

Department of Chemical Engineering Curriculum B.Tech. Programmes

IIT Jodhpur



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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-Graduate (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, process control, chemical engineering thermodynamics to chemical reaction engineering. 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 (streams) from the following areas:

- i. Chemical Engineering Design;
- ii. Process Engineering Intelligence
- iii. Complex Fluids & Interfacial Engineering;
- iv. Sustainability;
- v. Molecular Engineering and,
- vi. Biochemical Engineering.

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. Objective 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 for specialization in emerging and multidisciplinary areas including Molecular Engineering, Data Science and AI applications, Polymer Engineering, Sustainability, Biochemical Engineering and Complex Fluids & Interfacial Engineering.
- 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 Attribute

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/equipment.
- 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 Outcome

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: (i) Data Science & AI applications; (ii) Molecular Engineering.
- 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.
- 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, 3D Printing Materials and Processes, and Packaging of Electronic Devices.
- iv. Fluency with scientific computing techniques via courses including Material and Energy Balance, Scientific Computations and Data Analytics in Process Modelling and Simulation.

6. Topic clouds and Mapping of Topic clouds with proposed course

Table 1: Topics, and Mapping of Topics with Courses

Area	Topics	Category	Course (PC/PE/IE/IS)
Chemical Engineering Design	Fluid Statics, Dynamics, Viscous Flow, Turbulence and Compressible Flow Fundamentals, Fluid Handling.	Fundamentals and Techniques	Fluid Mechanics (PC)
	Material Balance, Energy Balance, Simultaneous Material & Energy Balance.	Fundamentals	Material and Energy Balance (PC)
	Liquid-Liquid Mass Transfer, Gas-Liquid Mass Transfer, Solvent Extraction.	Fundamentals and Techniques	Mass Transfer (PC)
	Conduction, Convection, Radiation, Boiling, Condensation, Heat Exchangers, Evaporators	Fundamentals and Techniques	Heat Transfer (PC)
	Kinetics of Homogeneous Reactions, Batch Reactor, CSTR, PFR.	Fundamentals and Techniques	Chemical Reaction Engineering (PC)
	Errors in computation, Linear systems of equations, ODE, PDE	Fundamentals	Scientific Computations (PC)
	Thermodynamics of Chemical Reaction, Fugacity, Thermodynamic analysis of processes	Fundamentals	Chemical Engineering Thermodynamics (PC)
	Process Plant Design, Equipment Design, Cost Economics	Fundamentals and Techniques	Process Plant Design & Economics (PC)
	Transport Properties, Continuity Equation, Momentum, energy and mass transport.	Fundamentals	Transport Phenomena (PC)
	Different forms of Corrosion and Mechanism	Fundamentals	Corrosion (IE)
	Industrial Management, Hazards & Safety, SOPs,	Techniques	Industrial Management and Safety for Chemical Engineers (PE)
	Product Design, Common Methodologies and Strategies	Techniques and Systems	Product Design in Chemical Engineering (PE)
	Conventional Unit Operations in Process Industries, Filtration and Membrane Separation, floatation, sedimentation	Technique	Unit Operations (PE)
	Fundamentals of Conventional Membrane Technology	Fundamentals, Techniques and Technology	Membrane Technology (PE)
Process Engineering Intelligence	Conventional Process Control, AI in Process Industries	Fundamentals and Techniques	Process Control and AI Applications (PC)
	Introduction of Machine Learning, Neural Networks, Statistical Learning Framework	Fundamentals	Machine Learning (IE)
	Neural network era, deep learning and data science era, AI based	Fundamentals and techniques	Applications of Artificial Intelligence in Chemical

	modeling, applications		Engineering (PE)
	Introductory Aspects of Petrochemical Engineering	Fundamentals	Petrochemical Engineering (PE)
	Data driven modeling of distillation units, FCC, catalyst regeneration units	Technology and techniques	Petroleum Refinery Process Modelling (PE)
	Reliability and Maintainability Engineering, failure detection models, reliability models, maintainability	Fundamentals	Basics of Reliability and Maintainability Engineering for System Safety (PE)
	Calibration methods, signals and process analysis in chemical plants, Spectroscopic data analysis	Fundamentals and Techniques	Chemometrics (PE)
	Reactor models, Bayesian estimators, observers, filters, applications	Fundamentals and techniques	Artificial Intelligence in Chemical Reactor Control (PE)
	Introduction to AI, predicate logic, uncertain reasoning	Fundamentals	Artificial Intelligence-1 (PE)
	Basics of ML, decision trees, neural networks, foundation of deep learning	Fundamentals	Machine learning-1 (PE)
	Introduction to IoT architecture, sensing, actuation, cloud, edge and fog computing	Fundamentals and Technology	Introduction to Internet of Things (IoT) (PE), Sensors and IoT lab (PE)
	Sensor types, nanoparticles as nanosensors, biosensors	Technology	Nanosensors (PE)
	Introduction to mathematical modelling, Equation solving approaches, Decomposition of networks, Convergence Promotion	Techniques	Data Analytics in Process Modelling and Simulation (PE)
	Introduction to manufacturing systems, cellular manufacturing, flexible, lean and agile systems, cloud based manufacturing	Fundamentals and systems	Industry 4.0 Applications in Manufacturing Systems (PE)
Complex fluids and interfacial engineering	Fundamentals and Introductory Aspects of Colloids and Suspensions	Fundamentals and Techniques	Colloids and Suspensions (IE)
	Introduction to Polymer	Fundamentals	Polymer (IE)
	Fundamentals of Complex Liquids	Fundamentals	Physics of Complex fluids (LS)
	Introductory aspects of Complex Fluids	Fundamentals	Introduction to Complex Fluids (PE)
	Fundamentals of Interfacial Engineering in Soft Matter	Fundamentals	Interfacial Engineering in Soft Matter (PE)
	Introduction, processes and applications of bioprinting	Fundamentals & technology	Bioprinting (PE)
	Various materials in 3-D printing and their processing, Post-processing and Inspection techniques	Technology	3-D Printing: Material Processing and Properties (PE)
	Polymer Engineering and Principles	Fundamentals and Techniques	Introductory Principles in Polymer Engineering (PE)

Sustainability	Environmental Studies	Fundamentals	Environmental Science (IS)
	Concepts of Conventional and Emerging Waste Management	Fundamentals, Techniques and Technology	Solid Waste Management (PE)
	Process related Air Pollution Control Technology	Techniques and Technology	Air Pollution Control Technology (PE)
	Introduction of Rare-earth Materials and Radioactive Materials, Their Processing, Unit Operations	Techniques and Systems	Processing of Rare-earth and Radioactive Materials (PE)
	Different kinds of Energy Resources and their Utilization	Technology and Systems	Energy Resources (PE)
	Waste Water Characteristics, Conventional Treatment	Techniques & Systems	Waste Water Treatment (PE)
	Forecasting environmental changes, EIA monitoring and auditing, environmental management plan	Fundamentals and techniques	Environmental Impact Assessment (EIA) (PE)
	Advanced treatment methodologies, Recycle and Reuse, ZLD.	Techniques & Systems	Advanced Waste Water Treatment (PE)
	Introduction, design and applications	Technology	Microfluidic Fuel Cell (PE)
	Fundamentals of Catalytic reactions and its application for energy production	Fundamentals and Technology	Catalysis for Energy (PE)
	Hydrogen and methanol as fuel sources, production methodologies, Challenges	Techniques & Technology	Hydrogen & Methanol Economy (PE)
	Ocean Thermal Energy Conversion (OTEC) cycles, hybrid OTEC systems and technological challenges	Fundamentals and Technology	Ocean Thermal Energy Conversion (OTEC) Processes (PE)
Molecular Engineering	Introduction, approached and applications in molecular engineering	Fundamentals and technology	Molecular engineering (PC)
	Transport at molecular level, Boltzmann equation, transport theory and properties of dilute gases, correlation function	Fundamentals	Molecular Transport Phenomena (PE)
	Thermodynamic Principles of Self-Assembly, Interaction Between Lipid Bilayer and Biological Membrane	Fundamentals	Fluid-Like Structures and Self-Assembling Systems (PE)
	Electronic and optoelectronic polymers, small molecules and complexes for electronic systems	Fundamentals and technology	Organic Molecules, Complexes and Polymers for Electronics and Optoelectronics (PE)
	Microstates of a system, statistical mechanics and thermodynamics, applications	Fundamentals	Molecular Thermodynamics (PE)

	Food engineering, preservation, composition, quality control	Fundamentals and techniques	Food Engineering (PE)
	Properties of water molecule, supercritical water, confined and interfacial water, purification, fuel cells, health and medicine	Fundamentals and technology	Molecular Engineering of Water (PE)
	Intermolecular and Molecule-Surface interactions	Fundamentals	Modelling of Atoms, Molecules and Surfaces (PE)
	Structure-property of electronic and optoelectronic polymers, piezoelectricity, applications, PCBs	Fundamentals and Technology	Polymers for Electronics and Optoelectronics I (PE)
	Molecular dynamics, basics of Monte Carlo method	Fundamentals and techniques	Molecular Simulations (PE)
Biochemical Engineering	Basics of Biology, Immobilized enzyme, metabolic pathways, interaction microbial population, bio-separation	Fundamentals	Biochemical Engineering (PE)
	Industrial importance of microorganisms, fermentation, industrial production of alcohol, citric acid, vinegar etc	Technology	Bioprocess Technology (PE)
	Momentum, heat and mass transfer in bio-systems and their analogous behavior	Fundamentals	Bio-Transport Phenomena (PE)
	Separation processes in biochemical industry, design variables and parameters, processes and methods	Technology	Biochemical Separation Processes (PE)
	Bioprocess overview, membrane reactor, bioreactor configuration, kinetics, basics of scale-up	Fundamentals and techniques	Bioreactors (PE)

7. Course Categories, credit distribution and Credit Structure of B.Tech. Programmes

Table 2: Proposed Course Categories and credit distribution in the proposed B.Tech. Programmes

S.N.	Course Type	Course Category	Regular B.Tech.		Double B.Tech.		B.Tech. with Specialization	
			Credit	Total	Credit	Total	Credit	Total
1	Institute Core (I)	Engineering (IE)	34	69	34	59	34	69
		Science (IS)	16		16		16	
		Humanities (IH)	12		9		12	
2	Programme Linked (L)	Science (LS)	7		0		7	
3	Programme Core (P)	Programme Compulsory (PC)	50	71	50	71	50	71
		Programme Electives (PE)	18		18		18	
		B.Tech. Project (PP)	3		3		3	
4	Open (O)	Open Electives (OE)	10	10	0	0	0	0
5	Engineering Science (E)	Engineering Science/ Specialization Core	0	0	22	22	8	8
		Engineering Science/ Specialization Elective (EE)	0	0	8	8	12	12
Total Graded				150		160		160
6	Non-Graded (N)	Humanities (NH)	6	15	6	15	6	15
		Engineering (NE)	3		3		3	
		Design/Practical Experience (ND)	6		6		6	
Total Graded + Non-Graded				165		175		175

8. Credit Structure of B.Tech. Programmes

Table 3. Credit Structure for B.Tech. Programmes

Type	L-T-P	Distribution of contact and beyond contact hours			Total Credits (TC=TH/3)
		Contact Hours (CH)	Beyond Contact Hours (BCH)	Total Hours (TH)	
1 hour of Lecture	1-0-0	1 hr	2 hr	3 hr	1
1 hour of Tutorial	0-1-0	1 hr	2 hr	3hr	1
1 hour of Lab/Project	0-0-1	1 hr	0.5 hr	1.5 hr	0.5

#Contact hour for project refers to the involvement of students in the laboratory, discussion, etc.

List of Program Compulsory (PC) Courses

Sr. No	Course Name	LTP	Contact Hours	Credit
1	Fluid Mechanics	3-1-0	4	4
2	Data Structure and Algorithm-CS	3-0-2	5	4
3	Molecular Engineering	3-0-0	3	3
4	Material and Energy Balance	3-0-0	3	3
5	Mass Transfer I	3-0-3	6	4.5
6	Heat Transfer	3-0-0	3	3
7	Chemical Reaction Engineering	3-0-3	6	4.5
8	Scientific Computations	3-0-2	5	4
9	Chemical Engineering Thermodynamics	3-0-0	3	3
10	Heat Transfer-Lab	0-0-2	2	1
11	Mass transfer II	3-0-3	5	4.5
12	Process Plant Design & Economics	3-0-3	6	4.5
13	Transport Phenomena	3-1-0	4	4
14	Process Control and AI Applications	3-0-2	5	4
15	Fluid Mechanics-Lab	0-0-2	2	1
Total				52

Stream-wise Program Elective (PE) Courses

Stream	S .No	Courses	L-T-P	Credit	Course Level
Chemical Engineering Design	1	Industrial Management and Safety for Chemical Engineers	3-0-0	3	4XX0
	2	Product Design in Chemical Engineering	2-0-0	2	4XX0
	3	Unit Operations	3-0-0	3	4XX0
	4	Membrane Technology	3-0-0	3	4XX0
Process Engineering Intelligence	5	Applications of Artificial Intelligence in Chemical Engineering	3-0-0	3	4XX0
	6	Petrochemical Engineering	3-0-0	3	4XX0
	7	Petroleum Refinery Process Modelling	1-0-2	2	4XX0
	8	Basics of Reliability and Maintainability Engineering for System Safety	3-1-0	4	4XX0
Complex fluids and interfacial engineering	9	Introduction to Complex Fluids	3-0-0	3	4XX0
	10	Interfacial Engineering in Soft Matter	3-0-0	3	4XX0
	11	Bioprinting	3-0-0	3	4XX0
	12	3-D Printing: Material Processing and Properties	3-0-0	3	4XX0
	13	Introductory Principles in Polymer Engineering	3-0-0	3	4XX0
Sustainability	14	Solid Waste Management	3-0-0	3	4XX0
	15	Air Pollution Control technology	3-0-0	3	4XX0
	16	Processing of Rare-earth and Radioactive Materials	3-0-0	3	4XX0
	17	Energy Resources	3-0-0	3	4XX0
	18	Waste Water Treatment	3-0-0	3	4XX0
Molecular Engineering	19	Molecular Transport Phenomena	2-0-0	2	4XX0
	20	Fluid-Like Structures and Self-Assembling Systems	2-0-0	2	4XX0
	21	Organic Molecules, Complexes and Polymers for Electronics and Optoelectronics	3-0-0	3	4XX0
	22	Molecular Thermodynamics	3-0-0	3	4XX0
Biochemical Engineering	23	Biochemical Engineering	3-0-0	3	4XX0
	24	Bioprocess Technology	3-0-0	3	4XX0
	25	Bio-Transport Phenomena	2-0-0	2	4XX0
	26	Biochemical Separation Processes	2-0-0	2	4XX0
	27	Bioreactors	3-0-0	3	4XX0

Mini-Project(0-0-6)

Program elective component for 8th semester

Design/Practical Experience (ND)

Options: Three Summer Design Projects (0-0-4) for 2 Credits each or in regular semesters.

