 lectures] Determination of kinetic parameters, Interpretation of data, design equation using batch- and semi batch- reactors (5 lectures), CSTR, PFR and recycle reactor, auto catalytic reactions, reactor choice for single reaction, Reactor design for ideal flow reactors (5 lectures).

Design for Multiple Reactions: [5 lectures] Parallel and series reactions, analysis of product distribution and determination of reactor size (2 lectures), selectivity and yield factors, Denbigh reactions, reactor choice for multiple reactions (3 lectures).

Reactor design and operation: [13 lectures] Isothermal and non-Isothermal design of ideal reactors, tubular reactor, auto-thermal process (4 lectures), CSTR, first order reversible reaction, Residence time distribution (RTD) theory, role of RTD in reactor behavior (5 lectures), age distribution (E) of fluid, relationship between E and F curve; non-ideal flow (4 lectures).

Catalytic reaction: [8 lectures] Physical and chemical adsorption(1 lecture) , Rate controlling steps, Kinetics of solid catalyzed gas phase reactions, (3 lectures); intra- and inter- particle mass transfer, Thiele modulus and effectiveness factor, performance equations (4 lectures).

Text Book

1. Fogler H. S., (2006), Elements of Chemical Reaction Engineering, 4th Ed., PearsonPrentice Hall.
2. Levenspiel O., (2000), Chemical Reaction Engineering, 3rd Ed., John Wiley and Sons.

Reference Book

Schmidt L. D., (2005), The Engineering of Chemical Reactions, 2nd Ed., Oxford University Press.

Online Course Material

Mandal, B., CHEMICAL REACTION ENGINEERING – I, NPTEL Course Material, Department of Chemical Engineering IIT Guwahati, https://nptel.ac.in/courses/103/103/103103153/

Title	**Mass Transfer I**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

Share basic concepts of mass transfer operation, definitions and overview of various mass transfer processes.

Learning Outcomes

The students are expected to:

Gain basic understanding of the mass transfer operations and its industrial applications.

Contents

Introduction to Mass Transfer: [9 lectures] Overview with examples and definitions, Fick's Law (1st law), steady state molecular diffusion for fluids in laminar flow, diffusivity of gases and liquids (5 lectures), applications of molecular diffusion, method of separation, penetration and surface renewal theories (2 lectures), Mass transfer coefficient and diffusion in various solid geometries (2 lectures).

Gas-Liquid Mass Transfer: [6 lectures] Bubble column, Agitated vessels with single phase liquid, Agitated vessels with gas-liquid contact (2 lectures), Tray tower, Wetted-wall tower, Spray tower and scrubbers (2 lectures), Co-current and counter-current flow, end effects and axial mixing (2 lectures).

Gas Absorption (in Liquids/ Solvents): [12 lectures] Type of separation processes, equilibrium relation between phases, single and multiple equilibrium stages (3 lectures), Mass transfer between phases, continuous humidification processes (3 lectures), Absorption in plate and packed tower, absorption of concentrated mixture in packed tower (4 lectures), Estimation of mass transfer coefficients for packed tower (2 lectures).

Drying: [12 lectures] Introduction of various drying methods, equipment of drying, vapour pressure of water and humidity (2 lectures), Bound and unbound moisture, equilibrium moisture, free moisture, total moisture, drying curves (2 lectures), Constant rate drying, falling rate drying (3 lectures), Combined effect of conduction-convection-radiation on mass transfer, falling rate drying by diffusion (2 lectures), Falling rate drying by capillary flow, various dryer design, freeze drying (3 lectures).

Textbook

1. Treybal R.E. (1981) Mass Transfer Operation, 3rd Ed., McGraw Hill Education, New Delhi.
2. Dutta, B.K. (2007) Principles of Mass Transfer and Separation Processes, 2nd edition, Prentice Hall of India

Reference Book

1. McCabe W.L., Smith J.C. and Harriott P. (2017), Unit Operations of Chemical Engineering, 7th Ed., McGraw Hill

Online Course Material

1. Majumdor S.K. and Das C., Mass Transfer Operations I, NPTEL Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/103103035/
2. Mandal B., Mass Transfer Operations I, NPTEL Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/103/103/103103145/

Title	**Fuel and Energy Technology**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
1. To provide students with a fundamental understanding of different types of fuels and their role in energy systems and industrial processes.
2. To develop knowledge of renewable energy technologies and emerging fuels

Learning Outcomes
The students are expected to:
1. Classify different types of fuels and energy resources and explain their role in global and industrial energy systems.
2. Evaluate emerging energy technologies and able to assess the environmental impacts and sustainability aspects of different fuels and energy systems.

Contents
Introduction: Global and indian energy landscape, energy demand trends and sectoral consumption, energy resources and classification, renewable vs non-renewable energy, energy units and conversions [3 lecture]

Solid Fuels:
Coal: Formation and classification of coal, chemical composition of coal, industrial importance of coal, characterization, Coal gasification, Fisher-Tropsch synthesis [5 lecture]
Biomass: Biomass fuels and properties, biomass densification and briquetting, biomass conversion technologies [3 lecture]

Liquid Fuels:
Petroleum and Liquid Fuels: Origin and formation of petroleum, composition of crude oil, crude oil classification, petroleum properties relevant to fuels, petroleum refining, alternative liquid fuels [6 lecture]

Gaseous Fuels:
Natural gas composition and properties, LPG and LNG, producer gas and water gas, syngas production and applications [4 lecture]

Combustion reactions and stoichiometry, air–fuel ratio calculations, excess air concept, heat of combustion, combustion efficiency, pollutant formation (NOx, SOx, particulate matter) [5 lecture]

Conventional energy conversion systems, thermal power plants, rankine cycle concept, gas turbine power plants [4 lecture]

Renewable energy technologies, electrochemical energy systems, solar energy systems, wind energy systems, hydropower, bioenergy technologies, emerging energy technologies and sustainability, hydrogen as a fuel. hydrogen production routes, Carbon capture technologies, Fuel cell, Green Ammonia [7 lecture]

Energy policy, Environmental & Safety: Regulations, Sustainability, and Environmental, Social, and Governance (ESG) frameworks [2 lecture]

Textbook
1. Samir Sarkar, Fuels and Combustion; Taylor & Francis
2. Godfrey Boyle, Renewable Energy: Power for a Sustainable Future, Oxford University Press.
3. James G. Speight, The Chemistry and Technology of Petroleum, CRC Press.

Reference Book
1. O P Gupta, Elements of Fuel & Combustion Technology, Khanna Book Publishing Co. (P) LTD.
2. G. W. Himus, The Elements of Fuel Technology, Leonard Hill

Title	**Chemical Engineering Lab I**	Number	CHL2XXX
Department	Chemical Engineering	L-T-P [C]	0-0-6 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will:

1. Introduce various forms of flow measuring devices and techniques.
2. Provide the practical knowledge about the determination of the rate of heat exchange in various modes of heat transfer.

Learning Outcomes

The students are expected to have the ability to:

1. Apply fundamental knowledge in modelling and analysis of fluid flow problems in engineering.
2. Interpret data from experiments of fluid flows, momentum transfer and solve using differential equations and charts.
3. Able to estimate the performance of heat exchanges in various modes of heat transfer.
4. Understand basic laws of conduction, convection, and radiation heat transfer processes.

Contents

Tentative List of Laboratory Experiments for Momentum Transfer Operation

- Study the hydrodynamics in a packed bed to calculate the pressure drop per unit length of the packed bed.
- Study of frictional head losses through pipes, fittings, and flow metering devices.
- Study of discharge through the venturi-meter, orifice-meter, and rotameter test rig.
- Study of different types of flow through the Reynolds' number.
- Study the motion of a solid particle moving through different viscous liquids to determine the drag coefficient.
- Verification of Bernoulli's equation experimentally to calculate the total energy at different points.

Tentative List of Laboratory Experiments for Heat Transfer

- Determination of thermal conductivity of a metal rod under steady state heat conduction conditions.
- The study of boiling heat transfer characteristics in a pool boiling system and obtain the
- boiling curve between heat flux and surface temperature.
- Study of heat transfer between two fluids in a double pipe heat exchanger under parallel flow and counter flow conditions and to determine the overall heat transfer coefficient and exchanger effectiveness.
- Study of heat transfer between two fluids in a Shell & Tube heat exchanger under parallel flow and counter flow conditions and to determine the overall heat transfer coefficient and exchanger effectiveness.
- Study of heat transfer under forced convection conditions and determine the convective heat transfer coefficient for fluid flow over a heated surface.
- Determination of the emissivity of a given surface and to study the radiation heat transfer characteristics of different materials.

Reference Book

1. Fox, R. W., Pitchard, P. J and McDonald, A. T., (2010), Introduction to Fluid Mechanics, 7th Edition, John Wiley & Sons Inc.
2. Cimbala, J.M., Cengel, Y. A. (2010), Fluid Mechanics: Fundamentals and Applications, McGraw-Hill.
3. Incropera, F. P. & Dewitt, D. P., (2011), Fundamental of Heat and Mass Transfer, John Wiley & Sons.
4. Holman J.P., Heat Transfer, Tata McGraw-Hill Edition, New Delhi.

Title	**Mass Transfer II**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The Instructor will:
Share basic concepts of mass transfer operation, definitions and overview of various mass transfer processes. This is a 2nd course in the series of mass transfer followed by Mass Transfer I.

Learning Outcomes
The students are expected to:
Gain detailed understanding of the mass transfer unit operations and its industrial applications.

Contents
Principles of Gas-Liquid Mass Transfer: [6 lectures] Mixture VLE, phase rule, Raoult's law, Modified Raoult's law, Henry's law, Antoine equation, Clausius-Clapyeron equation, P-xy and T-xy diagrams (4 lectures), Azeotropes, thermodynamic equilibrium factor, relative volatility (2 lectures).