9. Specializations to be offered by the department:

Table 6: Specialization and courses

S.No.	Name of specialization	Specialization Core (8 credits)			Specialization Elective (12 Credits)		
1	Process Engineering Intelligence	Applications of Artificial Intelligence in Chemical Engineering	3-0-0	4XX0	Basics of Reliability and Maintainability Engineering for System Safety	3-1-0	4XX0
		Petroleum Refinery Process Modelling	1-0-2	4XX0	Chemometrics	3-0-0	7XX0
		Petrochemical Engineering	3-0-0	4XX0	Artificial Intelligence in Chemical Reactor Control	3-0-2	7XX0
					Nanosensors	3-0-0	7XX0
					Data Analytics in Process Modelling and Simulation	2-0-2	7XX0
					Artificial Intelligence-1	3-0-0	7XX0
					Machine Learning-1	3-0-0	7XX0
					Introduction to Internet of Things (IoT)	1-0-0	7XX0
					Sensors and IoT Lab	0-0-2	7XX0
					Industry 4.0 Applications in Manufacturing Systems	1-0-0	7XX0
					Specialization focused Mini Project	0-0-6	4XX0
					Specialization focused Design & practical experience	0-0-4	4XX0
					Specialization focused research review	0-0-2	4XX0

S.No.	Name of specialization	Specialization Core (8 credits)			Specialization Elective (12 Credits)		
2	Sustainability	Solid Waste Management	3-0-0	4XX0	Air Pollution Control technology	3-0-0	4XX0
		Waste Water Treatment	3-0-0	4XX0	Energy Resources	3-0-0	4XX0
		Ocean Thermal Energy Conversion	1-0-0	7XX0	Catalysis for Energy (CY)	3-0-0	6XX0
		Microfluidic Fuel Cell	1-0-0	7XX0	Membrane Technology	3-0-0	4XX0
					Unit Operations	3-0-0	4XX0
					Processing of Rare-earth and Radioactive Materials	3-0-0	4XX0
					Advanced Waste Water Treatment	3-0-2	7XX0
					Environmental Impact Assessment (EIA)	3-0-0	7XX0
					Hydrogen & Methanol Economy	3-0-0	7XX0
					Specialization focused Mini Project	0-0-6	4XX0
					Specialization focused Design & practical experience	0-0-4	4XX0
					Specialization focused research review	0-0-2	4XX0

S.No.	Name of specialization	Specialization Core (8 credits)			Specialization Elective (12 Credits)		
3	Molecular Engineering	Molecular Transport Phenomena	2-0-0	4XX0	Organic Molecules, Complexes and Polymers for Electronics and Optoelectronics	3-0-0	4XX0
		Introduction to Complex Fluids	3-0-0	4XX0	Introductory Principles in Polymer Engineering	3-0-0	4XX0
		Interfacial Engineering in Soft Matter	3-0-0	4XX0	Molecular Thermodynamics	3-0-0	4XX0
					Fluid-Like Structures and Self-Assembling Systems	2-0-0	4XX0
					Molecular Engineering of Water	1-0-0	7XX0
					Polymers for Electronics and Optoelectronics	2-0-0	7XX0
					Molecular Simulations	2-0-0	7XX0
					Food Engineering	3-0-0	7XX0
					Modelling of Atoms, Molecules and Surfaces	3-0-0	7XX0
					Specialization focused Mini Project	0-0-6	4XX0
					Specialization focused Design & practical experience	0-0-4	4XX0
					Specialization focused research review	0-0-2	4XX0

10. Curriculum of B.Tech. Chemical Engineering (Regular)

Table 7. Curriculum of B.Tech. in Chemical Engineering

I Semester						II Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	N C	GC
IE	Engineering Mechanics	2-1-0	3	-	3	IE	Introduction to Electrical Engineering	3-0-2	5	-	4
IS	Chemistry	3-0-0	3	-	3	IE	Introduction to Computer Science	3-0-2	5	-	4
IS	Physics	3-0-0	3	-	3	IE	Introduction to Bioengineering	3-0-2	5	-	4
IS	Chemistry Lab	0-0-2	2	-	1						
IS	Physics Lab	0-0-2	2	-	1						
IS	Mathematics I	3-1-0	4	-	4	IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1	IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-	NH	Communication Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-	NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts I /Sports I	0-0-1	1	0.5	-	NH	Performing Arts II/Sports II	0-0-1	1	0.5	-
Total		11-2-12	25	3	16	Total		12-1-14	27	3	17
III Semester						IV Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	N C	GC
LS	Probability, Statistics & Stochastic Process	3-1-0	4	-	4	IE	Materials Fractals: Polymer, Corrosion, Colloids & suspensions	3 × 1-0-0	3	-	3
IE	Thermodynamics	3-1-0	4	-	4	IE	Signals & Systems	3-1-0	4		4
PC	Fluid Mechanics	3-1-0	4	-	4	PC	Data Structure and Algorithm	3-0-2	5		4
IE	Introduction to Machine Learning	3-0-2	5	-	4	PC	Molecular Engineering	3-0-0	3	-	3

LS	Physics of Complex Fluids	3-0-0	3	-	3	PC	Material and Energy Balance	3-0-0	3	-	3
NE	Intro. To Profession	0-0-2	2	1		IH	Humanities	3-0-0	3	-	3
Total		15-3-4	22	1	19	Total		18-1-2	21	-	20
V Semester						VI Semester					
Cat	Course	LTP	CH	N C	GC	Cat	Course	LTP	CH	N C	GC
PC	Mass Transfer I	3-0-3	6	-	4.5	PC	Mass transfer II	3-0-3	6	-	4.5
PC	Heat Transfer	3-0-0	3	-	3	PC	Process Plant Design & Economics	3-0-3	6	-	4.5
PC	Chemical Reaction Engineering	3-0-3	6	-	4.5	PC	Transport Phenomena	3-1-0	4	-	4
PC	Scientific Computations	3-0-2	5	-	4	PC	Process Control and AI Applications	3-0-2	5	-	4
PC	Chemical Engineering Thermodynamics	3-0-0	3	-	3	PC	Fluid Mechanics-Lab	0-0-2	2		1
PC	Heat Transfer Lab	0-0-2	2	-	1	PE	Programme Elective-1	3-0-0	3	-	3
IH	Humanities II	3-0-0	3	-	3	NH	Professional Ethics II	0-1-0	1	1	-
NH	Professional Ethics I	0-1-0	1	1	-						
Total		18-1-10	29	1	23	Total		15-2-10	27	1	21
VII Semester						VIII Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	N C	GC
PP	B. Tech. Project	0-0-6	6	-	3	IH	Humanities IV	3-0-0	3	-	3
PE	Programme Elective-2	3-0-0	3	-	3	PE	Programme Elective-4	3-0-0	3	-	3
PE	Programme Elective-3	3-0-0	3		3	PE	Programme Elective-5	2-0-0	2		2
OE	Open Elective-1	3-0-0	3		3	PE	Programme Elective-6	2-0-0	2		2
IH	Humanities III	3-0-0	3	-	3	OE	Open Elective-2	3-1-0	4		4
IS	Environment al Science	2-0-0	2	-	2	OE	Open Elective-3	3-0-0	3		3
Total		14-0-6	20	-	17	Total		16-1-0	17	-	17
Total of Non-graded and Graded Credit respectively										9	150
Non-Graded Design Credits										6	-
Grand Total										15	165

11. Curriculum of Double B.Tech. : B.Tech. Chemical Engineering and Engineering Science

Table 8. Programme structure of Double B.Tech.

I Semester						II Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	NC	GC
IE	Engineering Mechanics	2-1-0	3	-	3	IE	Introduction to Electrical Engineering	3-0-2	5	-	4
IS	Chemistry	3-0-0	3	-	3	IE	Introduction to Computer Science	3-0-2	5	-	4
IS	Physics	3-0-0	3	-	3	IE	Introduction to Bioengineering	3-0-2	5	-	4
IS	Chemistry Lab	0-0-2	2	-	1						
IS	Physics Lab	0-0-2	2	-	1						
IS	Mathematics I	3-1-0	4	-	4	IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1	IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design I	0-0-2	2	1	-	NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-	NH	Communication Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-	NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts I /Sports I	0-0-1	1	0.5	-	NH	Performing Arts II/ Sports II	0-0-1	1	0.5	-
Total		11-2-12	25	3	16	Total		12-1-14	27	3	17
III Semester						IV Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	NC	GC
ES	Probability and Statistics	3-1-0	4	-	4	IE	Materials Science & Engineering	3 × 1-0-0	3	-	3
ES	Modern Physics	3-0-0	3	-	3	ES	Embedded Systems and IoT	3-0-2	5	-	4
IE	Thermodynamics	3-1-0	4	-	4	ES	Data Structure and Algorithm	3-0-2	5	-	4

IE	Signals and Systems	3-1-0	4	-	4	ES	Design of Experiments	3-0-0	3	-	3
IE	Machine Learning	3-0-2	5	-	4	ES	Modelling and Simulation	3-0-2	5	-	4
NE	Intro. To Profession	0-0-2	2	1		IH	Humanities I	3-0-0	3	-	3
Total		15-3-4	22	1	19	Total		18-0-6	24	-	21
V Semester						VI Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	NC	GC
PC	Mass Transfer I	3-0-3	6	-	4.5	PC	Mass transfer II	3-0-3	6	-	4.5
PC	Heat Transfer	3-0-0	3	-	3	PC	Process Plant Design & Economics	3-0-3	6	-	4.5
PC	Chemical Reaction Engineering	3-0-3	6	-	4.5	PC	Transport Phenomena	3-1-0	4	-	4
PC	Fluid Mechanics	3-1-0	4	-	4	PC	Process Control and AI Applications	3-0-2	5	-	4
PC	Chemical Engineering Thermodynamics	3-0-0	3	-	3	PC	Fluid Mechanics-Lab	0-0-2	2		1
PC	Heat Transfer Lab	0-0-2	2	-	1	PC	Material and Energy Balance	3-0-0	3	-	3
IH	Humanities II	3-0-0	3	-	3	PE	Programme Elective-1	3-0-0	3	-	3
NH	Professional Ethics I	0-1-0	1	1	-	NH	Professional Ethics II	0-1-0	1	1	-
Total		17-3-8	28	1	23	Total		18-2-10	30	1	24
VII Semester						VIII Semester					
Cat	Course	LTP	CH	NC	GC	Cat	Course	LTP	CH	NC	GC
PP	B. Tech. Project	0-0-6	6	-	3	PE/ES	Programme/Engineering Science Electives	14-0-0	14	-	14
PC	Scientific Computations	3-0-2	4	-	4	PC	Molecular Engineering	3-0-0	3	-	3
PE/O E	Programme/Engineering Science Elective-2	11-0-0	11	-	11	IH	Humanities III	3-0-0	3	-	3
IS	Environmental Science	2-0-0	2	-	2						

Total	16- 1-6	23	-	20	Total	20- 0-0	20	-	20
Total of Non-Graded and Graded Credits respectively								9	160
Non-Graded Design Credits								6	-
Grand Total								15	175

12. Detailed Course Content of Programme Compulsory Courses

Title	Fluid Mechanics	Number	MEL2XX0/ CHL2XX0
Department	Mechanical Engineering/ Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech (ME, CH)	Type	Program Compulsory (PC)
Prerequisite			

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.

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 [5 Lectures]: Kinematics of fluids - Deformations in fluid particle, strain rate, vorticity, stream function, potential function, streamlines, pathlines, streaklines, 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, venturimeter, 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.

Dimensional analysis and similarity [2 Lectures]: Buckingham Pi theorem and examples.

Introduction to Turbulent flows [3 Lectures]: Decomposition of instantaneous velocities, time-averaged continuity and Navier-Stokes equations, Reynolds stresses, turbulent viscosity.

Basics of Compressible flow [3 Lectures]: Acoustic waves, isentropic equations, concept of shock waves

Few Industrial Applications [4 Lectures]: Pipe networks, Flow past immersed objects, Agitation and Mixing.

Text Book

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 Edn., Associated Press.
4. McCabe, W.L., Smith, J.C., Harriott, P., (2005), Unit Operations of Chemical Engineering, 7th edition, McGraw-Hill International edition.

Reference Books

1. White, F. M.,(2003), Fluid Mechanics, 5thEdition, McGraw-Hil
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.
4. Panton, Ronald L - Incompressible flow, John Wiley & Sons, 2006. Third edition is available from Wiley Student Edition

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/#>

Course Title	Data Structures and Algorithms	Course No.	CSxxx
Department	Computer Science and Engineering	L-T-P [C]	3-0-2 [4]
Offered for	B.Tech of all branches	Type	PC
Prerequisite	Introduction to Computer Programming		

Objectives

1. To introduce and practice the implementation of various data structures used for indexing, searching, and sorting operations.
2. To introduce basic mathematical techniques for algorithm analysis and design.

Learning Outcomes

1. Ability to design and implement appropriate data structures for indexing, searching, and sorting operations for real-world problems.
2. Designing of new algorithms using standard data structures.
3. Analyzing the time and space complexities of standard data structures and basic algorithms.

Contents

Algorithm analysis and complexity: Big/little -Oh, Omega, Theta notation, Recurrence equations [2 Lectures]

Abstract data types: Linear data structures, Tree, Binary trees, Tree traversal, Applications [7 Lectures]

Search trees: Binary search trees, Balanced search trees, AVL trees, B-Trees [5 Lectures]

Heaps: Binary Heap, Heap order property and min/max heaps [3 Lectures]

Sets: Disjoint set ADT, Basic operations on Sets, Union/Find Algorithm [2 Lectures]

Sorting algorithms: Bubble sort, Selection sort, Bucket sort, Insertion sort, Overview of Divide-and-conquer, Quick sort, Merge sort [6 Lectures]

Hashing: Hash tables and operations, Hash function, Open and closed hashing, External and internal hashing, Collision resolving methods, Rehashing [5 Lectures]

Graph algorithms: Definitions, Branch and bound, Backtracking, Representation, Traversal, Shortest-path algorithms, Minimum Spanning Tree algorithm, Topological sorting [8 Lectures]

Greedy techniques and Dynamic programming [4 Lectures]

Laboratory

1. Implementation of data structures using C programming language.
2. Practically verifying and comparing run-time performance and asymptotic behavior of various data structures and related algorithms.
3. Applications of data structures from real-life scenarios.

Text Book

1. M. A. WEISS (2002), Data Structures and Algorithm Analysis in C, Addison-Wesley, 2nd Edition.

Reference Book

1. T. H. CORMEN, C. E. LEISERSON, R.L. RIVEST, C. STEIN (2009), Introduction to Algorithms, MIT Press, 3rd Edition.

Title	Molecular Engineering	Number	CHL2XX0
Department	Department of Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

1. Provide background about the basic concepts of molecular engineering, biomolecules and their structure, sensors that are used for the detection and principles of recognition along with overview of relevant manufacturing processes and applications.

Learning Outcomes

The students are expected to:

1. Gain an overview of overall molecular engineering starting from biomolecules to manufacturing processes and applications.
2. This course will enable and motivate scholars to pursue higher-level courses in focused areas.

Contents

Introduction to Molecular Engineering: [10 lectures] Scope of molecular engineering (1lecture), building blocks of molecular engineering (Monosaccharides, amino acids, nucleic acids, synthetic monomer, macrocyclic molecules, metal chelates and cluster) (5 lectures), Redox unit and reactive functional groups, chromophore and fluorophore (4 lectures),

Approaches in Molecular Engineering: [16 lectures] Chemical conjugation, Chemical polymerization (4 lectures), enzymatic modification, molecular self-assembly (4 lectures), methods of recognition for chemical and biomolecules (4 lectures), Nanomaterials and Polymers in Chemical Sensors (4 lectures)

Molecular Engineering Applications for Chemical Engineering: [16] Chemical sensor technology, Definition of chemical sensors, application of chemical sensors (5 lectures), hydrogels, encapsulation, polymer membranes (4 lectures), micro fabrication methods, existing molecular diagnostic devices, wearable sensors, Catalysis (5 lectures), downstream processing (affinity purification, product modification, membrane technology)(2 lectures)

Textbook

1. Banica F.G,(2012) Chemical Sensors and Biosensors: Fundamentals and applications, 1st ed., Wiley

Reference Books

1. Nielsen M .B., (2014), Organic Synthesis and Molecular Engineering, John Wiley & Sons, Inc.
2. Malhotra B.D., Pandey C.M., (2017), Biosensors: Fundamentals and applications, Smithers, Rapra

Online Course Material

1. Pandya H.J., Fabrication Techniques for MEMs-based sensors: Clinical perspective, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Science Bangalore, <https://nptel.ac.in/courses/108108113/#>

Title	Material and Energy Balance	Number	CHL2XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

1. 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, use of psychrometric and enthalpy concentration diagrams(4 lectures). [14 lectures]

Simultaneous Material and Energy Balances: Degrees of freedom analysis for multicomponent systems (3 lectures), combined steady state material and energy balances for units with multiple sub-systems (3 lectures). [6 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	Mass Transfer I	Number	CHL3XX0
Department	Chemical Engineering	L-T-P [C]	3-0-3 [4.5]
Offered for	BTech	Type	PC
Prerequisite	None		

Objectives

The Instructor will:

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

Learning Outcomes

The students are expected to:

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

Contents

Introduction to Mass Transfer: [8 lecture] 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 (3 lectures)

Direct Contact Mass Transfer Operations for Immiscible Phases: [10 lectures] Equilibrium, diffusion between two insoluble phases, ideal stage, local diffusion, overall diffusion (4 lectures), material balance in co-current processes; counter-current processes; stage-wise processes; continuous and batch processes (4 lectures), minimum stages for total reflux (2 lectures).