Distillation in Tray Columns: [10 lectures] Flash vaporization, partial condensation (1 lectures), differential distillation, Ponchon and Savarit Method for tray towers, Single Vs multiple feeds (3 lectures), McCabe & Thiele Method, reflux ratios, azeotropic mixtures (3 lectures), enthalpy concentration diagrams, Multicomponent systems (3 lectures).

Distillation with Packed Towers: [8 lectures] Multicomponent systems, reflux ratios (3 lectures). Lewis and Matheson Calculation, Method of Thiele and Geddes, azeotropic distillation (3 lectures), extractive distillation, low pressure distillation (2 lectures).

Solid-Fluid Operations: [8 lectures] Effect of temperature and pressure, liquid-solid systems, the Freundlich equation (3 lectures), stage wise operations, equipment, fluidized and moving beds, principles of ion-exchange (5 lectures)

Liquid-Extraction (Solvent Extraction) & Solid-Fluid Operations: [7 lectures] Basics Definitions including feed, solvent, extract, raffinate (4 lectures); liquid-liquid equilibria, the mixture rule, effect of temperature and pressure, three liquid systems (3 lectures).

Textbook

1. Treybal, R.E., (1981), Mass Transfer Operation, 3rd Ed., McGraw Hill Education.
2. Dutta, B.K., (2007), Principles of Mass Transfer and Separation Processes, 2nd edition, Prentice Hall of India.
3. Foust, A.S., (1980), Principles of Unit Operations, 2nd Edition, Wiley, New York.

Reference Book

1. McCabe W.L., Smith J.C. and Harriott P. (2017), Unit Operations of Chemical Engineering, 7th Ed., McGraw Hill

Online Course Material

1. Majumdor S.K. and Das C., Mass Transfer Operations I, NPTEL Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/103103035/
2. Mandal B., Mass Transfer Operations I, NPTEL Course Material, Department of Chemical Engineering, Indian Institute of Technology Guwahati, https://nptel.ac.in/courses/103/103/103103145/

Title	**Process Dynamics and Control**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will:

1. Impart knowledge of the dynamics and control strategies of linear and nonlinear chemical processes.
2. Introduce modeling techniques and analysis methods for dynamic process behavior.
3. Develop understanding of feedback control systems, controller design, and stability analysis.

Learning Outcomes

Students will be able to model and analyze the dynamic behavior of chemical processes and design appropriate control strategies, including PID and digital control methods, for stable and efficient process operation.

Contents

Introduction: Significance of Chemical Process Control, Design aspects of a control system, Elements of a control loop [2 lectures]

Process Modeling: Process variables, significance of mathematical modeling in process control, degrees of freedom analysis, dynamic modeling of simple processes, state-space models. [4 lectures]

Analysis of Dynamic Behavior of Processes: Linearization of non-linear systems, Laplace transforms, Dynamic model building - transfer functions, Response of first and second order processes, Approximation of higher-order processes transfer function, Process with time delays, MIMO Processes [7 lectures]

Feedback control systems: Block diagram representation of control systems, introduction to feedback control, Dynamic behavior of Feedback-controlled systems [4 lectures]

Stability analysis and Controller Design: Review of stability analysis (Routh-Hurwitz test), root-locus method [2 lectures]; PID Controller design, Tuning, and Applications in Process control [3 Lectures]

Frequency Response Analysis: Bode and Nyquist plots, Gain and Phase margins, Stability using frequency response [3 lectures]; Effect of process parameters on Bode and Nyquist plots, control system design by frequency response methods [2 lectures]

Advanced control systems: Cascade control, feed-forward control, ratio control, dead time compensation, Multi-variable control & Relative Gain Array [5 lectures]

Digital and Industrial Process Control: Sampling and data acquisition, analog-to-digital and digital-to-analog conversion, discrete representation of continuous signals, digital implementation of PID controllers, PLC/DCS-based control systems. [2 lectures]

Controller Performance Assessment: Identifying drifts, poor dynamics and variability, detecting oscillations, Fundamentals of Controller Performance Diagnosis [5 lectures]

Text Book

1. Coughanowr D. R. and LeBlanc S., (2008), Process System Analysis and Control, 3rd Ed.,McGraw Hill.
2. Ogunnaike B. A. and Ray W. H., 1994, Process Dynamics Modeling and Control, Oxford University Press.

Reference Book

1. Stephanopoulos G., (1990), Chemical Process Control – An Introduction to Theory and Practice, Prentice-Hall of India.
2. Seborg D. E., Edgar T. F. and Mellichamp D. A., 2004, Process Dynamics and Control, 2nd Ed., John Wiley and Sons.
3. Rengaswamy, R., Srinivasan, B., & Bhatt, N. P. (2020). Process control fundamentals: analysis, design, assessment, and diagnosis. CRC Press.

Online Course Material

1. Jogwar, S., Chemical Process Control, NPTEL Course Material, Department of Chemical Engineering IIT Bombay, https://nptel.ac.in/courses/103/101/103101142/

2. Rengasamy, R., Process Control-Design, Analysis and Assessment, NPTEL Course Material, Department of Chemical Engineering IIT Madras, https://nptel.ac.in/courses/103/106/103106148

Title	**Data Analytics in Chemical Engineering**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will:

- Introduce students to data-driven approaches in chemical engineering
- Develop skills in data preprocessing, visualization, and statistical analysis
- Understand the role of big data and digitalization in process industries

Learning Outcomes

The students are expected to:

1. Identify and preprocess different types of chemical engineering data
2. Apply statistical methods to analyze process data
3. Use multivariate techniques (PCA/PLS) for process analysis
4. Understand fundamentals of big data in chemical industries

Course Content

Introduction to Data Analytics [3 lectures]: Data-driven chemical engineering, Evolution of process industries - Industry 4.0, Types of data and life cycle of data, importance of domain knowledge and illustrative case studies from chemical process industries.

Big Data in Chemical Engineering (8 Lectures): Introduction to Big data concepts (Volume, Velocity, Variety), Industrial data sources (sensors, IoT, SCADA), Data streaming and real-time analytics in process industries, basic concepts of cloud computing and data infrastructure, Data security and integrity, challenges in big data in industrial environments.

Data Preprocessing and Management [10 lectures]: Introduction to data preprocessing, data visualization, transformation and normalization, data cleaning (missing data, outliers), basics of time-series analysis, data reconciliation and validation, Introduction to databases and data storage (SCADA, data historians) in industrial systems.

Statistical and Multivariate Methods [10 lectures]: Descriptive statistics and visualization, Probability distributions in process data, Hypothesis testing and confidence intervals, Correlation and covariance analysis, regression analysis, multivariate data analysis, Principal Component Analysis (PCA), Partial Least Squares (PLS) and Design of Experiments (DoE), Application of statistical methods for process monitoring.

Modern Data Analytics Techniques [4 Lectures]: Introduction to interpretable and explainable AI in engineering analytics, feature importance and model interpretation, SHAP (SHapley Additive Explanations), LIME (Local Interpretable Model-Agnostic Explanations), Integrated Gradients, counterfactual explanations and “what-if” analysis for process decision-making, applications in chemical engineering systems.

Applications & Integrated Case Studies (4 Lectures): Process monitoring using statistical tools, Quality control in chemical manufacturing, Process optimization using data driven approaches and DoE, Integrated industrial case study.

Text Book

1. Montgomery, Douglas C., and George C. Runger. Applied statistics and probability for engineers. John wiley & sons, 2010.
2. Hastie, Trevor, Robert Tibshirani, and Jerome Friedman. "The elements of statistical learning." (2009).
3. Zavala, V. M. (2025). Statistics for chemical engineers: from data to models to decisions. Cambridge University Press.

Reference Book

1. Qin, S. Joe. "Process data analytics in the era of big data." AIChE Journal 60.9 (2014): 3092-3100.

2. Mustafy, Tanvir, and Md Tauhid Ur Rahman. Statistics and data analysis for engineers and scientists. Singapore:: Springer, 2024.
3. Balusamy, Balamurugan, Seifedine Kadry, and Amir H. Gandomi. Big data: concepts, technology, and architecture. John Wiley & Sons, 2021.

Title	**Chemical Engineering Lab II**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	0-0-6 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will:

1. Share basic overview and working of different batch and continuous reactors.
2. Share basic overview and working principle of separation equipment
3. To provide hands-on experience in experimental chemical reaction engineering, Mass Transfer I.

Learning Outcomes

The students are expected to have the ability to:

1. Gain basic understanding on the operations of different chemical reactors and its working principle.
2. Gain basic understanding on the Mass Transfer I equipment's and its working principle.

Contents

Tentative List of Laboratory Experiments for Chemical Reaction Engineering

- Study of Isothermal CSTR Reactor
- Study of Isothermal PFR
- Study of Isothermal Batch Reactor
- Study of Isothermal Semi-Batch Reactor
- Study of RTD in CSTR
- Study of RTD in PFR (Straight Tube type)
- Study of RTD studies in packed bed reactor
- Study of Cascade CSTR Reactor
- Study of Packed-Bed Reactor
- Study of PFR followed by CSTR and vice versa
- Study of Adiabatic Batch Reactor

Tentative List of Laboratory Experiments for Mass Transfer I

- Study of Vapor in air Diffusion Apparatus
- Study of Solid in Air Diffusion Apparatus
- Study of Liquid Diffusion Coefficient Apparatus
- Study of Natural Draft Tray Dryer Apparatus
- Study of Forced Draft Tray Dryer Apparatus
- Study of Absorption in Packed Bed Apparatus with single column
- Study of Absorption in Packed Bed Apparatus with multiple column
- Study of Absorption in Sieve-Plate Column Apparatus
- Study of Humidification & Dehumidification apparatus
- Study of Experimental Water Cooling Tower

Reference Book

1. Fogler H. S., (2006), Elements of Chemical Reaction Engineering, 4th Ed., PearsonPrentice Hall.
2. Levenspiel O., (2000), Chemical Reaction Engineering, 3rd Ed., John Wiley and Sons.
3. Treybal, R.E., (2017), Mass Transfer Operation, 3rd Ed., McGraw Hill Education and Sons.

Title	**Transport Phenomena**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

1. Provide knowledge about momentum, heat and mass transfer in chemical engineering systems and their analogous behavior.
2. Train the student to create chemical engineering knowledge using the transport phenomena approach special focus on combined transport problems.

Learning Outcomes

The students are expected to have the ability to:

1. Identify and analyze the properties and mechanisms of momentum, energy and mass transport.
2. Analyze, design and solve problems combining these transport phenomena in chemical engineering.

Contents

Basics of Transport phenomena: Introduction (1 lecture), Basic concepts of Vector and Tensor Analysis (3 lectures)
Momentum transport: Basic concepts, Euler/Lagrangian viewpoint, laminar and turbulent flows (3 lectures), boundary layers, stress tensor, Shell momentum balances, equations of change, dimensional analysis (5 lectures), applications to isothermal flow of Newtonian & non-Newtonian fluids (2 lectures).

Energy transport: Basics of energy transport, conductive, convective and viscous dissipation energy fluxes (5 lectures), Equations of change for non-isothermal systems (3 lectures), dimensional analysis, and applications to steady- state conduction and convection (6 lectures)

Mass transport: Basics of mass transport, mechanisms, and mass and molar fluxes
Continuity equation: Derivation for a binary mixture (2 lectures), convection- diffusion problems, Unsteady state mass, heat and momentum transport (4 lectures), Formulation of transport problems from nature (5 lectures).

Text Book

1. Bird, R.B., Stewart, W.E. and Lightfoot, E.N., (2006), Transport Phenomena, 2nd ed., Wiley India.
2. Welty, C. E., Wicks, R. E., Wilson, G. L. Rorrer, (2007), Fundamentals of Momentum, Heat, and Mass Transfer. 5th ed., Wiley India Pvt. Ltd.

Reference Book

1. Geankoplis C.J., 2004, Transport Processes and Separation Process Principles, 4th Ed., Prentice-Hall of India.
2. Brodkey, R.S., Hershey H.C., 2003, Basic concepts in transport phenomena, a unified approach. Vol 1, Brodkey
Publishing.32
3. Deen, W.M., (1998), Analysis of Transport Phenomena, Oxford University Press.
4. Thompson, W.J., (2000) Introduction to Transport Phenomena, Prentice Hall

Online Course Material

Transport Phenomena’ by Prof. S.K. Gupta, NPTEL: https://nptel.ac.in/courses/103/102/103102024/

Title	**Project Management and Process Economics**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will introduce basic concepts in project management, Process Equipment Design, engineering economics, and its application to chemical engineering.

Learning Outcomes

The students are expected to have the ability to:
1. Understand the importance of project management for the development of the chemical industry
2. Understand the importance of process economics for any chemical industry

Contents

Project Definitions
Concept of Capital Project and capital budgeting. Major components of Project Analyses and the critical issues associated with it. Feasibility studies for Project selection and the key factors in major investment decision. [4 lectures]

Project Strategies
Formulations and Resource allocation, Generation and Flow of Project ideas, Tools for identifying investment opportunities. Preliminary screening, identification of positive NPV. [5 lectures]

Process economics based on Project Analysis
Market and Demand analyses: Market survey, Characterization of the market. Demand forecasting. Technical analysis: Manufacturing Process/Technology, Choices and Appropriateness. Material inputs & Utilities, Product mix and Plant capacity. Financial analysis: key aspects of Project cost, means of Finance, Cost of Production, working capital requirement and its financing. Profitability projections, Cash flow statements, Balance Sheet. Criterial for investment: list and classify. Net present Value (NPV) and Internal rate of Return (IRR).
Social cost-benefit analysis. Concept of Depreciation and methods of estimation. [14 lectures]

Project Risk Analysis
Project Risk analysis: sources, measures and properties on risk, Sensitivity analysis, Scenario analysis & Break-even analysis. Strategy for measuring Risk. [4 lectures]

Project Management & Case Studies
Life cycle of a Project, Project control, Human aspects of Project management, pre-requisites for successful project implementation. Network Techniques for Project management: Development of Project network, Project time estimation, Determination of Critical Path. PERT and CPM model. Environment Impact Assessment (EIA) of a typical Industrial Project, LCA [12 lectures]

Textbook

1. H. Kerzner: Project Management: A systems Approach to Planning, Scheduling & Controlling, 13th Edition, Wiley, 2022
2. M.S. Peters, K.D. Timmerhaus, R. West, 2003 'Plant Design and Economics for Chemical Engineers', 5th edition, McGraw Hill
3. Chemical Engineering Design Principles, Practice and Economics of Plant and Process Design (2nd edition), Gavin Towler (Author), Ray Sinnott (Author), Butterworth-Heinemann, Elsevier

Reference Book

1. F.C. Jelen and J.H. Black, 1992, 'Cost and Optimization Engineering', McGraw Hill, 3rd ed.
2. S. Walas, 1988,'Chemical Process Equipment Selection and Design', Butterworth

Title	**Applications of AI in Chemical Engineering**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The instructor will:

- Provide a conceptual and historical foundation of AI in engineering
- Introduce AI techniques relevant to chemical engineering
- Enable students to apply AI methods to real chemical engineering problems
- Develop ability to analyze, model, optimize, and control processes using AI

Learning Outcomes

The students are expected to:

1. Gain fundamental understanding of the application of AI in chemical engineering.
2. Learn to develop AI-based models, approaches for chemical engineering systems.
3. Understand emerging trends in intelligent chemical systems

Contents

Artificial Intelligence in Chemical Engineering Background [2 lectures]: Early Attempts, Expert System Era, Neural Network Era, Effects and Lacunae of Expert System Era and Neural Network Era on Chemical Engineering, Deep Learning and Data Science Era.

AI Techniques [16 lectures]:
Expert systems - Knowledge representation and rule-based reasoning in expert systems, inference mechanisms;
Machine learning in Chemical plants: Introduction, basics of decision trees and Random forests.
Artificial Neural Networks - fundamentals of artificial neural networks including biological inspiration and architecture, multi-layer perceptrons, feedforward neural networks and training concepts including backpropagation, development of ANN-based models for chemical engineering systems and practical considerations;
Deep Learning - Introduction to deep learning and need for multi-layer representations, convolutional neural networks, recurrent neural networks for sequential data and process time-series, long short-term memory networks.
Reinforcement learning - fundamentals of reinforcement learning including agent–environment interaction, concept of Markov decision processes.
Introduction to Generative and Agentic AI.

AI in process modelling [5 lectures]: First-principles vs data driven models in chemical engineering, Modelling Real-World Processes: Deep and Shallow Knowledge Integrated with Approximate Reasoning in a Diagnostic Expert System, development of AI-based models for chemical engineering systems - Reactors, separation processes and complex systems.

AI in Optimization [5 lectures]: Overview of optimization problems in chemical engineering, limitations of classical methods, introduction to AI-based optimization including heuristic and evolutionary approaches, Case studies: Applications to chemical reactor analysis.

AI in Control [5 lectures]: Limitation of conventional control techniques, Fuzzy logic control, Neural Network Control and Reinforcement learning control, case study on control of reactive distillation column and discussion on practical implementation issues.

AI techniques in fault detection and diagnosis of chemical engineering [5 lectures]: Introduction to fault detection and diagnosis in chemical processes, application of artificial neural networks for fault detection, Multi-fault diagnostics, Discrete event systems, Industrial fault detection system.

AI in Chemical Engineering Recent Trends and Future Outlook : [1 lecture]: Self-organizing intelligent systems and Digital twins.

Text Book

1. Michael L. Mavrovouniotis, 1990, Artificial Intelligence in Process Engineering, Academic Press

2. Bishop, C. M., & Nasrabadi, N. M. (2006). Pattern recognition and machine learning (Vol. 4, No. 4, p. 738). New York: springer.

Reference Book

1. Venkat Venkatasubramanian, 2019, The Promise of Artificial Intelligence in Chemical Engineering: Is It Here, finally? AIChE, Vol. 65, No. 2
2. Zeinab Hajjar, Shokoufe Tayyebi and Mohammad Hosein Eghbal Ahmadi, 2018, Application of AI in Chemical Engineering.
3. Eghbal-Ahmadi M-H, Zaerpour M, Daneshpayeh M, Mostoui N. Optimization of fluidized bed reactor of oxidative coupling of methane. International Journal of Chemical Reactor Engineering. 2012; 10:1-21

Title	**Process Equipment Design**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives
The instructor will introduce the concepts related to the process equipment design, mechanical design and its application to chemical engineering

Learning Outcomes
The students are expected to:
1. Develop the fundamentals of mechanical design of equipment related to the chemical industries.
2. Understand the detailed design of different heat exchange and mass transfer equipment applicable in chemical industries.