Gas-Liquid Mass Transfer: [8 lectures] Bubble columns, multi-stage absorption, tray efficiency, NTU (Number of Transfer Units) (4 lectures), HTU (Height of Transfer Unit), wetted-wall towers, tray towers, packed towers, Ergun equation, end effects and axial mixing, q-line location (4 lectures).

Special Cases in Gas-Liquid Mass Transfer: [12 lectures] Liquid-vapor equilibrium (1 lecture), vapor pressure curve, triple point, critical point, Clausius-Clapeyron equation, absolute humidity, saturation, humidification, dry-bulb temperature, dew point, psychrometric charts, wet-bulb temperature, the Lewis relation (5 lectures), distillation - Pressure-Temperature- Concentration phase diagram for binary systems, constant pressure and constant temperature equilibria (4 lectures), relative volatility, Raoult's law, azeotropes, enthalpy concentration diagrams (2lectures).

Liquid-Extraction (Solvent Extraction) & Solid-Fluid Operations: [4 lectures] Basics Definitions including feed, solvent, extract, raffinate (2 lectures); liquid-liquid equilibria, the mixture rule, effect of temperature and pressure, three liquid systems (2 lectures).

Laboratory Experiments

Experiments on mass transfer such as

Diffusivity in gases, diffusivity in liquids (3 experiments)

Absorption such as packed bed tower/ plate column (4 experiments)

Distillation (3 experiments)

Textbook

1. Treybal R.E. (2017) 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 Books

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

Online Course Material

1. Majumdar 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	Heat Transfer	Number	MEL3XX0
Department	Mechanical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Basics of Thermodynamics & Fluid Mechanics		

Objectives

1. To inculcate understanding, formulation, designing and solving problems with concepts in conduction, convection and radiation
2. To explain design concepts of fins, heat exchangers
3. To introduce physical background associated with empirical correlations for heat transfer coefficients using real world problems

Learning Outcomes

The students will have the ability to:

1. Analyze empirical situation of steady and transient conduction heat transfer
2. Evaluate transfer coefficients in natural and forced convection in and out of control areas
3. Assess performance of various heat exchangers
4. Solve numerical problems related to conduction and radiation heat transfer

Contents

Introduction (1 Lectures): Modes of heat transfer, Fourier's law, conductivity, diffusivity

Introduction to Heat conduction (3 Lectures): General heat conduction equations, 1D Heat conduction, Boundary and initial conditions, Heat generation

Steady heat conduction (4 Lectures): Heat conduction in plane wall, cylinder, sphere, network analysis, critical radius of insulation, heat transfer from fins

Transient heat conduction (4 Lectures): Lumped system analysis, transient heat conduction in large plane walls, long cylinders and sphere with spatial effect, Heisler and Grober charts

Numerical methods of heat conduction (2 Lectures): Finite difference formulation, numerical methods for 1D and 2D steady state heat conduction

Introduction to convection (4 Lectures): Velocity and thermal boundary layer, laminar, turbulent flows, solution of boundary layer equations, Non-dimensional numbers

External heat transfer (4 Lectures): Drag and heat transfer, parallel flow over flat plates, flow across cylinders and spheres

Internal heat transfer (4 Lectures): Mean Velocity and Temperature, Critical Reynolds number, The entrance regions, Hydrodynamic and thermal entry lengths, fully developed flow

Natural/free convection (2 Lectures): Physical Mechanism, Natural convection over surfaces, Criteria for forced and natural convection

Boiling and condensation (3 Lectures): Boiling Curve, Nucleate boiling, film boiling, Dropwise and film condensation, Nusselt's theory of film condensation

Heat Exchangers (4 Lectures): Classifications, Overall Heat Transfer Coefficient, LMTD, Effectiveness-NTU method, Operation Issues, Introduction to Design of Heat Exchanger

Introduction to radiation (4 Lectures): Physical Mechanism, Radiations laws, Intensity of Radiation, gray body

View factors (3 Lectures): View Factor Integral for diffuse surfaces, Radiation exchange, Electric Circuit Analogy

Text Book

1. Incropera, F. P. & Dewitt, D. P., (2011), Fundamental of Heat and Mass Transfer, John Wiley & Sons
2. Cengel, Y. A. & Ghajar, A. J., (2008), Heat and Mass Transfer, McGraw Hill

Reference Books

1. Holman J.P., Heat Transfer, Tata McGraw-Hill Edition, New Delhi

Self-Learning Material

1. <https://www.youtube.com/watch?v=qa-PQOjS3zA&list=PL5F4F46C1983C6785>

Title	Chemical Reaction Engineering	Number	CHLP3XX0
Department	Chemical Engineering	L-T-P [C]	3-0-3 [4.5]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objective

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: [4 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: [6 lectures] Parallel and series reactions, analysis of product distribution and determination of reactor size (3 lectures), selectivity and yield factors, Denbigh reactions, reactor choice for multiple reactions (3 lectures).

Reactor design and operation: [14 lectures] Isothermal and non-Isothermal design of ideal reactors, tubular reactor, auto-thermal process (5 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] Rate controlling steps, intra- and inter- particle mass transfer, Thiele modulus and effectiveness factor, performance equations (4 lectures), product distribution in multiple reactions, Unreacted core model for spherical particles, rate of reaction, rate-controlling step determination (4 lectures).

Laboratory Experiments

1. Residence Time Distribution (3 h)
2. Kinetics of reaction (3h) such as condensation polymerization etc.
3. Batch reactor (6h)
4. Flow Reactors (18 h) CSTR PFR Tubular
5. Catalysis (3h)
6. Half-life method analysis of kinetic data (3h)
7. Batch reactive distillation (6h)

Text Books

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

Reference Books

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	Scientific Computations	Number	MAL2XX0
Department	Mathematics	L-T-P-D [C]	3-0-2 [4]
Offered for	B.Tech ME, MT, CHE	Type	Compulsory
Prerequisite			

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

Roots of equation [8 Lecture]: Iterative methods, order of convergence, Iterative methods for roots of nonlinear system of equations.

Linear systems of equations [8 Lecture]: 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 [7 Lecture]: Lagrange, Newton divided difference formula, Newton's interpolations, errors in interpolation.

Differentiation and Integration [7 Lecture]: Differentiation using interpolation formulas, Integration using interpolation, Newton-Cotes formulas, Gauss quadrature rules.

Ordinary differential equations [4 Lecture]: Taylor series method, Euler's Method, Modified Euler's Methods, multistep methods, Runge-Kutta Methods.

Advanced methods for Differential Equations [6 Lecture]: Adaptive methods, BVP finite difference methods and their extension to PDEs, 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.
4. Golub, G.H., and Loan, C.F.V., (2000) Matrix Computation, JHU Press.
5. Santosh Kumar Gupta, 2012, Numerical Methods for Engineers, New Academic Sciences.

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	CHL3XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	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

Review : Laws of thermodynamics, PVT behavior of fluids, Gibb's phase rule, cubic equations of state and generalized correlations. [2 lectures]

Vapor-liquid equilibrium (VLE): Phase rule, simple models for VLE, VLE by modified Raoult's law(4 lectures), VLE from K-value correlations, Flash calculations(2 lectures). [6 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 (4 lectures), the ideal solution and excess properties (3 lectures). [9 lectures]

Liquid phase properties from VLE: Models for excess Gibbs energy, heat effects and property change on mixing [5 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). [7 lectures]

Thermodynamic Analysis of Processes: Work and free energy, availability (2 lectures), analysis of mixing, separation processes (3 lectures), heat exchange, lost work calculations (2 lectures). [7 lectures]

Textbook

1. Smith J.M., Van Ness H.C. and Abbott M.M., (2005), Introduction to Chemical Engineering Thermodynamics, 7th Ed., McGraw Hill.

Reference Books

1. Rao, Y.V.C., (1997), Chemical Engineering Thermodynamics, University Press, Hyderabad.
2. Koretsky M.D., (2004), Engineering and Chemical Thermodynamics, John Wiley & sons.
3. Kyle B.G., (1999), Chemical and Process Thermodynamics, 3rd ed., Prentice Hall.
4. Sandler S.I. (2006), Chemical, Biochemical and Engineering Thermodynamics, 4th Ed., John Wiley & Sons.

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	Heat Transfer Lab	Number	MEP3XX0
Department	Mechanical Engineering	L-T-P [C]	0-0-2 [1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Heat and Mass Transfer		

Objectives

The instructor will:

- 1) Provide the practical knowledge with regard to the determination of rate of heat exchange in various modes of heat transfer
- 2) Provide practical exposure to various temperature measurement instruments and its working principle

Learning Outcomes

The students will have the ability to:

- 1) Compare the performance of different convection processes
- 2) Measure the heat transfer properties of various metals
- 3) Understand basic laws of radiation heat transfer
- 4) Measure the temperature of objects using different temperature measurement instruments

Contents

1. Study on Temperature distribution during 1-D heat transfer in (a) Plain Wall (b) Cylinder (C) Sphere. (2 week)
2. Measurement of Thermal Conductivity of unknown material. (1 week)
3. Effect of Size of Plain wall on Temperature distribution and contact resistance. (1 week)
4. Demonstration of domestic solar water heating system (Time vs Temperature plots). (1 week)
5. Investigation of the influence of solar luminous intensity, the water flow rate and the angle of incidence of the light on the efficiency and temperature difference. (1 week)
6. Study on forced and free convection heat transfer for flow over flat plate, Tube bundle and Fins. (1 week)
7. Testing the accuracy and time response of different temperature sensors (PT100, NTC, Thermocouple, Mercury Thermometer, Gas Pressure Thermometer, Bimetallic Thermometer). (1 week)
8. Calibration of PT100 temperature sensor and derive equation of temperature as function of resistance. (1 week)
9. Calibration of K-Type thermocouple temperature sensor and derive equation of temperature as function of voltage. (1 week)
10. Study on validation of different radiation laws (a) Lambert's Distance Law (b) Lambert's Direction Law (Cosine Law) (C) Stefan Boltzmann's Law (d) Kirchhoff's Law. (2 week)

Reference Books

1. Incropera, F. P. & Dewitt, D. P., (2011), Fundamental of Heat and Mass Transfer, John Wiley & Sons
2. Cengel, Y. A. & Ghajar, A. J., (2008), Heat and Mass Transfer, McGraw Hill
3. Holman J.P., Heat Transfer, Tata McGraw-Hill Edition, New Delhi

Title	Mass Transfer II	Number	CHL3XX0
Department	Chemical Engineering	L-T-P [C]	3-0-3 [4.5]
Offered for	BTech	Type	PC
Prerequisite	Mass Transfer I		

Objectives

The Instructor will:

Provide details of mass transfer unit operations and overview of the equipment. 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 it's industrial applications.

Contents

Mass Transfer Overview and Diffusion in Solids: [4 lectures] various solid geometries in diffusion (1 lecture), diffusion (1 lecture), structure of solids and diffusion (2 lectures)

Gas Absorption (in Liquids/ Solvents): [12 lectures] Equilibrium solubility (1 lecture), two component systems, ideal and non-ideal liquid solutions, solvent selection (5 lectures), material balances – countercurrent flow, absorbers, concurrent flow, stage operations, absorption factor, non-isothermal operations, tray efficiency (4 lectures), continuous contact equipment, Henry's law, transfer units, multi-component systems (2 lectures).

Distillation in Tray Columns: [10 lectures] Multicomponent systems, flash vaporization, partial condensation (3 lectures), differential distillation, Ponchon and Savarit Method for tray towers, Single Vs multiple feeds (3 lectures), McCabe & Thiele Method, reflux ratios, azeotropic mixtures (4 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, drying (5 lectures)

Laboratory Experiments

Liquid-liquid extraction (3 experiments)

Adsorption

Ion exchange

Drying

Cooling Tower (2 experiments)

Membrane process (2 experiments)

Textbook

1. Treybal, R.E., (2017), 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 Books

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

Online Course Material

1. Majumdar 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 Plant Design & Economics	Number	CHLP4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-3 [4.5]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objective

The Instructor will:

1. Introduce basic concepts in Process Equipment Design, engineering economics, safety features and its application to chemical engineering.

Learning Outcomes

The students are expected to have the ability to:

1. Understand technical and business related information to design equipment required in Chemical industries.
2. Follow a logical sequence of interconnected unit operations for an effective chemical engineering process.

Contents

Mechanical design of process equipment: Background and relevance, Concept of design and economics in chemical industries, pressure vessels, tall columns, process piping design (5 lectures); Materials and Fabrication Selection, Design variations, Selection criteria, process calculations (4 lectures). [9 lectures]

Heat Exchange Equipment: Rating of an existing unit and design of a new system of shell and tube heat exchangers (4 lectures); design of multiple-effect evaporator (3 lectures). [7 lectures]

Mass Exchange Equipment: Design of a sieve-tray tower for distillation (3 lectures); design of a packed tower for gas absorption (3 lectures). [6 lectures]

Pump and Compressor: Types of pumps and selection criteria (2 lectures), calculations of a pumping circuit and rating, characteristic curves (2 lectures), Cavitation and NPSH, blowers and compressors, Single/multistage compression, Typical multistage compressor calculations (4 lectures). [8 lectures]

Economics: Basic concepts in economics, Economic Design criteria; Cost and Asset Accounting; Cost Estimation; Interest and Investment Costs (4 lectures); Profitability, estimation of various costs to install and run a plant; interest costs and present/future worth of cash flows (4 lectures); methods for depreciation calculation; discounted cost flow/net present worth methods for profitability analysis (4 lectures). [12 lectures]

Laboratory Experiments

1. Process and mechanical design calculations for process equipment. (6h)
2. Numerical studies in reactor design. (6h)
3. Design and analysis of separation equipment. (6h)
4. Steady-state simulation of flow sheets. (6h)
5. Optimization and costing in flow sheets. (3h)
6. Design and analysis of control systems. (3h)
7. Process flow simulations using commercial simulators. (6h)
8. Process economics and Profit analysis. (6h)

Text Books

1. M.S. Peters, K.D. Timmerhaus, R. West, 2003 'Plant Design and Economics for Chemical Engineers', 5th edition, McGraw Hill.
2. R. Smith, 1995, 'Chemical Process Design', McGraw Hill.

Reference Books

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.

Online Course Material

Moholkar V.S., Process Design Decisions and Project Economics, NPTEL course material, Department of Chemical Engineering, Indian Institute of Technology Guwahati,
<https://nptel.ac.in/courses/103103039/>

Title	Transport Phenomena	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech	Type	PC
Prerequisite	None		

Objective

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 with 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

Fractal 1: [14 Lectures]

Basics of Transport phenomena: Introduction (1 lecture), Basic concepts of Vector and Tensor Analysis (3 lectures) [4 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). [10 lectures]

Fractal 2: [14 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) [14 lectures]

Fractal 3: [14 Lectures]

Mass transport: Basics of mass transport, mechanisms, and mass and molar fluxes [3 lectures] 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). [11 lectures]

Tutorials

Tutorial sheets will be provided every week as homework assignments and will be discussed in the next slot. It will help the students to conceptualize the problems and understand the methods to solve transport related problems.