Contents
Mechanical design:
Design preliminaries: Design codes and design parameters, stress, Equipment fabrication and testing [2 lectures]
Mechanical design: Background and relevance, Design of cylindrical and spherical vessels, Design of heads and closures, Design of process vessels and pipes, Design of tall vessels, Design of high-pressure vessels, Design of support for process vessels [7 lectures]

Design of Heat Exchange Equipment:
Double pipe heat exchanger: Introduction, Film coefficients, Pressure drop calculations, double pipe exchangers in series-parallel arrangements [3 lectures]
Shell and tube heat exchangers: Introduction, components, calculation of film coefficients, pressure drop calculations, heat exchange using water, and its impact on exchanger design [6 lectures]
Design of cooling tower: Introduction, diffusion theory, relationship between wet-bulb temperature and dew-point temperature, humidification-dehumidification, heat balance [3 lectures]

Design of Mass Exchange Equipment:
Design for multi-component distillation: Approximate method, FUG method; Equilibrium-Based Methods, MESH equation, Bubble point method, sum-rates method [6 lectures]
Design of flash vessel; Design of a packed tower for absorption/extraction column (4 lectures)

Design of Pump and Compressor: Types of pumps and selection criteria, calculations of a pumping circuit and rating, characteristic curves, Cavitation and NPSH, blowers and compressors, Single/multistage compression, Typical multistage compressor calculations. [8 lectures]

Textbook
1. Introduction to Chemical Equipment Design, Mechanical Aspects, B. C. Bhattacharyya; CBS Publishers and Distributors
2. Process Heat Transfer, Donald Q. Kern, Tata McGraw-Hill Edition
3. Separation Process Principles, 4th edition, Seader, Henley, Roper, Wiley
4. Plant Design and Economics for Chemical Engineers by M. S. Peters and K. D. Timmerhaus

Reference Book
1. S. Walas, 1988,'Chemical Process Equipment Selection and Design', Butterworth.
2. R. Smith, 1995, 'Chemical Process Design', McGraw Hill.
3. Process Equipment Design: Vessel Design, Lloyd E. Brownell, Edwin H. Young

Title	**Chemical Engineering Lab III**	Number	CHL3XXX
Department	Chemical Engineering	L-T-P [C]	0-0-6 [3]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

- Share basic overview and working principle of mass transfer II equipment.
- Provide hands-on experience in analyzing the dynamic behavior of process systems.
- Demonstrate the implementation of feedback control strategies such as PID control.
- Enable students to model processes using experimental data and evaluate controller performance.

Learning Outcomes

The students are expected to:

1. Gain basic understanding on the mass transfer II equipment and its working principle.
2. Students will be able to experimentally analyze process dynamics and implement basic control strategies for regulating process variables in various process systems.

Contents

List of experiments for Mass Transfer

- Study of Vapour Liquid Equillibrium Apparatus
- Separation of Separation using Simple Batch Distillation Apparatus
- Separation of liquid mixture using Steam distillation setup
- Separation of liquid mixtures using Fractional distillation apparatus
- Determination of number of theoretical plates in a Sieve Plate Distillation Column Apparatus
- Study the performance of adsorption in a packed bed column.
- Study the performance of liquid-liquid extraction in a packed bed.
- Understanding Dissolution Process Using the Mass transfer with/without chemical reaction
- Study the performance of Solid-Liquid Extraction in a Packed-Bed Apparatus
- Study of separation using Ion Exchange Apparatus

List of experiments for Process Dynamics and Control

- Determination of Time constants of Thermocouple and U-tube Manometer
- Dynamics of level tank system - Interacting and Non-interacting
- Flow control trainer
- Level control trainer
- Characteristics of PID controller
- Temperature control of heater board - performance criteria based methods
- Stability analysis of Chemical Reactor system - Simulink based study
- Level control in multi tank system (conical and spherical system) - Cascade control scheme
- Level control of quadruple tank system - RGA Analysis

Reference Book

1. Stephanopoulos G., (1990), Chemical Process Control – An Introduction to Theory and Practice, Prentice-Hall of India.

2. Seborg D. E., Edgar T. F. and Mellichamp D. A., 2004, Process Dynamics and Control, 2nd Ed., John Wiley

3. Treybal, R.E., (2017), Mass Transfer Operation, 3rd Ed., McGraw Hill Education nd Sons.

Detailed Course Content of Programme Elective Courses

Title	**Petroleum and Petrochemical Engineering**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
Provide in-depth knowledge about the Provide background information about the petroleum and petrochemical engineering including crude oil reservoir, upstream and downstream processing of crude oil as well as some notable petrochemical products and processes

Learning Outcomes
The students are expected to gain:
1. Gain a holistic view of petroleum reservoir engineering as well as Petrochemical Engineering
2. To learn about the importance of crude oil formation, extraction, petrochemical products and processes.

Contents
[Part A: Petroleum Engineering]

Introductory concepts: Introduction to Petroleum and Petrochemical Engineering, Crude Petroleum Oil, Physical Properties of Crude Oil, origin of hydrocarbons, Exploration Techniques, Resource estimation, Oil Field Development, Oil Production Processes, Crude Conditioning and Storage, sustainable refining, hydrogen economy, carbon capture, bio-based petroleum products, and energy integration (10 lectures)

Petroleum Products and Test Methods: Transportation and Metering of Crude Oil, Crude Oil Analysis, domestic and automotive fuels, Aviation Fuels, Furnace fuels, EOR (6 lectures)

Chemical Processes in Petrochemicals: Transport Process and Process Equipment in Petroleum and Petrochemical Engineering, Dissociation and dehydrogenation (catalytic cracking, isomerization, alkylation, coking, hydrodesulfurization), hydrogenation, addition, condensation, polymerization (6 lectures)

[Part B: Petrochemical Engineering]

Petrochemical Intermediates from Petroleum Products:
Introduction, manufacturing processes for carbon black from methane/ natural gas, polyethylene production from ethane, Terephthalic acid and PET from xylene, Naphtha for olefins, sulfuric acid from sulfur, cosmetics and food grade coating wax from wax, naphtha cracking (8 lectures).

Petrochemical Finished Products from Intermediates: Manufacturing of paint, fiber, plastics, rubber, Nylons, fibers, processing of plastic, rubber, and fibers (9 lectures).

Text Book
1. Hatch, Lewis Frederic, and Sami Matar (1981) From hydrocarbons to petrochemicals, Gulf Publishing Company, Book Division.
2. Chaudhuri U. R. (2011) Fundamentals of Petroleum and Petrochemical Engineering, CRC Press

Reference Book
1. Meyers, Robert, and Robert Allen Meyers, eds. (2005) Handbook of petrochemicals production processes. McGraw-Hill.
2. James H. Gary, Glenn E. Handwerk and Mark J. Kaiser (2007) Petroleum Refining. Technology and Economics, Fifth Edition

Online Course Material
1. Pant, K.K. and Kunzru, D., Petroleum Refinery Engineering, NPTEL Course Material, Department of Chemical Engineering, IIT Delhi and Department of Chemical Engineering, IIT Kanpur https://nptel.ac.in/courses/103102022
2. Prof. Sonali Sengupta, NOC: Petroleum Technology, IIT Kharagpur, NPTEL Course Material, Department of Chemical Engineering, IIT Kharagpur https://nptel.ac.in/courses/103105221

Title	**Biochemical and Bioprocess Engineering Fundamentals**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
Provide the description of biochemical systems, processing of biochemical systems and the associated chemical engineering operations to handle biochemicals.

Learning Outcomes
The students are expected to:
1. gain understanding of structure and properties of biochemical systems
2. gain knowledge of applying chemical engineering concepts as applied to biochemical systems.

Contents

Introduction to biochemical and bioprocess engineering:
Fundamentals of biochemistry and microbiology, procaryotic and eucaryotic systems, biological vs. systems engineering approaches [3 lectures]

Structure and functions of biomacromolecules:
Proteins: Heirarchical structure of proteins; techniques for determination of protein structure; thermodynamics of protein folding; drug-substrate interactions [6 lectures].
Nucleic acids: Nucleotides, nucleobases, ribose and de-oxyribose sugar, nucleotide polymerisation; double helix structure of DNA; genetic functions and protein synthesis [6 lectures].

Enzyme kinetics:
Enzymes as biocatalysts; Michalis menten kinetics; mechanisms of mono- and bimolecular biochemical reactions; inhibition; co-operativity and allostery in enzyme kinetics; kinetics of immobilised enzymatic systems and applications [6 lectures].

Bioenergetics and metabolism:
Catabolism and anabolism; glucose utilisation and cellular respiration; fermentation technology [5 lectures]

Bioreactors and biomass growth:
Bioprocess models; constitutive and balance equations; kinetics of growth, product formation and biomass growth, kinetics of substrate utilization, product formation and biomass production; bioreactor modelling, stability and control [8 lectures].

Metabolic flux analysis:
Metabolic engineering; flux balance and metabolic flux analysis; flux variability analysis; case studies for metabolic engineering for product optimisation [5 lectures].

Textbook
1. Bailey J. E., Ollis D. F., (1986), Biochemical Engineering Fundamentals, 2nd Ed., Tata McGraw Hill Publishing Company Ltd.
2. Shuler M. L., Kargi F., (2002), Bioprocess Engineering: Basic Concepts, 2nd Ed., Prentice Hall PTR.

Reference Books
1. Nelson D. L., Cox M. M. (2013), Principles of Biochemistry, 6th Ed., W. H. Freeman and Co.
2. Douglas S. Clark and Harvey W. Blanch (1997), Biochemical Engineering, 2nd edition, Marcel Dekker Incorporated.
3. Mohanty K., Sasmal S. (2025) Biochemical Reaction Engineering, 1st Ed., CRC press

Title	**Introduction to Complex Fluids**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide information of various materials that do not follow the characteristics of simple fluid like water (Newtonian Fluid).
2. Highlight the underlying intermolecular interactions and its relation to the material properties.

Learning Outcomes
The students are expected to have the ability to:
1. Analyze and explain the anomalous behavior of different fluids.
2. Explain the rheological behavior of viscoelastic materials and the structure-property relation of fluid.