1. Formulation of transport problems [1 lectures]
2. Vector, Tensor analysis [1 lectures]
3. Newtonian and non-Newtonian momentum transport [4 lectures]
4. Boundary layer problems [1 lectures]
5. Steady state energy transport [2 lectures]
6. Flux [1 lectures]
7. Diffusion and convection [1 lectures]
8. Unsteady state transport problems [3 lectures]

Text Books

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 Books

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.
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	Process Control & AI Applications	Number	CHLP4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-2 [4]
Offered for	B.Tech.	Type	PC
Prerequisite	None		

Objective

The Instructor will:

1. To impart knowledge about the dynamics and control strategies for linear and non-linear processes along with control elements in continuous and discrete domains.
2. Introduce various paradigms that come under the broad umbrella of AI and the application of Internet of Things (IoT) in process Control.

Learning Outcomes

The students are expected to have the ability to:

1. Have fair understanding of the dynamics and control strategies for linear and non-linear processes along with control elements in continuous and discrete domains.
2. Have fair knowledge of IoT and AI application and have the ability to develop an understanding of where and how AI can be used in the field of chemical engineering.

Contents

Introduction

The concept of process dynamics and control, History and Relation of AI and IoT in control systems [2 lectures]

Review of feedback control, On-Off Control, Valve Gains, transfer function, dynamic model building [3 lectures]

Dynamic Behavior of Processes

Response of first and second order processes, Approximation of higher-order processes transfer function, Process with time delays, MIMO Processes [4 lectures]

Stability and Controller Design

Review of stability analysis (Routh-Hurwitz test), root-locus method [4 lectures] PID Controller design, Tuning, and Applications in Process control [5 Lectures]

Frequency Response

Review of Bode and Nyquist plots, Gain and Phase margins, Stability using frequency response [5 lectures]

Effect of process parameters on Bode and Nyquist plots, control system design by frequency response methods [4 lectures]

AI and IoT in control systems

Modes of control action, integration of AI and IoT, Fuzzy controllers, neural network for controllers [5 Lectures]

Control of complex chemical processes and equipment, valve, real time computer control of process equipment [5 Lectures]

AI in Chemical Processes

AI techniques in process monitoring, fault detection and diagnosis. [5 lectures]

Laboratory experiments

1. Basics of control system components, signals and standards (2 hrs.)
2. Pressure measuring devices (2 hrs.)
3. Level measurement (2 hrs)
4. Flow measuring devices (2 hrs.)

5. Temperature measuring devices (2 hrs)
6. Humidity, density, viscosity and pH measuring devices (2 hrs.)
7. Pressure controllers: regulators, safety valves (2 hrs)
8. Flow control actuators: different types of valves (2 hrs.)
9. Computer process control, PLC, DCS, SCADA (4 hrs.)
10. AI/IoT in Chemical plants (4 hrs)

Text Books

1. Coughanowr D. R. and LeBlanc S., (2008), Process System Analysis and Control, 3rd Ed., McGraw Hill.
2. Quantrille, T.E. and Liu, Y.A., (1991), Artificial Intelligence in Chemical Engineering, Academic Press.

Reference Books

1. Stephanopoulos G., (1990), Chemical Process Control – An Introduction to Theory and Practice, Prentice-Hall of India.
2. Boullart, L., Krijgsman, A., Vingerhoeds, R.A., (1992), Application of Artificial Intelligence in Process Control, Pergamon Press Ltd. England.

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	Fluid Mechanics Lab	Number	MEP3XX0
Department	Mechanical Engineering	L-T-P [C]	0-0-2[1]
Offered for	B. Tech (ME)	Type	Program Compulsory (PC)
Prerequisite	Fluid Mechanics		

Objectives

1. To introduce various forms of flow measuring devices and techniques
2. To provide hands on experience on in the area of experimental fluid mechanics

Learning Outcomes

The students will have:

- 1) Ability to design experimental methods for fluid flow problems
1. Ability to interpret data from experiments of fluid flows and usage of charts and hand books

Contents (13-14 Classes)

1. Determination of head loss in pipes having different diameters, different materials and different roughness
2. Determination of pressure drop at different types of bends and valves
3. Reynolds apparatus to measure critical Reynolds number for pipe flows
4. Lift and Drag measurement in an airfoil using pressure measurements
5. Wake profile measurement
6. Wind tunnel air velocity profile measurement using Pitot static tube
7. Working principle of different flow meters (orifice plate, venture meter, turbine, Rota meter, electromagnetic flow meter)
8. Flow measurement around an object or blockage using PIV technique

Reference Books

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

15. Detailed Course Content of Programme Elective Courses

Title	Industrial management and safety for Chemical engineers	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Program Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Provide information about handling of hazardous materials and safety in Chemical plants.
2. Illustrate the method of risk assessment to avoid accidents in plants.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the industrial practices of handling hazardous materials and safety assessment.
2. Assess the safety in chemical plants and provide recommendations to avoid accidents in process industries.

Contents

Risk Assessment and safety: Introduction; Probability theory; event trees; fault trees; LOPA; QRA; practical application of QRA; software for QRA; (4 lectures) safety and Loss Prevention; hazard and risk; accident and loss statistics; nature of accident process; inherent safety (4 lectures). [8 lectures]

Toxicity, Dispersion models and Industrial Hygiene: Definition; effect of toxicants; dose and response curves; relative toxicity and threshold limits; Parameters affecting dispersion(4 lectures); neutrally buoyant dispersion models; toxic effect criteria; release mitigation, Govt. Regulations for industrial safety; occupational health hazards and their control(5 lectures). [9 lectures]

Fires and Explosions in Chemical plants: Fire Triangle; flammability characteristics of liquid and vapour; flammability diagram; ignition energy; auto ignition and auto oxidation (4 lectures); adiabatic compression; ignition sources; sprays and mists; explosions; fire protection systems, designs to prevent fires and explosions; ventilation; sprinkler systems(5 lectures). [9 lectures]

Accident Investigation and Case Histories: Theories; methodologies; impact of human factors; root cause analysis; developing effective recommendations (5 lectures) ; study of major accidents, Strategies to avoid accidents (such as, System design; chemical reactivity; static electricity; procedures, etc.) (4 lectures). [9 lectures]

Integrity Management: Definition; risk management; Barrier models; Safety Critical Equipment (3 lectures); Risk Register; Project Health, Safety and Environment Review; Safety Management; reliability management (4 lectures). [7 lectures]

Textbook

1. Daniel A. Crowl and Joseph F Louvar, 2002, Chemical Process Safety Fundamentals with Applications, 3rd edition, Prentice Hall.
2. Trevor A. Kletz., 2001, Hazop & Hazan, 2nd edition, I.ChemE.

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	Product Design in Chemical Engineering	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	2-0-0 (2)
Offered for	B.Tech.	Type	PE
Prerequisite	None		

Objectives

The Instructor will:

1. Provide information about discovery, design and delivery in the chemical industry.
2. Illustrate the conceptual implementation of product development in industries.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the process associated with new product development and commercialization in chemical engineering.

Contents

General features: Introduction, Factors, idea generation and screening (screening vs. high resolution), Framework for chemical product design (3 lectures), processing and verification of new material, Classification of chemical products, environmental impact and sustainability (3 lectures). [6 lectures]

Product development aspects: Structure of Chemical Product Engineering, concept development and testing (4 lectures), product architecture and industrial design (2lectures). [6 lectures]

Computer aided methods: Heuristics, Molecular dynamics for property prediction(5 lectures), Population-based model, Factorial design, Group contribution methods (5 lectures). [10 lectures]

Case studies: water filter, heat exchanger, paints and inks, adhesives, liquid fuels by cracking of heavy oil, production of fine Chemicals, fuels and chemicals from syngas, etc. [6 lectures]

Textbook

1. Montgomery, D. C., 2009, Design and Analysis of Experiments, John Wiley & Sons.
2. Jess,A., Wasserscheid, P., 2020, Chemical Technology: From Principles to Products. Willey, Second Edition.

Reference Books

1. Ulrich, Karl T., Eppinger, Steve D., and Yang, Maria C., 2020, Product Design and Development, 7th ed., McGraw-Hill Education.
2. Recent published journal articles on relevant topics.

Title	Unit operations	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite			

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 (4 lectures), enlargement and separation, Crushers and Grinders (3 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 (5 lectures), general equation, microfiltration, fouling, electrolysis (5 lectures), reverse osmosis, pervaporation (4 lectures). [14 lectures]

Flotation and sedimentation: Fundamental concept, froth flotation (3 lectures), gravity settling, centrifugation, design criteria (4 lectures). [7 lectures]

Textbook

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

Reference Books

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	Membrane Technology	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite	Fluid Mechanics		

Objectives

The Instructor will:

1. Provide an insight to the membrane-based separations that is an integral part of the down-stream processing of various industries.

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.

Contents

Introduction: Membrane and membrane materials, Material properties. [4 lectures]

Membrane Preparation: Phase inversion process, Preparation of composite membrane, Inorganic membranes (4 lectures)

Membrane Characterization: Microfiltration (MF) characterization, Ultrafiltration (UF) characterization [4 lectures]

Membrane Transport: Pressure driven transport through porous and nonporous membrane, Osmosis concepts (5 lectures), Reverse Osmosis (RO), Nanofiltration (NF), Transport models, Micellar-enhanced and affinity UF (5 lectures). MF transport, Facilitated transport, Membrane contactors (3 lectures). [13 lectures]

Concentration/ Temperature driven and Hybrid membrane processes: Liquid membranes, Gas separation, Membrane distillation, hybrid membrane processes [5 lectures]

Challenges and solutions: Membrane fouling (2 lectures), RO, NF, UF, MF(5 lectures), Dialysis, Electrodialysis, Pervaporation (5 lectures). [12 lectures]

Textbook

1. Baker, R.W., (2004), Membrane Technology and Applications, 2nd Edition, Membrane Technology and Research Inc., Menlo Park, CA.

Reference Books

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

Online Course Material

Mohant K, Membrane Technology, NPTEL course material, Department of Chemical Engineering, IIT Guwahati, <https://nptel.ac.in/courses/103103163/>

Title	Applications of Artificial Intelligence in Chemical Engineering	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech, Dual Degree	Type	PE
Prerequisite	Material and Energy Balance, Scientific Computations		

Objectives

The Instructor will:

1. Provide background on AI in chemical engineering and allied systems

Learning Outcomes

The students are expected to:

1. Gain fundamental understanding of the application of AI in chemical and allied engineering.
2. Learn to develop AI model equations, approaches for chemical and allied engineering systems.
3. Learn to write basic codes of AI for simple systems.

Contents

Artificial Intelligence in Chemical Engineering Background: Early Attempts, Expert System Era (1 Lecture) , Neural Network Era, Effects and Lacunae of Expert System Era and Neural Network Era on Chemical Engineering (2 Lectures), Deep Learning and Data Science Era (2 Lectures). [5 Lectures]

Application of AI in modelling: AI in chemical process modelling (2 Lectures), AI in optimisation of chemical process (2 Lectures), Application of neural networks in chemical process control, Modelling Real-World Processes: Deep and Shallow Knowledge Integrated with Approximate Reasoning in a Diagnostic Expert System (4 Lectures), Application of AI techniques in fault detection and diagnosis of chemical engineering (3 Lectures), Numeric to Symbolic Structures and Relationships (1 Lecture). [12 Lectures]

Case Studies: Oxidative coupling of methane (OCM) over the Mn/Na₂WO₄/SiO₂ catalyst in a fluidized bed reactor (4 Lectures), Control of Reactive Distillation Column (4 Lectures), Use of Qualitative Models in Discrete Event Simulation to Analyze Malfunctions in Processing Systems (4 Lectures), Fault Detection and Diagnosis Using Artificial Neural Networks (4 Lectures), A Modular Approach to Multiple Faults Diagnosis (4 Lectures), Design of Protein Purification Processes by Heuristic Search (4 Lectures). [24 Lectures]

AI in Chemical Engineering Recent Trends and Future Outlook: Emergence in large scale systems of self-organizing intelligent agents. [1 Lecture]

Textbook

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

References

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
4. Araromi DO, Sonibare JA, Emuoyibofarhe JO. Fuzzy identification of reactive distillation for acetic acid recovery from waste water. Journal of Environmental Chemical Engineering. 2014; 2:1394-1403
5. Shih-Bo Hung and Ming-Jer Lee, 2006, Control of Different Reactive Distillation

Configurations, AIChE, Vol. 52, No. 4
6. Neha Sharma and Kailash Singh, 2010, Control of Reactive Distillation Column: A Review, International Journal of Chemical Reactor Engineering, Vol. 8

Title	Petrochemical Engineering	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	Type	PE
Prerequisite	None		

Objectives

The Instructor will:

1. Provide background information about the petrochemical engineering including definition, petrochemical products and processes

Learning Outcomes

The students are expected to:

1. Gain a holistic view of Petrochemical Engineering and learn about the importance of petrochemical products and processes

Contents

Introductory Concepts for Crude Petroleum and Petrochemicals: Composition of crude oil, physical properties of crude oil, origin of hydrocarbons (3 lectures), petrochemical global and domestic petrochemical industries, definitions, feedstock for petrochemicals, intermediate and finished products in petrochemicals (3 lectures) [6 lectures]

Chemical Processes in Petrochemicals: Dissociation and dehydrogenation (thermal and catalytic cracking) (3 lectures), hydrogenation, addition, condensation, polymerization (3 lectures) [6 lectures]

Petrochemical Intermediates from Petroleum Products: Introduction, manufacturing processes for carbon black from methane/ natural gas, polyethylene production from ethane (5 lectures), Terephthalic acid and PET from Xylene, Naphtha for olefins, sulfuric acid from sulfur, cosmetics and food grade coating wax from wax, naphtha cracking (5 lectures). [10 lectures]

Petrochemical Finished Products from Intermediates: Manufacturing of paint, fiber, plastics (5 lectures), rubber, Nylons, fibers (3 lectures), processing of plastic, rubber and fibers (4 lectures). [12 lectures]

Layout and Unit Operations in Petrochemical Plants: Petrochemical complex, Reactors processing units, offsite facilities, power and steam generating plants, cooling tower. [4 lectures]

Sustainability and Latest Trends in Petrochemical Plants: Effluent water treatment, gaseous effluent treatment, latest trends [4 lectures]

Textbook

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 Books

1. Meyers, Robert, and Robert Allen Meyers, eds. (2005) Handbook of petrochemicals production processes. McGraw-Hill.

Online Course Materials

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/103/102/103102022/>

Title	Petroleum Refinery Process Modelling	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	1-0-2 [2]
Offered for	B.Tech., Dual Degree in Chemical Engineering	Type	PE
Prerequisite	None		

Objective

The Instructor will provide:

1. Thorough understanding in the area of process models for petroleum refinery operations.

Learning Outcomes

The students are expected to:

1. Understand various process models available for refinery processes.
2. Learn simulations using Aspen Hysys/ Matlab for petroleum refinery units

Contents

Energy conservation and new trends in petroleum refinery operations: Data Driven Modelling of Atmospheric and Vacuum Distillation Unit (4 Lectures), Data Analytics of: Fluid Catalytic Cracking (FCC) Process (2 Lectures), Continuous Catalyst Regeneration (CCR) and Reforming Process (3 Lectures), Hydroprocessing Units (2 Lectures). Alkylation, Delayed Coking, and Refinery-Wide Simulations (3 Lectures). [14 lectures]

Experiments [28 hours]

1. Building the Model in Aspen HYSYS Petroleum Refining Components Design
2. Model Applications to Process Optimization
3. Rebuild Model Using "Backblending" Procedure
4. Simplified VDU Model
5. Rigorous Model from a Simplified Model
6. Kinetic Models
7. Unit-Level Models
8. Aspen HYSYS Petroleum Refining FCC Model
9. Calibrating the Aspen HYSYS Petroleum Refining FCC Model
10. Basic FCC Model
11. Perform Case Studies to Quantify Effects of Key FCC Operating Variables
12. Generate Delta-Base Vectors for Linear Programming
13. Aspen HYSYS Petroleum Refining Catalytic Reformer Model
14. Model Calibration
15. Build a Downstream Fractionation System
16. Aspen HYSYS Petroleum Refining HCR Modelling
17. H₂-to-Oil Ratio versus Product Distribution, Remained Catalyst Life and Hydrogen Consumption
18. Build and Calibrate a Preliminary Reactor Model of HCR
19. Hydrofluoric Acid Alkylation Process Simulation
20. Simulation and Calibration of a Delayed Coking
21. Simplified Model of Delayed Coker by Petroleum Shift
22. Refinery-Wide Process Simulation

Textbook

1. Y. A. Liu, Ai-Fu Chang, and Kiran Pashikanti, 2018, Petroleum Refinery Process Modeling Integrated Optimization Tools and Applications, Wiley

Title	Basics of Reliability and Maintainability Engineering for System Safety	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-1-0 [4]
Offered for	B.Tech, Dual Degree	Type	Elective
Prerequisite	Mathematics I and Mathematics II		

Objectives

The Instructor will:

1. Provide background on Reliability Engineering Models that can be integrated for AI development in system safety.

Learning Outcomes

The students are expected to:

1. Gain fundamental understanding of the models used for failure detection and reliability design.
2. Learn to connect failure and reliability models for AI approach towards system safety.