Contents
Complex fluids: Introduction, common features & applications (3 lectures), Viscoelasticity, Microstructures, Intermolecular and Surface forces (5 lectures), Forces in colloidal system and stability (3 lectures), Mechanical Rheology (2 lectures). [13 lectures]

Types of complex fluids and their properties: Colloidal dispersions, polymeric solutions (3 lectures), gels, liquid crystals (4 lectures), Emulsions and Blends (3 lectures), Surfactants and micelles (3 lectures). [13 lectures]

Micro and Mesoscopic Systems: Self-assembly, phases(4 lectures), Characterization of structureproperty relationships in complex fluids(5 lectures), Structures and Rheology of dispersions(4 lectures). [13 lectures]

Textbook
1. R. G. Larson, 1999, The Structure and Rheology of Complex Fluids, 1st Edition, Oxford University Press,
2. Jones, R. A. L., 2002, Soft Condensed Matter, 1st Edition, Oxford University Press.

Reference Book
1. Isaraelachvili, J., 2011, Intermolecular and Surface Forces, 3rd Edition, Academic Press.

Title	**Interfacial Engineering in Soft Matter**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Introduce the fundamental concepts of interfaces and its application.
2. Provide quantitative and conceptual treatment of interfacial forces and phenomena.

Learning Outcomes

The students are expected to have the ability to:

1. Anticipate the stability of a given interface.
2. Infer microscopic processes at the interface and suggest design solutions to engineering problems.

Contents

Interface: Concept and definition, physical surfaces, surface chemistry and physics of colloids (4 lectures), thin films, dispersions, emulsions, foams (4 lectures), interfacial self-assembly, amphiphilic system (3 lectures), comparison and contrast of liquid and solid interfaces (3 lectures). [14 lectures]

Surfaces and forces: Interfacial energy and forces, wetting, shape of interfaces (4 lectures), Intermolecular forces and potentials; solvation, structural and hydration forces (5 lectures); particle-particle interactions, thin film stability (3 lectures), self-organized monolayers and bilayers, electro-kinetic phenomena, adsorption (3 lectures). [15 lectures]

Industrial aspects: Interfacial rheology and transport, Catalysis (4 lectures), reaction-injection moulding, emulsions and foams that require stabilization (4 lectures), emulsifier, Coating Processes (2 lectures). [10 lectures]

Textbook

1. Isaraelachvili, J., 2011, Intermolecular and Surface Forces, 3rd Edition, Academic Press.
2. Ghosh, P., 2009, Colloid and Interface Science, PHI Learning.

Reference Book

1. G.J.M. Koper, 2009, An Introduction to Interfacial Engineering, second edition.

Online Course Material

1. Ghosh, P., Introduction to Interfacial Engineering, NPTEL course material, Department of Chemical Engineering, IIT Guwahati, https://nptel.ac.in/courses/103103033/

Title	**Solid Waste Management**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide background about the solid waste management including types, sources and processes

Learning Outcomes
The students are expected to:
1. Gain holistic understanding of processes and challenges in solid waste management

Contents
Introduction: Waste generation and management in a technological society, environmental impact of solid waste, sources of solid waste,(3 lectures) functional elements of a solid waste management system, challenges in solid waste management, integrated waste management(3 lectures) [6 lectures]

Collection and Processing of Solid Waste: Collection of MSW, material separation and handling, recyclable components, (3 lectures) size reduction and separation, thermal processing of waste, biological processing of waste, chemical processing of waste (3 lectures)[6 lectures]

Landfills for Disposal of Solid Waste: Decomposition of solid waste in landfills, types of landfills, requirements of an engineered landfill,(3 lectures) layout of a landfill site, landfill operations, environmental monitoring of landfills(4 lectures), leachate management - landfill liners, geosynthetic materials(4 lectures) [11 lectures]

Hazardous Waste and Management: Characteristics, landfills for hazardous waste, (4 lectures) autoclaving, microwaving, biomedical waste (4 lectures) [8 lectures]

Recycling of Electronic waste and PCBs: Electronic waste management in India, electronic waste recycling, Current approach for PCB recycling,(3 lectures) PCB scrap characteristics, technologies for PCB recycling, toxins in PCB fabrication, lead-free soldering, polyester recycling, waste rubber recycling, polyethylene and polypropylene recycling.(5 lectures) [8 lectures]

Textbook
1. Khan I. H., Ahsan N. (2014) Textbook of Solid Wastes Management, CBS Publishers and Distributors
2. Khandpur R. S. (2010) Printed Circuit Boards: Design, Fabrication, Assembly and Testing, Tata McGraw Hill Education Private Limited

Reference Book
1. Tchobanoglous G., Kreith F. (2002) Handbook of Solid Waste Management, 2nd Edition, McGraw Hill
2. Shalh K. L., (1999) Basics of Solid and Hazardous Waste Management Technology, Prentice Hall.

Online Course Material
1. Ramachandra T. V., Municipal Solid Waste Management, NPTEL Course Material, Department of Environmental Science, IISc Bengaluru, https://nptel.ac.in/courses/120108005/
2. IITM-EWRE, Solid and Hazardous Waste Management, NPTEL Course Material, Department of Civil Engineering, IIT Madras, https://nptel.ac.in/courses/105106056/

Title	**Air Pollution Control Technology**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide a broad view of air pollution and how to reduce it.
2. Provide information about various techniques to control different air pollution.

Learning Outcomes
The students are expected to have the ability to:
1. Understand and explain the processes causing air pollution.
2. Anticipate and quantify air pollution and design methods to control it.

Contents
Air pollution: Overview, fossil fuel and automobile, nature and classification of pollutants,(4 lectures) BS-VI regulation, techniques to measure and quantify air pollution, air quality management, Active and future research(5 lectures). [9 lectures]

Industrial Air Pollution Sources and Prevention: Air Pollution in the Chemical Process Industries, Petroleum Industry, Power plants;(5 lectures) Aluminum, Iron and Steel Manufacturing(2 lectures); Copper, Lead and Zinc Smelting(2 lectures); Nickel Ore Processing and Refining(2 lectures). [11 lectures]

Air pollution controlling techniques: Fabric filtration, cyclones, electrostatic precipitation, wet and dry scrubbing, condensation, thermal oxidation, Catalytic processes, Activated carbon, gasphase biofiltration, emerging technologies. [13 lectures]

Ventilation and Indoor Air Quality Control: Overview, issues and impact; Diagnose, manage and control, Ventilation and Air Conditioning,(3 lectures) volatile organic compounds (VOCs) household pollutants and control of indoor air quality, Issues related to ambient air clean-up(3 lectures). [6 lectures]

Textbook
1. Heck, R. M., Farrauto, R. J., and Gulati, S. T., 2012, Catalytic air pollution control: commercial technology. John Wiley & Sons.
2. Licht, W.,1988, Air pollution control engineering: Basic calculations for particulate collection, Vol. 10, CRC Press.

Reference Book
1. Wang, L.K., Pereira, N.C., Hung, Y., 2004, Air pollution control engineering, Vol. 1, Springer science + Business media.
2. Karl B. Schnelle, Jr., Charles A. Brown, 2002, Air Pollution Control Technology Handbook, CRC Press LLC.

Online Course Material
Environmental Air Pollution, NPTEL course material, Department of Civil Engineering, Indian Institute of Technology Delhi, https://nptel.ac.in/courses/105102089/

Title	**Process Modelling and Simulation**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

Deliver the fundamental concepts of modeling and simulation of chemical process.

Learning Outcomes

The students are expected to:

1. Understand the importance of mass, energy, and momentum balances in process modeling.
2. Explain the principles of process modeling and the role of mathematical models in chemical engineering systems.

Contents

Introduction: Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models (lumped parameter models, distributed parameter models), Degree-of-freedom analysis, Selection of design variables, Model simulation. (9 lectures)

Fundamental laws: Continuity equations, equation of motion, energy equations, equations of state, equilibrium, chemical kinetics. Review of thermodynamic correlations for the estimation of physical properties like phase equilibria, bubble and dew points (10 lectures).

Mathematical Models for Chemical Engineering Systems: Series of isothermal constant holdup CSTRs, CSTRs with variable holdups, Non-isothermal CSTR, single-component vaporizer, Stirred tank heater Batch reactor, reactor with mass transfer, Batch distillation with holdup, Ideal binary distillation column, Lumped parameter model of gas absorber, Model for heat exchanger, Model for interacting & non-interacting tanks (12 lectures).

Simulation: Numerical Methods, Gravity-Flow Tank, Three CSTRs in Series, Nonisothermal CSTR, Binary Distillation Column, Multicomponent Distillation Column, Variable Pressure Distillation, Batch Reactor, Introduction and use of process simulation software (Aspen Plus/ Aspen Hysys) for flow sheet simulation, python tools (8 lectures).

Textbook

1. W.L. Luyben, Process Modeling Simulation and Control for Chemical Engineers, 2nd edition, McGraw Hill (1990).
2. B.V. Babu, Process Plant Simulation, Oxford University Press (2004).

Reference Book

1. A. Rasmuson, B. Andersson, L. Olsson, R. Andersson, "Mathematical Modeling in Chemical Engineering", Cambridge University Press, 2014.
2. B. W. Bequette, Process Dynamics- Modelling, Analysis and Simulation, PHI International (1998).
2. D.M. Himmelblau and K.B. Bischoff, Process Analysis and Simulation: Deterministic Systems, John Wiley (1968)
3. B. A. Finlayson, Introduction to Chemical Engineering Computing, 2nd edition, John Wiley & Sons Inc (2014).

Title	**Artificial Intelligence in Chemical Reactor Control**	Number	CHL4XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide background on AI in chemical reactor design

Learning Outcomes
The students are expected to:
1. Gain fundamental understanding of the application of AI in chemical reactor design.
2. Learn to develop AI model equations, approaches for chemical reactors.
3. Learn to write basic codes of AI control for chemical reactors.