Contents

Introduction: Study of Reliability and Maintainability Engineering, Concepts, Terms and Definitions, Applications (1 Lecture), Brief History (1 Lecture). [2 Lectures]

Failure Detection Models: Failure Distribution (4 Lectures), Constant Failure Rate Model (5 Lectures), Time Dependent Failure Models (5 Lectures). [14 Lectures]

Reliability Models: Reliability of Systems (4 Lectures), State Dependant Systems, Physical Reliability Models (5 Lectures), Design for Reliability (5 Lectures). [14 Lectures]

Maintainability: General Overview (4 Lectures), Design for Maintainability (4 Lectures), Availability (4 Lectures). [12 Lectures]

Tutorials

1. Problem solving on Failure Detection Models, Reliability Models and on Designing Maintainability

Textbooks

1. Charles E. Ebeling, 2004, An Introduction to Reliability and Maintainability Engineering, 3rd Edition, TMH.
2. Kailash C. Kapur and Michael Pecht, 2014, Reliability Engineering, John Wiley & Sons Inc.

References

1. Krishna B. Mishra, 2008, Reliability Engineering: A Perspective, DOI: 10.1007/978-1-84800-131-2_19.

Title	Introduction to Complex Fluids	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Program Elective
Prerequisite	Fluid Mechanics		

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 (5 lectures), Mechanical Rheology (2 lectures). [15 lectures]

Types of complex fluids and their properties: Colloidal dispersions, polymeric solutions (4 lectures), gels, liquid crystals (4 lectures), Emulsions and Blends (3 lectures), Surfactants and micelles (3 lectures). [14 lectures]

Micro and Mesoscopic Systems: Self-assembly, phases(4 lectures), Characterization of structure-property 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 Books

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

Title	Interfacial engineering in soft matter	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite			

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 (5 lectures), thin films, dispersions, emulsions, foams (5 lectures), interfacial self-assembly, amphiphilic system (3 lectures), comparison and contrast of liquid and solid interfaces (3 lectures). [16 lectures]

Surfaces and forces: Interfacial energy and forces, wetting, shape of interfaces (5 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, electrokinetic phenomena, adsorption (3 lectures). [16 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 Books

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	Bioprinting	Number	BSBE4XX0
Department	BSBE	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech Program	Type	Program Elective
Prerequisite	Basic knowledge of bioengineering		

Objectives:

The instructor will provide the essential concepts of 3D bioprinting and will apprise the student about the potential of 3D bioprinting for various applications.

Learning Outcomes:

The student will be able to

- (i) analyze the properties and performances of different bioinks.
- (ii) design a bioprinting strategy for specific application.

Contents

Introduction to bioprinting (14 lecture): Scope, strategies and workflow (3 lecture), bioinks : types, components, physico-chemical and biological properties (5 lecture), cells and cellular micro-aggregates in bioinks (2 lecture), cross-linking strategies for bioinks, commercially available bioinks, bioinks vs biomaterial inks, scaffold free bioprinting (4 lecture).

Bioprinting processes (14 lecture): Digital designing of 3D organ/tissue model, (3 lecture), 3D bioprinting processes: extrusion based bioprinting, droplet bioprinting (4 lecture), laser assisted bioprinting, stereolithography based bioprinting, novel bioprinting processes (5 lecture), selection criteria for 3D printing processes, limitation of bioprinting processes (2 lecture).

Application of bioprinting (14 lecture): Bioprinting for tissue engineering and regenerative medicine (4 lecture), bioprinted tissue model for drug and cosmetic research, bioprinted food (4 lecture), bioprinted bacterial biofilm and biosensors (2 lecture), Bioprinting in chemical engineering (4 lecture).

Text book: W. Y. Yeong and C. K. Chua, Bioprinting: Principles And Applications, World Scientific Publishing Co Pte Ltd, 2015, 1st Ed

Reference book: A. Khademhosseini, G. Camci-Unal, 3D Bioprinting in Regenerative Engineering: Principles and Applications, CRC Press , 2018 , 1st Edr

Self-learning materials: Prof. Vignesh Muthuvijayan , IIT Madras, <https://nptel.ac.in/courses/102/106/102106081/>

Title	3-D Printing: Material Processing and Properties	Number	MTL4XX0
Department	Metallurgical and Materials Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech. Materials Engineering	Type	PE
Prerequisite	Nil		

Objectives

The Instructor will introduce:

1. Importance of 3-D printing of materials for various range of applications
2. Process control and product quality evaluation through application of basics

Learning Outcomes

The students are expected to gain:

1. Insight of the evolutionary technology for rapid and cost effective growth of products
2. Aptitude to translate the knowledge into novel components with industrialization competitiveness

Contents

Introduction [5 lectures]: 3-D printing small but multipurpose product inspiration, Science fiction to innovation, Multidisciplinary terminology, Current system configurations, Construction, Classification

Hardware – software – material Interdependence [5 lectures]:, Essence of hardware, software and materials, Impact on systems engineering in various industries, Processing philosophy

Raw Materials [4 lectures]: Forms and sources of raw materials, Processing methods and characteristic properties, Material specifications based industries and processing technology e.g. aerospace, medicine

3-D Printing Processes [2 lectures]: Process flow and basics of stages involved, Process control, Upgrading options, 3-D product design, evaluation, justification and integration (DEJI) model,

Additive Manufacturing of Metallic Systems [5 lectures]: Light metals and alloys, Superalloys, Intermetallic compounds, Shape memory alloys, porous metals, Rare earth permanent magnets

Thermo-mechanical Effects [2 lectures]: Phase transformation, Microstructure evolution, Variation in properties, Thermo-mechanical modeling of microstructure evolution and mechanical properties

3-D Printing of Polymers and Hydrogels [5 lectures]: Natural polymers, Synthetic polymers, Design considerations and guidelines, Mechanics modeling, AM of tooling for mass production processes, 3-D bioprinting hardware, Reactive inkjet printing of nylon materials, Stimuli responsive hydrogels, Biopolymer hydrogel biolinks

3-D Printing of Ceramics and composites [5 lectures]: Processing technology and options, Laminated object manufacturing, Laser Engineered net shaping, Bio-active ceramics and bio- active glasses, Engineering ceramics, Green-tape-based AM, Complex ceramic architecture, Metal matrix composites, Ceramic matrix composites, Polymer matrix composites and their variants, Nano-composites

Special Purpose 3-D Printing [5 lectures]: Functionally graded materials, Biomedical applications, Biomimetic design model, Frugal design sustainability, Smart material- DNA origami, 4-D printing, Reconstructive surgery, Patient specific 3-D printing, Hydrogen storage material, Printed and hybrid electronics enabled by digital AM technologies, Reverse Engineering

Post-processing and Inspection techniques [2 lectures]: Post processing problems and requirements, Rectification

Student Presentation & Discussion [2 lectures]: Concept for developing prototype object, Methodology, Examining novelty and market acceptability, Translation to business idea

Textbooks

1. Gibson, I., et al (Eds.) (2015), Additive Manufacturing Technology: 3D printing, Rapid

Prototyping, and Direct Digital Manufacturing, 2nd Ed., Springer

2. Maniruzzaman, M.. (Ed.), (2019), 3D and 4D Printing in Bio-medical Applications: Process-Engineering and Additive Manufacturing, Wiley- VCH Verlag GmbH & Co.

Reference Books

1. Declan, M.D.. (2019), Polymer Based Additive Manufacturing- Biomedical Applications, Springer Nature.
2. Gu, D., (2015), Laser Additive Manufacture of High-Performance Materials, Springer Verlag

Online Course Material

1. Ramkumar, J., 2018, NOC: Rapid Manufacturing, Department of Mechanical Engineering; IIT Kanpur, <https://nptel.ac.in/courses/112/104/112104265/>

Title	Introductory Principles in Polymer Engineering	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	Type	PE
Prerequisite	None		

Objectives

The Instructor will:

1. Provide background knowledge in polymer science and engineering to excite students to pursue further studies in the area of polymers and composites

Learning Outcomes

The students are expected to gain:

1. Basic understanding of polymers
2. Knowledge about application of polymers in traditional as well as advanced areas

Contents

Introduction: Origin, basics definitions, examples of polymers and their applications, classification of polymers based on structure, processing, crystallinity(5 lectures), case study, molar mass averages, polymerization reaction and classification, Tacticity and isomerism in polymers(5 lectures) [10 lectures]

Amorphous and Crystalline Polymers: Glass transition temperature, amorphous state, definition, free volume theory, polymer crystallinity, crystal structure and its determination, single crystals(5 lectures)semicrystalline polymers and examples, degree of crystallinity, melting and DSC, Defects in Crystalline Polymers (5 lectures)[10 lectures]

Deformation in Polymers : Elastic deformation, Definitions of stress, strain and their relationship for elastic deformation(5 lectures), elastic deformation in polymers,(4 lectures) viscoelasticity, examples, Mechanical Models(5 lectures) [14 lectures]

Applications and other Topics in Polymer Science & Engineering: Introduction, examples and applications of polymer blends(3 lectures), block-copolymers, elastomers, polymer composites(5 lectures) [8 lectures]

Textbook

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

Reference Books

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/>

Title	Solid Waste Management	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	BTech	Type	PE
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,(4 lectures) layout of a landfill site, landfill operations, environmental monitoring of landfills(4 lectures), leachate management - landfill liners, geosynthetic materials(4 lectures) [12 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,(5 lectures) PCB scrap characteristics, technologies for PCB recycling, toxins in PCB fabrication, lead-free soldering(5 lectures) [10 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 Books

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	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	Program 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, gas- phase biofiltration, emerging technologies. [15 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(4 lectures). [7 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 Books

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	Processing of rare earth & radioactive materials	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite			

Objectives

The Instructor will:

1. Provide in depth knowledge about the processes used to purify rare earth and radioactive materials and their applications.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the mechanism of rare earth and radioactive materials separation processes and their utility.

Contents

Basic Concept: Introduction and overview, definition, atomic structures, processing and handling, history and trade of RE and RA(5 lectures); geological distribution, application of rare earth (RE) and radioactive (RA) materials(4 lectures). [9 lectures]

Rare Earth elements: Ore mineral, classification, physical and chemical properties(4 lectures), chromatographic techniques for analysis, deposit exploration, mining, chemical treatment, separation processes(5 lectures), bio-sorption, recycling, economic aspects(4 lectures). (13 lectures)

Radioactive materials: Definition, physicochemical properties(3 lectures), Resource finding and mining, separation techniques(5 lectures), application in technology development, health and environment effects(4lectures). (13 lectures)

Sustainability and environment: Sustainability of sources and demand(2 lectures), sustainable mining, impact on environment, Geo-political considerations(5 lectures). (7 lectures)

Textbook

1. Voncken, J.H.L., 2016, The Rare Earth Elements: An Introduction, Springer.
2. Atwood, D. A., 2012, The Rare Earth Elements: Fundamentals and Applications, Wiley.
3. Lauf, R.J., 2008, Introduction to Radioactive Minerals, Schiffer Publishing Ltd.
4. L'Annunziata, M. F., 2016, Radioactivity: Introduction and History, From the Quantum to Quarks. 2nd edition, Elsevier.

Reference Books

1. I. B. De Lima, W. L. Filho, 2016, 'Rare Earths Industry: Technological, Economic, and Environmental Implications', Elsevier.

Title	Energy resources	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite	None		

Objectives

The Instructor will:

1. Provide information of various energy resources and their role in modern society, with both national and global perspectives.
2. Present different technologies to harness energy from different resources, and the environmental impacts.

Learning Outcomes

The students are expected to have the ability to:

1. Describe the energy sources in use today including the extraction and use of these resources.
2. Address the impacts of the use of different energy sources.

Contents

Energy production, environment and economy: Introduction to energy resources and their utilization, National and global power generation, role of chemical engineers in power generation, (4 lectures) Concepts of ecosystems and environment, local regional and global implications, role of energy on economy (3 lectures). [7 lectures]

Different resources and sustainability: Fossil fuel, natural gas, Biofuel (5 lectures), solar power, wind and tidal energy, geothermal, Nuclear energy, (5 lectures) energy from hydrogen and methanol, Electrochemical energy (3 lectures), other energy sources, sustainability of different resources (3 lectures). [16 lectures]

Energy harvesting and storage: Introduction and general concept, Techniques, materials (5 lectures); mechanism for different energy storage (4 lectures), AI and IoT in power generation and storage (4 lectures), storage demand, utilization (3 lectures). [16 lectures]

Industry 4.0: Prelude to the concept; smart energy production, storage and utilization; Indian Govt. Policies for green and sustainable energy. [3 lectures]

Textbook

1. G. A. Olah, A. Goeppert, G. K. S. Prakash, (2006), Beyond Oil and Gas: The Methanol Economy, Wiley-VCH, Weinheim, Germany.
2. Ball M. and Wietschel M., (2009), The Hydrogen Economy Opportunities and Challenges, Cambridge University Press.
3. Vertes, A. A., Qureshi, A., Yukawa, H., Blaschek, H.P., (2010), Biomass to Biofuels, Wiley.
4. R.A. Huggins, Energy Storage, Springer, 2010.
5. Joao Cruz, Mairead Atcheson (2016). Floating offshore wind energy (1st Ed). Springer.
6. A.G. Ter-Gazarian, Energy Storage for Power Systems, IET Publications, 2nd Edition, 2011
7. G. N. Tiwari, M K. Ghosal, 2004, Renewable Energy Resources: Basic Principles and Applications. Narosa Publishing House, New Delhi.

Online Course Material

Mondal P., Waste to Energy Conversion, NPTEL course material, Department of Chemical Engineering, IIT Roorkee, <https://nptel.ac.in/courses/103107125/>

Title	Waste Water Treatment	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech.	Type	PE
Prerequisite	None		

Objectives

The Instructor will:

1. Illustrate quantitative and conceptual foundation of conventional wastewater treatment.
2. Provide information related to the practical configurations, design and operation of conventional wastewater treatment processes.

Learning Outcomes

The students are expected to have the ability to:

1. Understand and apply the knowledge to waste water treatment and management.
2. Advance the operation of waste water treatment plant and maintenance of equipment

Contents

Overview of water management: Water demand, supply and wastewater generation, water in operating units and effluent rejection, water quality parameters and standards (5 lectures); Waste water specifications, epidemiological and toxic aspects, nature of water pollutants, measurement techniques of water pollution, on-line analyzers, screening and primary Treatment (5 lectures). [10 lectures]

Water treatment processes: General theory, primary water treatment systems such as primary settlers, sedimentation, Coagulation and flocculation(5lectures), filtration, disinfection, physicochemical treatment, process water stripping(5 lectures), insoluble hydrocarbons and sludge; biological treatment of waste water (aerobic, anaerobic, biofiltration, activated sludge basins)(5 lectures), biological sludge treatment, aerobic, adsorption kinetics in water treatment design of water treatment plants(5 lectures). [20 lectures]

Tertiary wastewater treatment systems: Root zone technology, Ion exchange, ultraviolet (UV) treatment, removal of N, P, K and other trace elements, (5 lectures) sludge treatment and disposal, low cost water treatment systems, design of conventional wastewater treatment plants (5 lectures). [10 lectures]

Disposal of treated wastewater: Inland surface water, land for irrigation, marine coastal areas. [2 lectures]

Textbook

1. Peavy, H.S., Rowe, D. R., and Tchobanoglous, G., 2013, Environmental Engineering. McGraw-Hill, Indian edition.
2. Riffat, R., 2013, Fundamentals of Wastewater Treatment and Engineering, CRC press.
3. Spellman, F.R., 2003, Handbook of Water and Wastewater Treatment Plant Operations, CRC press.