Contents
Reactor Models: Review of Mixing Problem, Batch Reactors (1 Lecture), CSTR, PFR, Bioreactor (1 Lecture), Non-isothermal reactors (1 Lecture), Fluidised bed and Packed bed reactors (1 Lecture), Slurry Reactor, Cholette's Model (1 Lecture), Non-Ideal Reactors (1 Lecture). [6 Lectures]

Basic Concepts of Filters: Bayesian Estimators, Luenberger Observer (3 Lectures), Kalman Observer, Extended Kalman Filter (4 Lectures), Unscented Kalman Filter, Particle Filter, Moving Horizon Estimation (4 Lectures), Multi-rate Estimations (3 Lectures), Multi-rate Observer (3 Lectures). [17 Lectures]

Case Studies: Qualitative Modelling of Chemical Reaction Systems (3 Lectures), Exothermic Batch Chemical Reactor Automation via Expert System (3 Lectures), State Estimation in a Batch Suspension Polymerization Reactor (3 Lectures), Dynamic Real-Time Optimization of Transitions in Industrial Polymerization Processes using Solution Models (2 Lectures), On-Line Nonlinear Model-Based Estimation and Control of a Polymer Reactor (2 Lectures), Recursive Estimation in Constrained Nonlinear Dynamical Systems (3 Lectures). [16 Lectures]

Textbook

1. Fogler, H. S., (2016), Elements of Chemical Reaction Engineering, Prentice-Hall
2. Michael L. Mavrovouniotis, 1990, Artificial Intelligence in Process Engineering, Academic Press

Reference Material

1. Mohammad Shahrokhi and Mohammad Ali Fanaei, 2001, State Estimation in a Batch Suspension Polymerization Reactor, Iranian Polymer Journal, Vol. 10, Number 3

Title	**Advanced Wastewater Treatment**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The instructor will:

1. Impart comprehensive knowledge of industrial and municipal wastewater.
2. Discuss mechanism and methodologies for wastewater treatment.
3. Discuss case studies

Learning Outcomes

The students are expected to have the:

1. Comprehensive knowledge of the wastewater treatment.
2. Knowledge of advanced methodologies such as wastewater management, recycle and reuse.

Contents

Introduction: Wastewater engineering: an overview, characterisation of wastewater and monitoring of industrial and municipal wastewater, emerging contaminants, environmental impacts of wastewater constituents. (4 lectures)

Conventional Water/ Wastewater Treatment: Existing unit operations and processes, basic philosophy of water and wastewater treatment plants; physio-chemical treatment methods: (i) Screening, (ii) conventional filtration, (iii) coagulation, (iv) flocculation, (v) floatation, (vi) Clari-flocculation (vii) sedimentation, (viii) sand filtration, etc. (10 lectures)

Aerobic and Anaerobic Suspended and Attached Growth Wastewater Treatment Processes: Aerated lagoon, activated sludge systems, trickling filter, sequential batch reactor, fluidized bed bioreactors, Up-flow Anaerobic Sludge Blanket (UASB) and hybrid Up-flow Anaerobic Sludge Blanket (UASB) reactors. (8 lectures)

Advanced Treatment Processes: Membrane Filtration, microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and electrodialysis; wet air oxidation, adsorption, and ion exchange; wet-land and root-zone treatment of industrial and municipal wastes; design of sludge drying beds, thermal and biological processes for sludge and land fillings. Membrane reactors, new technologies for wastewater disinfection. (10 lectures)

Water Recycling and Reuse: Different unit operations for water recycling depending on end use, energy considerations, recovery of valuables from wastewater, zero liquid discharge (ZLD). (7 lectures).

Text Book

1. Burton F.L., Tchobanoglous G., Stensel H.D., 2017, Waste Water Engineering Treatment and Reuse, 4th ed.,Tata McGraw-Hill.
2. Arceivala S.J. and Asolekar S.R., 2007, Wastewater Treatment for Pollution Control and Reuse, 3rd Ed., Tata McGraw Hill.

Reference Book

1. Henze M., van-Loosdrecht M.C.M., Ekama G.A. and Brdjanovic D., 2008, Biological Wastewater Treatment: Principles, Modelling and Design, IWA publishing.
2. Sincero A.P. and Sincero G.A., 1996, Environmental Engineering – A Design Approach, Prentice-Hall.
3. Tewari P.K., 2020, Advanced Water Treatment, CRC Press, Taylor and Francis Group (USA)

Online Course Material

1. Tiwari M K, Wastewater treatment and recycling, NPTEL course material, Department of Civil Engineering, IIT Kharagpur, https://nptel.ac.in/courses/105105178/

Title	**Chemometrics**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The instructor will:
Impart knowledge of modern methods of analyzing chemical data.

Learning Outcomes
The students are expected to have the:
Comprehensive knowledge of the modern methods of reducing and analyzing chemical data.

Contents
Prelude to chemometrics: Introduction and history of Chemometrics, factorial analysis; reverse, surface and mixture design; correlograms and time series analysis; sequential methods, Pattern recognition. (6 lectures)

Calibration: introduction to multivariable calibration, selectivity problems, statistical problems in calibration, Univariate calibration, multiple linear and principal components regression, model validation, outlier detection. (6 lectures)

Evolutionary signals and process analysis in chemical plants: exploratory data analysis and processing, determining composition, resolution pre-processing, composition of sequential data, screening. (6 lectures)

Derivatives in Spectroscopy: Theoretical and computed derivatives, derivative approximation, calibrating with derivatives, spectroscopic monitoring of reactions, kinetics and multivariable model, online spectroscopy. (6 lectures)

General Data Analysis: simple analysis of variance and experimental design (one-way, two-way with and without replicates, randomized and blocked designs). (6 lectures)

Computational methods: control structures for selection and iteration, functions, array data structure, numerical methods for data analysis. (4 lectures)

Machine learning in Chemical plants: Introduction, basics of decision trees, combining multiple learner, reinforcement learning, experimental design and analysis. (5 lectures)

Text Book
Richard G. Brereton, 2003, Chemometrics: Data Analysis for the Laboratory and Chemical Plant, Wiley

Reference Book
1. Harald Martens, Tormod Næs, 1989, Multivariate Calibration, John Wiley & Sons.
2. Howard Mark, Jerry Workman, Jr, 2018, Chemometrics in Spectroscopy, Elsevier Academic Press.
3. Richard G. Brereton, 2007, Applied Chemometrics for Scientists, John Wiley & Sons.
4. Ethem Alpaydin, 2004, Introduction to Machine Learning, MIT Press.
5. Vandeginste, B.G.M., Massart, D.L., Buydens, L.M.C., Jong, de D., Lewi, P.J., Smeyers- Verbeke, J., 1998, Handbook of Chemometrics and Qualimetrics: Part B, Elsevier.
6. Kreyszig, Erwin, 2014, Advanced Engineering Mathematics, John Wiley and Sons, 10th Edition.

Title	**Computational Fluid Dynamics**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Impart knowledge about various computational methods of fluid flow and heat transfer.
2. Provide insight to design and simulate the hydrodynamics and multi-physics systems.

Learning Outcomes

The students are expected to have the ability to

1. In-depth understanding of numerical methods for solution of partial differential equations of fluid flow and heat transfer.
2. Acquire knowledge of grid generation, processing and applications of CFD.

Contents

Introduction: Fundamental principles of conservation, Reynolds transport theorem, conservation of mass, conservation of linear momentum: Navier-Stokes equations, conservation of energy, Mathematical classification of partial differential equations, physical, boundary conditions. (8 lectures)

Finite Difference Method (FDM): Discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, grid generation, uniform vs non-uniform grids, Discretization of unsteady diffusion problems: Explicit, Implicit and Crank-Nicolson's algorithm; stability of solutions, stream function - vorticity approach, Poisson equation (12 lectures)

Finite Volume Method (FVM): Discretization methods, approximations of surface integrals and volume integrals, Modelling of Convection- Diffusion Problems: One dimensional convection-diffusion problem: Central difference scheme; Discretization based on analytical approach (exponential scheme); Hybrid and power law discretization techniques; Higher order schemes (QUICK algorithm) (10 lectures)

Flow modeling: Discretization of incompressible flow equations; Pressure based algorithm: SIMPLE, SIMPLER etc; Unstructured grids; Introduction to turbulence modeling; Large Eddy Simulation (LES); Direct Numerical Simulation (DNS) (9 lectures)

Text Book

1. Anderson J.D., 1995, Computational Fluid Dynamics, McGraw Hill.
2. Ghoshdastidar P.S., 1998, Computer Simulation of Flow and Heat Transfer, Tata McGraw Hill.
3. Patankar, S. . Numerical Heat Transfer and Fluid Flow. Mcgraw Hill, 2017

Reference Book

1. Fletcher C.A.J., 1998, Computational Techniques for Fluid Dynamics, Vol. 1: Fundamental and General Techniques, Springer-Verlag.
2. Fletcher C.A.J., Computational Techniques for Fluid Dynamics, 1998, Vol. 2: Specific Techniques for Different Flow Categories, Springer-Verlag.
3. Ferziger J.H. and Peric M., 2002, Computational Methods for Fluid Dynamics, 3rd Ed., Springer

Online Course Material

Jayanti, S., Computational Fluid Dynamics, NPTEL Course Material, Department of Chemical Engineering, IIT Madras, https://nptel.ac.in/courses/103/106/103106119/

Title	**Heterogeneous Catalysis and Catalytic Reactors**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
Impart knowledge about the basic concepts, detailed structures, preparation methods and reactivities of solid catalysts, its properties and relationship between the structures and reactivities.

Learning Outcomes
The students are expected to have the ability to:
Understand and gain knowledge of the detailed structures, preparation methods and reactivities of solid catalysts, its properties and relationship between the structures and reactivities.