Online Course Material

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

Title	Molecular Transport Phenomena	Number	CHL4XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objective

The Instructor will provide basic knowledge about molecular transport phenomena.

Learning Outcomes

The students are expected to gain knowledge about molecular transport phenomena.

Content

Theory of transport phenomena from a molecular view point. [5 lectures]

Classical concept from statistical mechanics and derivation of Boltzmann equation. [6 lectures]

Transport theory and properties of dilute gases. [6 lectures]

Development of transport theories and properties from Boltzmann equation. [6 lectures]

Introduction to time correlation functions. [5 lectures]

Text Book

1. Deen W. M., 1998, Analysis of Transport Phenomena, Oxford University Press, New York.
2. Bird. R. B., Stewart, W. E. and Lightfoot, E. N., 2006, Transport Phenomena, 2nd edition, John Wiley & Sons.

Reference Books

1. Slattery J.C., 1999, Advanced Transport Phenomena, Cambridge University Press.
2. Leal L. G., 2010. Advanced Transport Phenomena: Fluid mechanics and convective transport processes, Cambridge University Press.
3. Ramachandran, P. A. 2014. "Advanced Transport Phenomena", Cambridge University Press.

Online Learning Materials

1. R. Nagarajan, Advanced Transport Phenomena, NPTEL Course Material, Chemical Engineering, IIT Madras, <https://nptel.ac.in/courses/103106068/#>
2. V. Kumaran, Fundamentals of Transport Processes, NPTEL Course Material, Department of Chemical Engineering, Iisc Bangalore, <https://nptel.ac.in/courses/103/108/103108099/>

Title	Fluid-Like Structures and Self-Assembling Systems	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	2-0-0 [2]
Offered for	B.Tech, Dual Degree	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

1. Provide background on basic concepts of Micelles, Bilayers and Biological Membranes.

Learning Outcomes

The students are expected to:

1. Gain fundamental understanding of intermolecular forces present in Self-Assembly and fluid-like structures.
2. Learn about the importance of intermolecular forces in molecular modeling of Micelles, Bilayers and Biological Membranes

Contents

Thermodynamic Principles of Self-Assembly: Introduction, Fundamental thermodynamics (2 Lectures), Conditions for formation of aggregates, Critical micelle concentration (2 Lectures), Infinite aggregates versus finite aggregates, Size distribution of self-assembled structures (3 Lectures), More complex amphiphilic structures, Effect of interactions between aggregates (3 Lectures). [10 Lectures]

Aggregation of Amphiphilic Molecules: Introduction, Optimal head group area, Geometric Packing Considerations (2 Lectures), Spherical Micelles, Non-spherical and Cylindrical Micelle, Bilayers and Vesicles (3 Lectures), Factors affecting the changes, Curvature elasticity (2 Lectures), Biological Membranes, Membrane Lipids, Membrane Protein and Structure (3 Lectures). [10 Lectures]

Interaction Between Lipid Bilayer and Biological Membrane: Introduction, Attractive van der Waals Forces, Electrostatic Forces (1 Lecture), Hydration Forces, Hydration Model and its Limitation (2 Lectures), Steric Forces, Hydrophobic Forces, Specific Interactions (2 Lectures), Interdependence of inter- and intra-membrane forces (2 Lectures), Adhesion, Fusion (1 Lecture). [8 Lectures]

Textbook

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

Title	Organic Molecules, Complexes and Polymers for Electronics and Optoelectronics	Number	4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech	Type	PE
Prerequisite	Polymer as material fractal		

Objectives

The Instructor will:

1. Provide introductory knowledge about molecules, complexes and polymers that are relevant to electronics and optoelectronics

Learning Outcomes

The students are expected to:

1. Gain basic knowledge about organic materials for electronics and optoelectronics
2. build a foundation to pursue specialization in the area of molecular engineering and organics for electronics and optoelectronics

Contents

Fractal 1[14 lectures]:

Prelude: Concept of electronic polymers, synthetic electronic polymers and their chemistry, structure-property of polymers (4 lectures), nano-electronic polymers, electronic polymer based-compounds, electronic small molecules, electronic nanocomposites (5 lectures), electrical conductivity of electronic polymers and charge transport/ transfer (5 lectures)

Fractal 2 [14 lectures]:

Introduction to optoelectronic polymers: overview, optical polymers, optical electroactive polymers, organic photovoltaic polymers (5 lectures), properties of optical polymers, organic optoelectronic systems, emitters, organic photonics (5 lectures), optical amplifiers, detectors and receivers, electro-optic modulators (4 lectures)

Fractal 3 [14 lectures]:

Small Molecules and Complexes for Electronic Systems: overview, small molecules based on polycyclic aromatics, solution processable, small molecule dyes, donor-pi-acceptor structure (4 lectures), organic electronic complexes, polymer metal complexes, liquid crystalline elastomers (4 lectures), electro-viscoelastic polymers, electromagnetic shielding polymers (6 lectures)

Textbook

1. Sulaiman,K., (2020), Polymers in Organic Electronics – Polymer Selection for Electronic, Mechatronic & Optoelectronic Systems, 1st Edition, ChemTec Publishing

Title	Molecular Thermodynamics	Number	CHL4XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objective

The Instructor will provide basic knowledge about concepts, microstates of a system, statistical thermodynamics and classical statistical mechanics.

Learning Outcomes

The students are expected to gain fair knowledge of basic concepts of molecular thermodynamics, microstates of a system, statistical thermodynamics and classical statistical mechanics.

Contents

Review of classical thermodynamics, basic concepts, thermodynamic potential. [4 lectures]

Microstates of a system. [9 lectures]

Fundamentals of statistical mechanics, postulates of statistical thermodynamics, statistical ensembles, canonical ensemble. [7 lectures]

Ideal gas, Monoatomic and polyatomic ideal gases, statistical thermodynamics of ideal gases, statistical thermodynamics of diatomic ideal gases. [10 lectures]

Chemical reaction equilibrium, molar heat capacities, specific heat of solids, rate of chemical reaction. [2 lectures]

Application of molecular thermodynamics. [4 lectures]

Introduction to classical statistical mechanics. [6 lectures]

Text Book

Hanson, R.M., Green Susan (2008) Introduction to Molecular Thermodynamics, University Science Books.

Online Learning Materials

Srabani Taraphder, <https://nptel.ac.in/courses/104/105/104105088/>

Title	Biochemical Engineering	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech	Type	PE
Prerequisite			

Objectives

The Instructor will provide basic knowledge about chemical engineering aspects of biology and biotechnology, kinetics of enzyme catalysis, mass transfer, bioreactors, bio-separation and manufacture of biochemical products.

Learning Outcomes

The students are expected to gain understanding of chemical engineering aspects of biology and biotechnology, kinetics of enzyme catalysis, mass transfer, bioreactors, bio-separation and manufacture of biochemical products.

Contents

Basics of Biology: Overview of biotechnology [2 Lectures], diversity in microbial cells, cell constituents, chemicals for life. [5 Lectures]
 Kinetics of enzyme catalysis. [5 Lectures]
 Immobilized enzymes: Effects of intra and inter-phase mass transfer on enzyme kinetics. [5 Lectures]
 Major metabolic pathways: Bioenergetics, glucose metabolism, biosynthesis. [5 Lectures]
 Microbial growth: Continuum and stochastic models. [3 Lectures]
 Design, analysis and stability of bioreactors. [4 Lectures]
 Kinetics of receptor-ligand binding. [3 Lectures]
 Receptor-mediated endocytosis. [3 Lectures]
 Multiple interacting microbial population: prey-predator models. [2 Lectures]
 Bio-product recovery & bio-separations; manufacture of biochemical products. [5 Lectures]

Textbooks

1. Bailey, J.E. and Ollis, D. F. [1986] Biochemical Engineering Fundamentals, McGraw Hill Book Company.
2. Blanch, H.W. and Clark, D.S. [1997] Biochemical Engineering, Marcel Dekker Inc.

Reference Books

1. Shuler, M.L. and Kargi, F. [2003] Bioprocess Engineering (Basic Concepts), Prentice Hall of India.

Online Course Material

1. Ritu Banerjee and saikat Chakraborty, Biochemical Engineering, IIT Kharagpur, https://nptel.ac.in/content/syllabus_pdf/103105054.pdf

Title	Bioprocess Technology	Number	CHL4XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech	Type	PE
Prerequisite	An introductory course on Biochemical Engineering		

Objectives

The Instructor will provide basic knowledge about bioprocess technology, industrial importance of microorganisms, fermentation, industrial production of alcohol, glycerol, acetone, butanol and microbial production of organic acids like citric acid, vinegar etc.

Learning Outcomes

The students are expected to gain knowledge about industrial importance of microorganisms, fermentation, industrial production of alcohol, glycerol, acetone, butanol and microbial production of organic acids like citric acid, vinegar etc.

.

Contents

Industrial importance of microorganisms. [5 lectures]

Substrates for fermentation – major elements, minor elements, vitamins, hormones, trace elements and growth factors. [7 lectures]

Alcoholic fermentation – distilled alcohol, wine and beer. [6 lectures]

Baker's yeast production. [2 lectures]

Production of glycerol, acetone and butanol. [6 lectures]

Microbial production of organic acids – citric acid, gluconic acid, itaconic acid, gibberellic acid, lactic acid and vinegar. [8 lectures]

Production of industrial enzymes – amylases, proteases, invertases, pectinases, cellulases; mushroom production. [8 lectures]

Textbooks

1. Shuler, M.L. and Kargi, F. [2003] Bioprocess Engineering: Basic Concepts, Prentice Hall of India
2. Mansi El-Mansi and C. F. A. Bryce, C.F.A., Fermentation Microbiology and Biotechnology

Reference Books

1. Stanbury, P.F., Whitaker, A., Hall, S. Principles of Fermentation Technology
2. Friberg, Stig, Handbook of Food and Beverage Fermentation Technology (Food Science and Technology)

Online Course Material

Patel, N.K., <https://nptel.ac.in/courses/103/106/103106109/>

Title	Bio-Transport Phenomena	Number	CHL6XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0 (2)
Offered for	B.Tech	Type	PE
Prerequisite	None		

Objective

The Instructor will:

1. Provide knowledge about momentum, heat and mass transfer in bio-systems and their analogous behavior.
2. Train the student to create bio-engineering knowledge using the transport phenomena approach with 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 bio-engineering.

Contents

Transport processes across cell membrane: Transport mechanisms, transport by diffusion, filtration and osmosis, facilitated diffusion, vesicular transport, bulk transport, co-transport, membrane transport, transport of virus in cells. [8 lectures]

Intracellular Transport: Molecular mechanism of intracellular transport, membrane structure, transport of proteins, forms of endocytosis and intracellular transport, factors affecting intracellular transport. [8 lectures]

Models for blood flow: Non-newtonian fluid model, steady flow in tubes, pulsatile flow in a rigid tube, pulsatile flow in an elastic tube, blood flow dynamics in arteries and veins, heart-valve hemodynamics. [7 lectures]

Air flow in the lungs: Mechanics of breathing, gas exchange and transport. [3 lectures]

Application of the principle of bio-transport phenomenon in medical device development. [2 lectures]

Text Books

1. Truskey, G.A., Yuan, F., Katz, D.F., (2009) Transport Phenomena in Biological Systems, 2nd ed, Prentice Hall, New Jersey.
2. Bird, R.B., Stewart, W.E. and Lightfoot, E.N., (2006), Transport Phenomena, 2nd ed., Wiley India.

Reference Books

1. Welty, C. E., Wicks, R. E., Wilson, G. L. Rorrer, (2007), Fundamentals of Momentum, Heat, and Mass Transfer. 5th ed., Wiley India Pvt. Ltd.
2. 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.
3. Thompson, W.J., (2000) Introduction to Transport Phenomena, Prentice Hall, 2000.

Online Course Material

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

Title	Biochemical Separation Processes	Number	CHL400X
Department	Chemical Engineering	L-T-P (C)	2-0-0 (2)
Offered for	B.Tech.	Type	PE
Prerequisite	None		

Objective

The Instructor will:

1. Provide knowledge in biochemical separation.
2. Train the student in separation processes in biochemical engineering.

Learning Outcomes

The students are expected to have the ability to:

1. Understand different aspects of biochemical separation.
2. Analyze the different aspects of separation processes in the field of biochemical engineering.

Contents

Introduction: Role of separation process in biochemical industry. [2 lectures]

Design variables and parameters: feed, product, operating conditions, density, viscosity, diffusion coefficients, mass transfer data. [4 lectures]

Different processes and methods viz. vacuum distillation, adsorption, extraction, membrane processes etc. [8 lectures]

Process design [8 lectures]

Performance evaluation [4 lectures]

Case studies [2 lectures]

Text Books

1. Bajpai, P., Bajpai, P.K., Dochain, D. and Dutta, N.N. Biotreatment, Downstream Processing and Modelling (Advances in Biochemical Engineering / Biotechnology)
2. Blanch, H.W. and Clark, D.S. [1997] Biochemical Engineering, Marcel Dekker Inc.

Reference Books

1. Atkinson, B. and Mavituna, F. Biochemical Engineering and Biotechnology Handbook
2. Bailey, J.E. and Ollis, D. F. [1986] Biochemical Engineering Fundamentals, McGraw Hill Book Company.

Online Course Material

<https://nptel.ac.in/courses/103/105/103105060/>

Title	Bioreactors	Number	CHL400X
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	B.Tech	Type	PE
Prerequisite	None		

Objective

The Instructor will:

1. Provide knowledge about reactor design for biochemical engineering systems and scaleup.
2. Train the student in bioreactor configurations, design and analysis.

Learning Outcomes

The students are expected to have the ability to:

1. Design the reactors for the biochemical engineering systems.
2. Analyze the bioreactors.

Contents

Introduction: Bioprocess overview, Common types of bioreactors, sterilization, thermal sterilization. [5 lectures]

Thermodynamics and rate concept of biochemical engineering systems, enzyme bioreactors, enzyme kinetics. measurement principles and methods. [5 lectures]

Bioreactor configuration: batch reactor, continuous stirred-tank reactor (CSTR), tubular reactor, plug flow reactor, [5 lectures] packed bed reactor, solid state bioreactors, photobioreactor, air lift, fluidized bed reactor, membrane bioreactor. [5 lectures]

Kinetic expression: Monod's equation and its generalization. [3 lectures]

Bioreactor design: Basic calculation; Bioreactor design and optimum operations– mixing characteristics; [6 lectures] residence time distribution in bioreactors and non-ideality, concentration distribution and temperature distribution. [6 lectures]

Analysis of multiple interacting microbial populations: Biological system parameters; processes involving microbial flocs; bioreactors containing microbial films. [3 lectures]

Basic concept of scale-up of bioreactors and case studies. [4 lectures]

Text Books

1. Bailey, J.E. and Ollis, D. F. [1986] Biochemical Engineering Fundamentals, McGraw Hill Book Company.
2. Blanch, H.W. and Clark, D.S. [1997] Biochemical Engineering, Marcel Dekker Inc.