Contents
Introduction to basic concepts (2 lectures)

Catalysis: Acid-base catalysis, application of catalyst functionality concepts for control of reaction selectivity and kinetic models, Properties of catalysts, reaction selectivity and kinetic models (9 lectures)

Steps in catalytic reaction: Adsorption, Kinetic models, intraparticle transport process, Selection and design of catalysts, Preparation and characterization of catalysts, Catalyst deactivation, various deactivation models, Optimal distribution of catalyst in a pellet (12 lectures)

Zeolites: Preparation and characterization of various Zeolite catalysts and their application (4 lectures)

Commercial Reactors and catalysts: Adiabatic, fluidized bed, trickle bed, slurry; industrially important catalysts, Environmental catalysis (8 lectures)

Design of Catalytic Reactors for gas and two phase systems, Design of polymeric reactors. (4 lectures)

Text Book
1. Thomas, J.M., Thomas W.J., Principles and practice of heterogeneous Catalysis.
2. I. Chorkendorff, J.W Niemantsverdriet., Concept of Modern Catalysis and Kinetics, 3rd Edition, Wiley VCH

Reference Book
1. Bruce Gates , Catalytic Chemistry.
2. Morbidelli and Verma, Optimal distribution of catalyst in a pellet.
3. Ford M.E. and Marcel Dekker, Catalysis of Organic reactions.
4. Sharma M.M. and Doraiswamy, Heterogeneous Reactions, Vol 1 and Vol II

Online Course Material
Pant, K.K., Heterogeneous Catalysis and Catalytic Processes, NPTEL Course Material, Department of Chemical Engineering, IIT Delhi, https://nptel.ac.in/courses/103/102/103102012/

Title	**Modelling of Atoms, Molecules and Surfaces**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

Provide background on various forms of Intermolecular and Molecule-Surface interactions.

Learning Outcomes

The students are expected to:

1. Gain fundamental understanding on the molecular nature of systems and surfaces.
2. Learn about the importance of intermolecular forces in molecular modeling and simulations in chemical and allied engineering.

Contents

Introduction: [3 lectures] Four Forces of Nature, Early Scientific Period (1 Lecture), First Phenomenological Theories, Modern View of origin of Intermolecular Forces (2 Lectures).

Forces Between Atoms and Molecules, Principle and Concepts: [6 lectures] Some Thermodynamic Aspects of Intermolecular Forces (3 Lectures), Covalent and Coulomb Interactions (3 Lectures),

Various forms of Interactions: [12 lectures] Interactions Involving Polar Molecules, Interactions Involving Polarisation of Molecules (4 Lectures), van der Waals Forces (3 Lectures), Repulsive Forces, Total Pair Potentials (3 Lectures), Hydrogen Bonding, Hydrophobic and Hydrophilic Interactions (2 Lectures).

Forces Between Particles and Surfaces: [18 lectures] Concepts of Intermolecular and Interparticle Forces (2 Lectures), Contrast Between Intermolecular, Interparticle and Intersurface Forces (2 Lectures), van der Waals Forces Between Surfaces (2 Lectures), Electrostatic Forces Between Surfaces in Liquids (4 Lectures), Solvation, Structural and Hydration Forces (3 Lectures), Steric and Fluctuation Forces (3 Lectures), Adhesion (2 Lectures).

Text Book

J. N. Israelachvili, 2003, Intermolecular and Surface Forces, 2nd Edition, Academic Press.

Title	**Molecular Simulations**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

To impart theoretical understanding and working solutions for modelling and simulation of molecular systems, and to be able to relate molecular structure and properties to bulk observables.

Learning Outcomes

The students will be able to

1. Model molecular systems with appropriate details needed for relevant simulation techniques.
2. Make appropriate choices of simulation techniques to suit the molecular system and the properties to be determined.
3. Develop theoretical understanding and carry out elementary simulations based on molecular dynamics simulations, Monte-Carlo simulations and density functional theory calculations.

Contents

Preliminaries

Description of molecular systems, technique-appropriate system description of molecular systems (1 lecture)

Overview of statistical mechanics, partition function and property estimation in different ensembles (2 lectures)

Molecular dynamic simulations

Force-field description of molecular systems, coarse grain modelling, reactive force-fields (2 lectures)

Algorithms for dynamical evolution of molecular systems, thermo- and barostats (4 lectures)

Approaches to calculation of equilibrium and non-equilibrium transport properties, chemical potential and time-correlation and radial distribution functions (3 lectures)

Analysis of data from molecular dynamics simulations with examples and case studies, including but not limited to, separation processes, adsorption, gas-gas separation, molecular sieves and membrane separation, protein simulations (3 lectures)

Monte-Carlo simulations

Elementary statistical thermodynamics, bulk property estimation from partition function (3 lectures)

Generation of microstates and identification of Monte-Carlo moves for different molecular systems, averaging of properties in different ensembles, Metropolis algorithm, enhanced sampling techniques (4 lectures)

Average techniques, convergence and estimation of error with sampling (2 lectures)

Analysis of data from Monte-Carlo simulations with examples and case studies, including but not limited to, nanotechnology, nanocrystals, defects, condensed matter simulations, applications to the analysis of novel materials (3 lectures)

Density functional theory calculations

Introductory quantum mechanics and Schroedinger equation, description and solution of electronic structure of hydrogen (3 lectures)

Motivation for techniques for many-body molecular problems, elementary theory of ab initio methods, Hohenberg-Kohn theorems, Kohn-Sham formulation, self-consistent field calculation, structural optimization (6 lectures)

Analysis of data from DFT calculations with examples and case studies, including but not limited to, catalysis, surface process and adsorption, materials design (3 lectures)

Textbook

Leach A.R., Molecular Modelling: Principles and Applications (2nd Ed.), Prentice Hall, New York 2001.

Reference Book

1. Jensen F., An Introduction to Computational Chemistry (2nd Ed.) John Wiely and Sons, West Sussex 2007.
2. Frenkel D., Smit B., Understanding Molecular Simulation: From Algorithms and Applications (1st Ed.), Academic Press, London 2002.
3. Landau D.P., Binder K., A Guide to Monte Carlo Simulations in Statistical Physics (3rd Ed.), Cambridge University Press, Cambridge 2009.

Title	**Membrane Technology**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The instructor will provide:
1. Provide an insight into the membrane-based separations that are an integral part of the downstream processing of various industries.
2. Different applications of membrane technology.

Learning Outcomes
The students are expected to have the ability to:
1. Develop necessary skills to design appropriate membrane-based separation technique/s as per the need.
2. Its applications in different fields, such as water treatment, gas separation, etc., as well as its challenges and opportunities.

Contents
Introduction: Membrane and membrane materials, Material properties. [2 lectures]
Membrane Preparation: Phase inversion process, Preparation of composite membrane, Inorganic membranes. [4 lectures]
Membrane Characterization: Microfiltration (MF) characterization, Ultrafiltration (UF) characterization [2 lectures]
Membrane Transport: Pressure-driven transport through porous and nonporous membrane, Osmosis concepts, gel controlled, Reverse Osmosis (RO), Nanofiltration (NF), Transport models, Micellar-enhanced and affinity UF, MF transport, Facilitated transport.
[8 lectures]
Concentration/Temperature/Electrical driven and Hybrid membrane processes: Liquid membranes, Membrane distillation, Pervaporation, Membrane contactors, Dialysis, Electrodialysis, hybrid membrane processes. [8 lectures]
Gas Separation: Membrane for gas Separation, Gas separation membrane modelling [2 lectures]
Synthesis of Nanocomposite Membranes: Preparation techniques, homogeneous membranes, composite membranes, raw materials, processing methods, Conventional nanocomposites, thin film nanocomposites, TFC with nanocomposite substrate. [6 lectures]
Membrane Module and Process Design: Flat sheet, Tubular module, Hybrid dead-end/cross-flow system. [4 lectures]
Challenges and solutions: Membrane fouling, Membrane fouling modelling [3 lectures]

Text Book
1. Baker, R.W., (2004), Membrane Technology and Applications, 2nd Edition, Membrane Technology and Research Inc., Menlo Park, CA.
2. M. H. Mulder, Basic Principles of Membrane Technology, Springer, 2004.

Reference Book
Tewari, P.K., (2016), Nanocomposite Membrane Technology: Fundamentals and Applications, CRC Press, Taylor & Francis Group.

Online Course Material
1. Mohanty, K., Membrane Technology, NPTEL Course Material, Department of Chemical Engineering, IIT Guwahati, https://nptel.ac.in/courses/103/103/103103163/
2. Sirshendu De, Novel Separation Processes, NPTEL course material, Department of Chemical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/103105061

Title	**Novel Separation Processes**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
Provide in-depth knowledge about the multi-component separation processes that are relevant to industries today.

Learning Outcomes
The students are expected to gain:
1. Understanding of multicomponent separation processes with relevant industry examples and case studies.
2. Gaining knowledge about the design of separation processes.

Contents
Fundamentals & Identification of separation process: Mass Diffusion, Fick's law, Separation factor, chemical potential, use of Navier-Stokes equation in mass transfer, Types of existing processes, equilibrium governed processes, rate governed processes (6 lectures)

Membrane-based separation processes: Fundamentals: Membrane casting, barrier types, Types of motion of molecules through the barrier, Categorization of membrane processes, osmotic pressure, observed vs real retention, estimation of retention and permeability, modules, Driving forces in membrane separation processes, Transports in Reverse Osmosis (RO), solution-diffusion model, concentration polarization and membrane fouling (10 lectures)

Membrane-based separation processes: Design and applications: Design of Membrane modules, Dialysis, Gas Separation by membranes , Electric field enhanced membrane filtration; Electrophoretic Separation Processes (7 lectures)

Surfactant-based separation processes: Cloud point, mechanism of phase separation, ionic & non-ionic surfactants, volume reduction factor, partition coefficient, fractional coacervate volume, micellar enhanced ultrafiltration, liquid membranes (7 lectures)

Chromatographic separation processes: Chromatographic separation & ion exchange fundamentals, purpose of column, gas-liquid chromatography, liquid-liquid chromatography, involved processes, solute movement, ion exchange resin, ion movement theory (3 lectures)

Supercritical fluid extraction: critical condition, different supercritical fluids. Modifiers, methodology of SCF, solubility diagrams, Mollier diagrams (4 lectures)

Miscellaneous separation processes: Pervaporation, Membrane Distillation, etc. (2 lectures)

Text Book
1. Seader, Henley and Ropar (2011) Separation Process Principles, 3rd Edition Wiley.
2. W.S.W Ho and K. K. Sirkar, Membrane Handbook", Vol 1 and Vol 2;1992; Springer, https://doi.org/10.1007/978-1-4615-3548-5

Reference Book
1. Humphrey, J. L. and Keller, G. E., 1997, Separation Process Technology, McGraw- Hill, NY
2. Kister, H. Z., 1992, Distillation Design, McGraw-Hill.
3. Ross Taylor, R. Krishna, (1993) Multicomponent Mass Transfer, John Wiley & Sons.