Reference Books

1. Atkinson, B. and Mavituna, F. Biochemical Engineering and Biotechnology Handbook
2. Aiba, S., Humphrey, A.E. and Millos, N.F. Biochemical Engineering
3. Asenjo, J.A. Bioreactor System Design (Biotechnology and Bioprocessing Series)

Online Course Material

Suraishkumar, IIT Madras, <https://nptel.ac.in/courses/102/106/102106053/>

Title	Introduction to Internet of Things (IoT)	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	1-0-0 [1]
Offered for	M. Tech. 1st year	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Provide overview of applications of IoT and relevant technologies

Learning Outcomes

The students are expected to have the ability to:

1. Identify and integrate different components required for IoT applications

Contents

Introduction to IoT: Sensing, Actuation, Basics of IoT Networking (2 Lectures) IoT

Architecture, Communication Protocols for IoT (2 Lectures)

Sensor Networks: Wireless Sensor Network, Sensor nodes (2 Lectures)

Machine to machine Communication: Introduction, Node types and M2M Applications, Integration of Sensors and Actuators for Implementation of IoT (4 Lectures)

Introduction to Cloud, Fog, and Edge Computing, Smart cities and Smart homes, Industrial IoT (4 Lectures)

Textbook

1. Kamal, R., (2017), Internet of Things - Architecture and Design Principles, 1st Edition, Mcgraw Hill.

Preparatory Course Material

1. Misra, S., Introduction to Internet of Things, NPTEL Course Material, Department of Computer Science and Engineering, Indian Institute of Technology Kharagpur, <https://nptel.ac.in/courses/106105166/>

Title	Sensors and IoT Lab	Number	EEP7XX0
Department	Electrical Engineering	L-T-P [C]	0-0-2 [1]
Offered for	M. Tech. 1 st year	Type	Compulsory
Prerequisite			

Objective

1. To introduce students with sensors fabrication
2. To familiarize students with measurement instruments like Spectrum and Vector Network Analyzer
3. To introduce students with various kits and components required for IoT applications

Learning Outcomes

1. Familiarization with sensor fabrication process and characterization
2. Handling high frequency measurement instruments
3. Implementation of various circuits required to build a transceiver

Contents

The lab course will be dependent on the various core and elective components of the program. There will be a scope for modifying the contents depending on the recent developments in technology. Experiments from some of the following topics will be part of this lab.

- Implementation of Signal Conditioning Circuits
- Implementation of IoT components using Hardware/Software
- Sensor interfacing using off-the-shelf components
- Sensor Design, Fabrication and Characterization (Part of this in winter internship)
- RF components characterization; Antennas and RF amplifiers
- Implementation of real time examples of IoT using Embedded Systems
- Selected experiments from Communication Systems
- Recent topics of interest

Title	Industry 4.0 Applications in	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	1-0-0-0 [1]
Offered for		Type	Program Core
Prerequisite			

Objectives:
The Instructor will:

1. provide brief understanding about Industry 4.0 concepts in manufacturing systems

Learning Outcomes:
The students are expected to appreciate:

1. current trends at system level in manufacturing organizations
2. the importance of industry 4.0 concepts at manufacturing systems

Contents:

Introduction to Manufacturing systems (2 Lecture)

Automated Manufacturing Systems: Concept of Group Technology and cellular manufacturing, Flexible Manufacturing Systems, Lean Manufacturing, Agile Manufacturing (6 Lectures)

Industry 4.0 for Manufacturing Systems: Agent Based Manufacturing, Cloud Based Manufacturing (6 Lectures)

Reference Books:

1. Talavage J., and Hanman R. G, Flexible Manufacturing Systems in Practice, Taylor and Francis
2. Gunasekaran A., Agile Manufacturing: 21st Century Competitive Strategy, Elsevier
3. Wang L., and Vincent W. X., Cloud Based Cyber-Physical Systems in Manufacturing, Springer

Self-Learning Material:

1. <https://nptel.ac.in/courses/106105195/10>

Title	Chemometrics	Number	CHL7XX0
Department	Chemical Engineering,	L-T-P (C)	3-0-0 (3)
Offered for	B.Tech., M.Tech., M.Tech.-Ph.D.	Type	Programme Elective
Prerequisite	basics of chemical engineering		

Objective

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 lecture]

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. [6 lectures]

Machine learning in Chemical plants: Introduction, basics of decision trees, combining multiple learner, reinforcement learning, experimental design and analysis. [6 lectures]

Text Book

1. Richard G. Brereton, 2003, Chemometrics: Data Analysis for the Laboratory and Chemical Plant, Wiley
2. Howard Mark, Jerry Workman, Jr, 2018, Chemometrics in Spectroscopy, Elsevier Academic Press.
3. Ethem Alpaydin, 2004, Introduction to Machine Learning, MIT Press.

Reference Books

1. 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.
2. Kreyszig, Erwin, 2014, Advanced Engineering Mathematics, John Wiley and Sons, 10th Edition.
3. Harald Martens, Tormod Næs, 1989, Multivariate Calibration, John Wiley & Sons.
4. Richard G. Brereton, 2007, Applied Chemometrics for Scientists, John Wiley & Sons.

Title	Artificial Intelligence in Chemical Reactor Control	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-2 [4]
Offered for	B.Tech, M.Tech., M.Tech-Ph.D. Dual Degree	Type	Elective
Prerequisite	Material and Energy Balance, Chemical Reaction Engineering, Scientific Computations		

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 (4 Lectures), Kalman Observer, Extended Kalman Filter (4 Lectures), Unscented Kalman Filter, Particle Filter, Moving Horizon Estimation (5 Lectures), Multi-rate Estimations (3 Lectures), Multi-rate Observer (4 Lectures). [20 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]

Experiments

1. Simulation of CSTR
2. Simulation of PFR
3. Simulation of PBR
4. Simulation of Nonisothermal Reactors
5. Simulation of Slurry Reactor
6. Simulation of Bioreactor
7. Simulating Cholette's Model
8. Luenberger Observer
9. Kalman Filter
10. Extended Kalman Filter
11. Control of Isothermal & Non-isothermal Batch Reactors
12. Control of Polymer Reactor

Textbooks

1. Fogler, H. S., (1992), Elements of Chemical Reaction Engineering, Prentice-Hall
2. Michael L. Mavrovouniotis, 1990, Artificial Intelligence in Process Engineering, Academic Press

References

1. Mohammad Shahrokhi and Mohammad Ali Fanaei, 2001, State Estimation in a Batch Suspension Polymerization Reactor, Iranian Polymer Journal, Vol. 10, Number 3
2. J.V. Kadam, B. Srinivasan, W. Marquardt, D. Bonvin, Dynamic Real-Time Optimization of Transitions in Industrial Polymerization Processes using Solution Models
3. Rajendra K. Mutha, William R. Cluett, Alexander Penlidis, 1997, On-Line Nonlinear Model-Based Estimation and Control of a Polymer Reactor, AIChE Journal, Vol. 43, Number 11
Pramod Vachhani, Raghunathan Rengaswamy, Vikrant Gangwal, 2005, Recursive Estimation in Constrained Nonlinear Dynamical Systems, AIChE Journal, Vol. 51, Number 3

Title	Nanosensors	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0-0 [3]
Offered for	B. Tech, M. Tech and PhD	Type	Open Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide understanding about the importance of nanoscale materials for sensing applications.
2. Teach approaches for fabrication and characterizing of sensors based on nanomaterials.
3. Enhance critical, creative and innovative thinking to tailor nanomaterials for specific application.

Learning Outcomes

The students are expected to have the ability to:

1. Design and fabricate nanomaterial based sensors.
2. Undertake interdisciplinary research and exploit nanomaterials for new sensing applications.

Contents

Sensor types: Displacement, position and proximity sensors (3 lectures); velocity, motion, force and pressure sensors (4 lectures); components and classification of sensors (1 lecture); parameters for sensor characterization (1 lecture); sensor arrays (1 lecture).

Nanostructures and Nanoparticles: Nanostructures (1 lectures); nanostructure fabrication (top down and bottom up approach) (3 lectures); characterization of nanostructures using different techniques (Atomic Force Microscopy, Scanning Electron Microscopy, Tunneling Electron Microscopy) (3 lectures); nanoparticles (types and shapes) (1 lecture); nanoparticle production, shape control, functionalization and application (2 lectures); nanowires (properties, sensing mechanism, fabrication, and devices) (4 lectures); quantum dots (1 lecture).

Carbon nanotubes/nanofibres (CNT/CNF) and other Nanosensors: CNT structure, properties, synthesis, functionalization (3 lectures); CNT/CNF based sensors (single layer/multi-layer) (2 lectures); nanostructure, nanoparticles, nanowire and nanofibre based metal oxide sensors (3 lectures); flexible sensors and electronic skin (2 lectures); Nanosensors in engineering applications: optical, chemical, mechanical, electrochemical, mass sensitive, biosensors, mechanical sensors in liquid solution, thin film sensors (7 lectures).

Reference Books:

1. Khanna, V. K., (2011), Nanosensors: Physical, Chemical, and Biological, CRC Press.
2. Atta, N. F., (2014), Nanosensors: Materials and Technologies. IFSA Publishing.
3. Meyyappan, M., (2004), Carbon Nanotubes: Science and Applications, 1st Edition, CRC Press.

Self Learning Material

1. <https://nptel.ac.in/courses/112108092>
2. <https://www.coursera.org/learn/nanotechnology/home>

Title	Data Analytics in Process Modelling and Simulation	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-2 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree in Chemical Engineering	Type	Elective
Prerequisite	None		

Objective

The Instructor will:

1. Impart knowledge about the mathematical modelling of physical systems, data analytics and introduce flow-sheet simulation as a tool for process analysis, enabling systems approach in modelling of a process with interaction among several unit processes and unit operations.
2. Provide insight into development of simulators to do steady-state and dynamic simulation.

Learning Outcomes

The students are expected to:

1. Gain in-depth knowledge of the data analytics and mathematical modelling of physical systems and process with interaction among several unit operations and have insight into development of simulators to do steady-state and dynamic simulation.

Contents

Introduction to mathematical modelling: lumped vs distributed parameter systems, process synthesis, design, simulation & analysis, Modelling of various chemical systems covering heat, mass, momentum transfer, and reactions, Sequential and simultaneous modular approaches for flow-sheet Simulation (9 lectures).

Equation solving approaches: Partitioning, Decomposition, Disjointing, PTM, SWS-, Steward-, and Rudd-Algorithms, Direct Methods, Pivoting, Iterative methods, BTF, BBTF, Block Back Substitution, BTS. (4 lectures)

Decomposition of networks: Tearing algorithms, digraph, MCN, signal flow graph, B&M algorithm, BTA, K&S algorithm, M&H-1 & -2 algorithms, and related problems, Convergence Promotion. (6 lectures)

Data analysis: Sources and data banks of physical & thermodynamic properties, Modularity & Routing, Specific purpose simulation, Dynamic simulation (9 lectures)

Process Modelling and Simulation Design Lab (28 hrs)

Modelling of Heat exchange equipment (2)

Modular approaches for flow-sheet Simulation (4)

Process simulation using MATLAB (6)

Process simulation using ASPEN (6)

Distillation with reflux, reboiler and condenser (6)

Case studies: Process simulation of industrial scale processes and validation (4)

Text Book

1. Jana, A.K. Chemical Process Modelling & Computer Simulation, 2nd ed., PHI Learning, 2011

Reference Books

1. Babu, B.V. Process Plant Simulation, Oxford University Press, India, 2004.
2. Luyben, W.L. Process Modelling, Simulation & Control for Chemical Engineers, 2nd ed., McGraw Hill, 1990

Online Course Material

1. Agrawal, V.K., Process Modelling and Simulation, NPTEL Course Material, Department of Chemical Engineering, IIT Roorkee <https://nptel.ac.in/courses/103/107/103107096/>

Title	Artificial Intelligence-1	Number	CSXXX
Department	Computer Science and Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech. 1st year, Ph.D. 1st year	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Cover various paradigms that come under the broad umbrella of AI, with some of them being covered in depth

Learning Outcomes

The students are expected to have the ability to:

1. Develop an understanding of where and how AI can be used

Contents

Introduction (1 lecture)

Propositional logic (8 lectures)

Search: Uninformed strategies (BFS, DFS, Dijkstra), Informed strategies (A* search, heuristic functions, hill-climbing), Adversarial search (Minimax algorithm, Alpha-beta pruning) (10 lectures)

Predicate logic: Knowledge representation, Resolution (6 lectures)

Rule-based systems: Natural language parsing, Context free grammar (3 lectures) Constraint satisfaction problems (4 lectures)

Planning: State space search, Planning Graphs, Partial order planning (4 lectures) Uncertain

Reasoning: Probabilistic reasoning, Bayesian Networks, Dempster-Shafer theory, Fuzzy logic (6 lectures)

Textbook

1. Russel,S., and Norvig,P., (2015), Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall

Reference Books

1. Research literature

Self Learning Material

1. Department of Computer Science, University of California, Berkeley, _
<http://www.youtube.com/playlist?list=PLD52D2B739E4D1C5F>
2. NPTEL: Artificial Intelligence, <https://nptel.ac.in/courses/106105077/>

Title	Machine Learning-1	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3-0-0 [3]
Offered for	M.Tech. 1 st Year, Ph.D. 1 st Year	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Provide motivation and understanding of the need and importance of Machine Learning in today's world
2. Provide details about various algorithms in Machine Learning

Learning Outcomes

The students are expected to have the ability to:

1. Develop a sense of Machine Learning in the modern context, and independently work on problems relating to Machine Learning
2. Design and program efficient algorithms related to Machine Learning, train models, conduct experiments, and deliver ML-based applications

Contents

(fractal 1) Introduction: Motivation, Different types of learning, Linear regression, Logistic regression (2 lectures)

Gradient Descent: Introduction, Stochastic Gradient Descent, Subgradients, Stochastic Gradient Descent for risk minimization (2 lectures)

Support Vector Machines: Hard SVM, Soft SVM, Optimality conditions, Duality, Kernel trick, Implementing Soft SVM with Kernels (4 lectures)

Decision Trees: Decision Tree algorithms, Random forests (2 lectures) Nearest

Neighbour: k-nearest neighbour, Curse of dimensionality (1 lecture)

Neural Networks: Feedforward neural networks, Expressive power of neural networks, SGD and Backpropagation (3 lectures)

(fractal 2) Clustering: Linkage-based clustering algorithms, k-means algorithm, Spectral clustering (2 lectures)

Dimensionality reduction: Principal Component Analysis, Random projections, Compressed sensing (2 lectures)

Generative Models: Maximum likelihood estimator, Naive Bayes, Linear Discriminant Analysis, Latent variables and Expectation-maximization algorithm, Bayesian learning (4 lectures) Feature Selection and

Generation: Feature selection, Feature transformations, Feature learning (3 lectures)

Model selection and validation: Validation for model selection, k-fold cross-validation, Training-Validation-Testing split, Regularized loss minimization (3 lectures)

(fractal 3) Statistical Learning Framework: PAC learning, Agnostic PAC learning, Bias-complexity tradeoff, No free lunch theorem, VC dimension, Structural risk minimization, Adaboost (7 lectures) Foundations of

Deep Learning: DNN, CNN, RNN, Autoencoders (7 lectures)

Textbook

1. Shalev-Shwartz, S., Ben-David, S., (2014), Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press

Reference Books

1. Mitchell Tom (1997). Machine Learning, Tata McGraw-Hill

Self Learning Material

1. Department of Computer Science, Stanford University, <https://see.stanford.edu/Course/CS229>

Title	Ocean Thermal Energy Conversion (OTEC) Process	Number	CH7XX0
Department	Chemical Engineering	L-T-P [C]	1-0-0
Offered for	B. Tech./ M.Tech./M.Tech.-Ph.D./ Ph.D.	Type	Elective
Prerequisite	Thermodynamics		

Objectives

The Instructor will:

1. Provide understanding of Ocean Thermal Energy Conversion (OTEC) cycles, hybrid OTEC systems and technological challenges.

Learning Outcomes

The students are expected to have the:

1. Proper knowledge about Ocean Thermal Energy Conversion (OTEC) cycles and hybrid OTEC technologies.
2. Ability to understand OTEC design challenges.

Contents

Ocean as a Heat Engine: Concepts of ocean thermal energy, Favorable temperature difference, OTEC history. (2 lectures)

OTEC Cycles: Closed OTEC cycles, Open OTEC cycle, Flow diagrams, Comparison of OTEC Cycles, Products of OTEC: electricity, desalinated water, cold water for air-conditioning etc., Hybrid OTEC systems. (6 lectures)

OTEC System Design: System components, Heat exchangers, evaporators, Pumps, Turbines, Piping, Platform concepts, Dual Purpose OTEC Plants, Challenges, Case studies. (6 lectures)

Textbook

1. Takahashi, Patrick and Trenka, Andrew, (1996) Ocean Thermal Energy Conversion, 1st ed., Wiley.

Reference Books

1. Lockerby, R.W., (1981) Ocean Thermal Energy Conversion (OTEC), US Department of Energy, United States.

Title	Microfluidic Fuel Cells	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	1-0-0
Offered for	B. TECH, MTECH, MTECH-PhD	Type	Elective
Prerequisite	none		

Objectives

The Instructor will:

1. Provide in-depth knowledge about the fundamentals of microfluidics devices as fuel cells.

Learning Outcomes

The students are expected to have:

1. Detailed understanding of Microfluidic fuel cells.

Contents

Microfluidic cells: Introduction, concept, classification, and challenges, categories, Thermodynamic and kinetic of microfluidic fuel cells, electrochemical principles and transport. [7 lectures]

Designs: Microfabrication techniques, 2D, 3D electrodes in microfluidic fuel cells, performance evolution. [3 lectures]

Microfluidics devices: co-laminar streaming, fuel cells with biocatalysts, gas diffusion electrodes, microfluidics redox batteries, cell arrays and Stacks. [4 lectures]

Textbook

1. Erik Kjeang, 2014, Microfluidic Fuel Cells and Batteries, Springer.

Reference Books

Research Articles from different journals.

Title	Catalysis for Energy	Number	CY6XX0
Department	Chemistry	L-T-P [C]	3-0-0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. To give a overview about defining a roadmap for the role of catalysis in energy production
2. Relate catalysis with fuel cells, hydrogen production and storage, methane storage and industrial catalysis

Learning Outcomes

The students are expected to have the ability to:

1. Understand the role and the possibilities of catalysis in the production of new energy carriers and in the utilization of different energy sources.
2. to go beyond conventional application identifying new developments that may lead to breakthroughs in the production of alternative energy.

Contents

Catalysis: Introduction to heterogeneous catalysis, including models of surface reactivity, surface equilibria, kinetics of surface reactions, electronic and geometrical effects in heterogeneous catalysis. (Lectures 14)

Catalytic reactions and application: Trends in reactivity, catalyst structure and composition, electro-catalysis and photo-catalysis. (Lectures 12)

Selected applications and challenges in energy transformations: fuel cells, hydrogen production, OER and HER reactions, CO₂ oxidation, methane and hydrogen storage and industrial catalysis. (Lecture 14)

Textbooks

1. Hanefeld, U, Lefferts, L. (2018) Catalysis: An Integrated Textbook for Students, 1st Edition, Wiley

Reference Books:

1. Okada, Tatsuhiro, Kaneko, Masao, (2009), Molecular Catalysts for Energy Conversion Springer.
2. Gucci, László, Erdôhelyi, András, Catalysis for Alternative Energy Generation, Springer.
3. Pierluigi Barbaro, Claudio Bianchini, Catalysis for Sustainable Energy Production, Wiley

Self-Learning Material

1. Xile Hu, Angamuthu, R and Bera, J. K., Catalysis for Energy Storage, GIAN Course material, Indian Institute of Technology Kanpur, <https://www.youtube.com/watch?v=LvTfsIAI-VE>

Title	Advanced Waste Water Treatment	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-2 [4]
Offered for	B.Tech., M.Tech., M.Tech.-Ph.D.	Type	PE
Prerequisite	None		

Objective

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 wastewater treatment.
2. Knowledge of advanced methodologies such as waste water management, recycle and reuse.

Contents

Introduction: Waste water engineering: an overview, characterization of waste water and monitoring of industrial and municipal waste water, environmental impacts of waste water constituents. (4 lectures)

Conventional Waste Water Treatment: Existing unit operations and processes, basic philosophy of water treatment plants (4 lectures); physio-chemical treatment methods: (i) Screening, (ii) conventional filtration (iii) coagulation, (iv) flocculation, (v) floatation (vi) Clari-flocculation (vii) sedimentation, (viii) sand filtration, etc. (6 lectures). [10 lectures]

Aerobic and Anaerobic Suspended and Attached Growth Waste Water Treatment Processes: Aerated lagoon, activated sludge systems, trickling filter, (4 lectures) sequential batch reactor, fluidized bed bioreactors, Up-flow Anaerobic Sludge Blanket (UASB) and hybrid Up-flow Anaerobic Sludge Blanket (UASB) reactors, bio-towers (4 lectures). [8 lectures]

Advanced Treatment Processes: Membrane Filtration, reverse osmosis, ultrafiltration, nanofiltration and electrodialysis(3 lectures); wet air oxidation, adsorption and ion-exchange(2 lectures); 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(5 lectures). Membrane Reactors, New Technologies for Waste Water Disinfection (2 lectures). [12 lectures]

Water Recycling and Reuse: Different unit operations for water recycling depending on end use (3 lectures), recovery of valuables from waste water, zero liquid discharge (ZLD)(5 lectures). [8 lectures]

Waste Water Treatment Design Lab (28 hrs)

Clarifier

Aerator

Sand filtration system

Municipal waste water system

Grey water treatment system

Sewage water treatment system

Industrial waste water systems

Pond water treatment

Text Book

1. Burton F.L., Tchobanoglous G., Stensel H.D., 2017, Waste Water Engineering Treatment and Reuse, 4thed., 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 Books

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.

Online Course Material

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

Title	Environmental Impact Assessment (EIA)	Number	CHL7XX0
Department	(i) Chemical Engineering, (ii) Civil and Infrastructure Engineering	L-T-P [C]	3-0-0 [3]
Offered for	B.Tech., M.Tech., M.Tech.-Ph.D.	Type	PE
Prerequisite			

Objective

The instructor will:

1. Impart the knowledge to the students with the methods of assessment of environmental impacts due to developmental and industrial activities.
2. Expose the students with the EIA regulations and EMP.

Learning Outcomes

The students are expected to have the:

1. In-depth knowledge of the methods of assessment of environmental impacts due to developmental and industrial activities.
2. In-depth knowledge of EIA regulations and EMP.

Contents

Introduction to EIA; definitions and concepts (2 lectures); evolution of EIA historical development of EIA; forecasting environmental changes;(5 lectures) strategic environmental assessment; environmental clearance procedure (4 lectures). [11 lectures]

EIA documentation and processes; preliminary stages of EIA; project types and screening;(5 lectures) impact prediction; evaluation and mitigation (4 lectures); EIA monitoring and auditing (2 lectures). [11 lectures]

EIA regulations; TOR for EIAs; EIA at regional level (3 lectures), sectoral level, and policy level;(3 lectures) sustainable development; Environmental Management Plan (EMP)(5 lectures). [11 lectures]

Future strategies (4 lectures) and EIA case studies (5 lectures). [9 lectures]

Text Book

1. Canter, L., Environmental Impact Assessment, McGraw Hill, New York, 1996.

Reference Books

1. World Bank, 'Environmental Assessment Source Book', Environment Dept., Washington D.C., 1991.
2. Rau, G.J. and Wooten, C.D., Environmental Impact Analysis Handbook, McGraw Hill, New York, 1980. Preventive environmental management.

Online Course Material

Dubey B K, Introduction to Environmental Engineering and Science – Fundamental and Sustainability Concepts, NPTEL course material, Department of Civil Engineering, Indian Institute of Technology Kharagpur, <https://nptel.ac.in/courses/127105018/>

Title	Hydrogen and Methanol Economy	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	MTECH, MTECH-PhD, PhD	Type	Elective
Prerequisite	none		

Objectives

The Instructor will:

1. Provide in-depth knowledge about Hydrogen and Methanol production, storage, their Utility and infrastructure development.
3. Impart knowledge about the economic and environmental viewpoint of using Hydrogen and Methanol as fuel sources.

Learning Outcomes

The students are expected to have:

1. Proper knowledge about Hydrogen and Methanol production and related issues.
2. Economic view point of Hydrogen and Methanol as fuel and the related challenges & opportunities.

Contents

Hydrogen and methanol as fuels: General aspects, Prelude to the energy systems, Hydrogen and Methanol as energy sources, Future energy supply, Economy and Environment, Sustainability (6)

Hydrogen economy: Properties, production, storage, utilization and safely, Infrastructure requirement, Hydrogen as a transportation fuel, Hydrogen based fuel cell. (12)

Methanol economy: Properties, production, storage, transportation and safely, Infrastructure Requirement, Methanol as fuel and energy carrier, Methanol as automobile, marine and aviation fuel. (14)

Challenges and opportunities: Indian and global perspectives, Domestic and transportation application, Affordable Technology development, Policy. (6)

Case studies: Comparative study with other energy sources. (4)

Textbook

1. G. A. Olah, A. Goepfert, G. K. S. Prakash, (2006), Beyond Oil and Gas: The Methanol Economy, Wiley-VCH, Weinheim, Germany.
2. Ball M. and Wietschel M.,(2009) The Hydrogen Economy Opportunities and Challenges, Cambridge University Press.

Reference Books

1. A. Scipioni, A. Manzardo, J. Ren, (2017) Hydrogen Economy: Supply Chain, Life Cycle Analysis and Energy Transition for Sustainability, Academic Press.
2. M. Bertau, H. Offermanns, L. Plass, F. Schmidt, H. Wernicke,(2014) Methanol: The Basic Chemical and Energy Feedstock of the Future, Springer; 2014

Title	Molecular Engineering of Water	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	1-0-0
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objective

The Instructor will provide basic knowledge about molecular science and engineering of water.

Learning Outcomes

The students are expected to gain knowledge about molecular science and engineering of water.

Contents

Properties of the water molecule, hydrogen bonding, clusters, supercritical water, condensed phases, solutions, confined and interfacial water, clathrates, and nucleation. [7 lectures]

Methods of water purification, water splitting and fuel cells, water in atmospheric and climate science, and water in biology, health and medicine. [7 lectures]

Text Book

Leach, R. (2001) Molecular Modelling: Principles and Applications, Pearson Education.

Online Learning Materials

Srabani Taraphder, <https://nptel.ac.in/courses/104/105/104105088/>

Title	Polymers for Electronics and Optoelectronics	Number	7XX0
Department	Chemical Engineering	L-T-P [C]	2-0-0
Offered for	BTech	Type	PE
Prerequisite	Polymer as material fractal		

Objectives

The Instructor will:

1. Detailed know-how about polymers for electronics and optoelectronics

Learning Outcomes

The students are expected to:

1. Gain detailed knowledge about polymers that are relevant to Electronics and Optoelectronics
2. Learn about printed circuit board technology based on polymers

Contents

Fractal 1 [14 lectures]:

Introduction: basics of electronic polymers and their chemistry, structure-property of polymers (3 lectures), electronic nanocomposites, electrical charge transport/ transfer theories (4 lectures), optoelectronic polymers, optical polymers, optical electroactive polymers, organic photovoltaic polymers (3 lectures), basics of piezoelectricity, microelectronics, optoelectronics (4 lectures)

Fractal 2 [14 lectures]:

Properties of Organic Electronic Structures: band gap and excitation energy, absorption wavelength, transparency, optical absorption, birefringence, optical transmission, haze, polarizability, photoconductivity, optical emission, luminescence (4 lectures)

Polymers in Organic Printed Circuit Boards (PCBs): Overview, polymers for traditional PCBs, prepreg, single-sided and double sided circuit boards, multilayered PCBs, flexible PCBs (5 lectures), rigid-flex, 3D PCBs, molded interconnect devices, smart textile PCBs (5 lectures)

Textbook

1. Sulaiman,K., (2020), Polymers in Organic Electronics – Polymer Selection for Electronic, Mechatronic & Optoelectronic Systems, 1st Edition, ChemTec Publishing

Title	Molecular Simulations	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objective

The Instructor will provide basic knowledge about statistical mechanics, molecular dynamics and introduce the Monte Carlo method.

Learning Outcomes

The students are expected to gain knowledge about:

- (i) Statistical mechanics and molecular dynamics; and
- (ii) Monte Carlo method.

Contents

Statistical Mechanics: Basics of statistical mechanics, ideal monoatomic gas, canonical ensemble, grand-canonical and isobaric-isothermal ensemble. [8 lectures]

Molecular dynamics: Basics of molecular dynamics, force field and integrating algorithms, periodic box and minimum image convention, non-bonded interactions, estimation of pure component properties. [10 lectures]

Introduction to Monte-Carlo methods. [5 lectures]

Case studies like Monte Carlo simulation in polymers. [5 lectures]

Text Book

Leach, R. (2001) Molecular Modelling: Principles and Applications, Pearson Education.

Online Learning Materials

Srabani Taraphder, <https://nptel.ac.in/courses/104/105/104105088/>

Title	Food Engineering	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	B.Tech	Type	PE
Prerequisite	None		

Objective

The Instructor will:

1. Provide knowledge about different aspects of food engineering.
2. Train the student in food preservation and food processing.

Learning Outcomes

The students are expected to have the ability to:

1. Understand different aspects of food engineering and food preservation.
2. Analyze the food processing aspects.

Contents

General introduction of food, food engineering and food preservation. [4 lectures]

Composition of foods, chemistry, properties, and function of carbohydrates, proteins, amino acids, lipids, vitamins. [7 lectures]

General principles underlying spoilage and chemical changes of food caused by microorganisms. [5 lectures]

Food preservation by application of heat (canning), dehydration, freezing, ionization radiation, chemical preservatives, fermentation and the like. [7 lectures]

Case studies of food processing viz. meat, fish and poultry; vegetables and fruits; bakery and dairy products. [7 lectures]

Quality control of food and food products. [3 lectures]

Food laws, rules and standards, food engineering overview, [3 lectures]

Production of engineered food products, [3 lectures]

Case studies in food engineering, Industrial and commercial aspects of food technology. [3 lectures]

Text Books

1. Murano P. Understanding Food Science and Technology
2. Friberg, S. Handbook of Food and Beverage Fermentation Technology (Food Science and Technology)

Reference Books

1. Reed G, Prescott and Dunn's Industrial Microbiology
2. Shuler, M.L. and Kargi, F. [2003] Bioprocess Engineering: Basic Concepts, Prentice Hall of India

Online Course Material

<https://nptel.ac.in/courses/103/107/103107088/>

Title	Modelling of Atoms, Molecules and Surfaces	Number	CHL7XX0
Department	Chemical Engineering	L-T-P-D [C]	3-0-0 [3]
Offered for	B.Tech, M.Tech., M.Tech-Ph.D. Dual Degree	Type	Elective
Prerequisite	None		

Objectives

The Instructor will:

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

Forces Between Atoms and Molecules, Principle and Concepts: Some Thermodynamic Aspects of Intermolecular Forces (3 Lectures), Covalent and Coulomb Interactions (3 Lectures), Interactions Involving Polar Molecules, Interactions Involving Polarisation of Molecules (5 Lectures), van der Waals Forces (3 Lectures), Repulsive Forces, Total Pair Potentials (3 Lectures), Hydrogen Bonding, Hydrophobic and Hydrophilic Interactions (2 Lectures). [19 Lectures]

Forces Between Particles and Surfaces: Concepts of Intermolecular and Interparticle Forces (2 Lectures), Contrast Between Intermolecular, Interparticle and Intersurface Forces (3 Lectures), van der Waals Forces Between Surfaces (2 Lectures), Electrostatic Forces Between Surfaces in Liquids (5 Lectures), Solvation, Structural and Hydration Forces (3 Lectures), Steric and Fluctuation Forces (3 Lectures), Adhesion (2 Lectures). [20 Lectures]

Textbook

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