Online Course Material
Dr. Sirshendu De Professor, Department of Chemical Engineering, IIT Kharagpur, NPTEL: Novel Separation Processes, https://archive.nptel.ac.in/courses/103/105/103105061/

Title	**Principles of Electrochemical Engineering**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Provide the student with the essential knowledge needed to understand electrochemical engineering and technology.
2. Illustrate the basic principles of electrochemistry, electrokinetic phenomena required for modelling and design of electrochemical processes and devices.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the principles of electrochemistry processes and electro-analytical methods.
2. Correlate the principles of electrochemistry to electrochemical processes and suggest design solutions to engineering problems.

Contents

Basic Principles: Introduction to electrochemistry and fundamentals, Nernst equation, Electrode kinetics, Volta and Galvani potentials, electrochemical potential, electrochemical equilibrium, Enthalpy and Gibbs free energy calculation, solvation energy, ionic equilibrium. (5 lectures)

Cell potential: Electrochemical cell, standard electrode potential, Butler-Volmer formulation, Tafel equation, Pourbaix diagram, Activity Coefficients, Donnan potential, reversible electrode, Born model for ion-solvation energy, Batteries and Cell Chemistries. (6 lectures)

Ion-ion interactions and ionic transport: Debye-Huckel theory, activity coefficient of ionic solution, ion pair, Bjerrum theory and Fuoss theory, migration, extended Nernst-Planck equation, electrochemical mobility and its relation with diffusivity, Stokes-Einstein equation, ionic conductivity, transport number, Kohlrausch law. (11 lectures)

Charged interface: surface excess quantity, Lippmann equation, Gouy-Chapman model, Stern layer, internal and external Helmholtz layer, zeta potential, electric double layer. (8 lectures)

Electrochemical Kinetics: Nonequilibrium formulation, diffusion potential, junction potential, Planck-Henderson equation, pH electrode, electro-osmosis, electrophoresis, streaming potential, sedimentation potential. (7 lectures)

Application: Electro-chemical Processes, Fuel Cells. (2 lectures)

Text Book

1. Prentice ,G., 1991, Electrochemical Engineering Principles, Prentice Hall.
2. Girault, H., 2004, Analytical and Physical Electrochemistry, EPFL Press, 1st Edition.

Reference Book

1. Allen J. Bard, Larry R. Faulkner, 2005, Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons; 2nd Edition.
2. Fuller,T.F., Harb, J. N., 2018, Electrochemical Engineering, Wiley.

Online Course Material

https://nptel.ac.in/courses/104106105/

Title	**Process Optimization**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The instructor will:

Provide in-depth knowledge of various techniques of optimization and their application to chemical processes.

Learning Outcomes

The students are expected to:

Have fair knowledge of various techniques of optimization and their application to chemical processes.

Contents

Introduction: Optimization and calculus based classical optimization Techniques (4 lectures)

One Dimensional Minimization Methods: Elimination methods- equally spaced points method, Fibonacci method and golden section method; Interpolation methods- quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods, Linear Programming (10 lectures)

Multivariable Non-Linear Programming: Unconstrained- Different methods for non-linear programming; Constrained- complex method, feasible directions method, GRG method, penalty function methods and augmented Lagrange multiplier method. (9 lectures)

Dynamic Programming: Multistage processes- acyclic and cyclic, sub-optimization, principle of optimality and applications. (6 lectures)

Geometric Programming (GP): Differential calculus and Arithmetic-Geometric inequality approach to unconstrained GP; Constrained GP minimization; GP with mixed inequality constraints and Complementary GP, Emerging Optimization Techniques: Genetic algorithm, simulated annealing, particle swarm and ant colony optimization. (10 lectures)

Text Book

1. Edgar T.F., Himmelblau D.M. and Lasdon L.S., 2001, Optimization of Chemical Processes, 2nd Ed., McGraw Hill.

Reference Book

1. Beveridge G.S.G. and Schechter R.S., 1970, Optimization: Theory and Practice, McGraw Hill.
2. Rao S.S.,2009, Engineering Optimization Theory and Practice, 4th Ed., Wiley

Online Course Material

1. Sarkar, D., Optimization in Chemical Engineering, NPTEL Course Material, Chemical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/103/105/103105139/

Title	**Process Safety & Hazards**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

Provide comprehensive knowledge of safety regulations and their practices, chemical plant hazards and their control, risk assessment and management principles and techniques and accident analysis.

Learning Outcomes

The students are expected to have the ability to:

Identify and distinguish typical sources of risk and hazard in a process plant, undertake hazard and operability (HAZOP) study.

Contents

Safety in Industries: Concepts and definition, storage of dangerous materials, Plant layout Safety systems, Occupational Safety and Health Administration (OSHA) incidence rate, Fatal accident rate (FAR), Measures to take during accidents, Toxicology (10 lectures)

Industrial Hygiene: Government regulations, Industrial hygiene and safety aspects related to toxicity, noise, pressure, temperature, vibrations, radiation etc, Evaluation Methods, Evaluating workers Exposures to dusts, noise. (8 lectures)

Selection Mechanism: Technology and process selection, Scale of disaster, Fire triangle Ignition, Confined and unconfined explosion, Vapors cloud explosions, Boiling liquid expanding vapor explosion (BLEVE), Dust explosion, shock wave, Flammability characteristics of liquids and vapors, Minimum oxygen concentration (MOC) and Inerting. (8 lectures)

Handling Chemicals and toxicity: Control of toxic chemicals, Storage and handling of flammable and toxic chemical, Runway reactions, Relief system risk and hazards management, Miscellaneous Design for preventing Fires and Explosion. (7 lectures)

Hazards Identification: checklists, Surveys, Hazard and Operability Studies (HAZOP), Safety reviews. Risk Assessment, Hazard models and risk data. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, Technology and process selection. (6 lectures)

Text Book

1. Daniel A. Crowl and Joseph F. Louvar, 1990, Chemical Process Safety: Fundamentals with applications, Prentice Hall, Inc.
2. Lee, F.P., 1983, Loss prevention in the process Industries, Volume 1 and 2 Butterworth.
3. Hoboken, N. J., 2000, Guidelines for Chemical Process Quantitative Risk Analysis, Wiley-Interscience.

Reference Book

1. R. W. King and J. Magid, Industrial Hazards and Safety Handbook, Butterworth, 1982.
2. G. L. Wells, Safety in Process Plant Design, John Wiley and Sons Inc., 1980.
3. Fawcett, H.H. and W.S. Wood, Safety and Accident Prevention in Chemical Operations, 2nd Edition, Wiley-Interscience, New York, 1982.

Online Course Material

Sinha, S., Chemical Process Safety, NPTEL Course Material, Department of Chemical Engineering IIT Roorkee, https://nptel.ac.in/courses/103/107/103107156/

Title	**Structure and Property for Polymers**	Number	CHL7XXX
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B. Tech., M.Tech., Ph.D.	Type	Elective
Prerequisite	None		

Objectives
The Instructor will:
1. Provide knowledge about various structures in polymers and it's relation with the mechanical and thermal properties

Learning Outcomes
The students are expected to gain:
1. Understanding of structure-property for various polymeric systems
2. Understanding of thermal transition and deformation mechanisms in polymers

Contents
Introduction: Outline of the course, review of basics of polymers, polymerization reactions and classification (2 lectures)

Amorphous and Semicrystalline Polymers: Glass transition, free-volume theory, factors affecting glass transition temperature, solution grown single crystals and chain-folding mechanism, melt crystallization, spherulites, degree of crystallinity, Bragg's law, crystal thickness and chain extension, flow-induced crystallization, dimensionless numbers in crystallization, factors affecting melting, relationship between melting and glass transition (11 lectures)

Multicomponent Polymeric Systems: Polymer blends, block copolymers, thermoplastic elastomers, examples, phase diagram, glass transition, compatibilization, morphology diagram (6 lectures)

Deformation in Polymers: Elastic deformation, stress-strain relationship, polymer chain deformation, crystal moduli, elastic deformation in semicrystalline polymers, yield and crazing – necking and it's mathematical treatment, yield criteria, mechanisms, plastic deformation (9 lectures)

Viscoelasticity: Introduction, examples, Mechanical models, Boltzmann superposition principle, dynamic mechanical testing, transitions and polymer structure, t-T superposition, entanglements (8 lectures)

Polymer Composites: Matrix and fillers, composition, elastic deformation, fracture, packing, experiments, nanocomposites (3 lectures)

Text Book
1. Young R.J. and Lovell P.A. (2011) Introduction to Polymers, 3rd Edition, CRC Press

Reference Book
1. Chanda M. (2006) Introduction to Polymer Science & Chemistry, CRC Press

Online Course Material
1. Adhikari B, Science & Technology of Polymers, NPTEL Course Material, Department of Metallurgy & Material Science, Indian Institute of Technology Kharagpur, https://nptel.ac.in/courses/113105028/