M.Tech & M.Tech-PhD
Program Course Curriculum

Department of Chemical Engineering
IIT Jodhpur

Program's Structure
Overall Structure (M. Tech. Degree Requirements for Chemical Engineering)

Summary of Course Categories and credit distribution for M.Tech. (Chemical Engineering)

S.N.	Course Type	Credits
1	M.Tech. Compulsory (MC)	17
2	M.Tech. Electives (ME)	17
3	M.Tech. Open (MO)	6
4	M.Tech. Project (MP)	16
	Total Graded	**56**
5	Non-Graded (NG)	4
	Total	**60**

Course Structure: Semester wise distribution of credits

Cat.	*Course Title*	*L-T-P*	*Credits*		*Cat.*	*Course Title*	*L-T-P*	*Credits*
I Semester					**II Semester**			
MC	*Advanced Transport Phenomena*	3-0-0	3		MC	*Advanced Process Control and AI Applications*	3-0-0	3
MC	*Advanced Reaction Engineering*	2-0-2	3		MC	*Multi-component Separation Processes*	2-0-2	3
MC	*Advanced Chemical Engineering Thermodynamics*	2-0-0	2		ME	*Program Elective*	3-0-2	4
MC	*Advanced Mathematical Methods in Chemical Engineering*	3-0-0	3		ME	*Program Elective*	3-0-2	4
ME	*Program Elective*	3-0-0	3		NG	*Professional Ethics*	1-0-0	1
NG	*Technical Communication*	1-0-0	1					
Total (Graded+Non-graded)			**15**		*Total (Graded+Non-graded)*			**15**
III Semester					**IV Semester**			
MP	Project	0-0-10	5		MP	Project	0-0-22	11
ME	*Program Elective*	3-0-0	3		MO	*Open Elective*	3-0-0	3
ME	*Program Elective*	3-0-0	3		NG	*IP Management and Exploitation*	1-0-0	1
MO	*Open Elective*	3-0-0	3					
NG	*Systems Engineering and Project Management*	1-0-0	1					
Total (Graded+ Non-graded)			**15**		*Total (Graded+Non-graded)*			**15**

M. Tech. Program: Topic Clouds

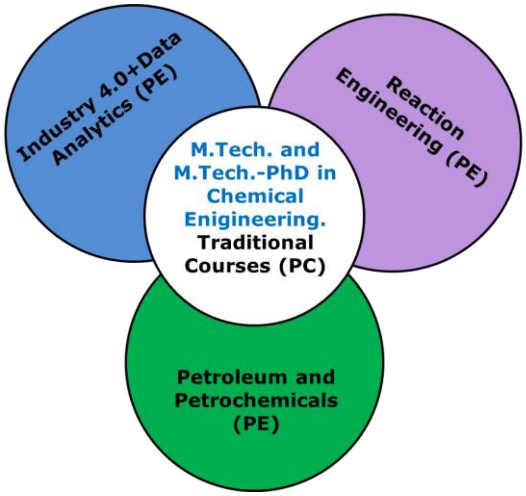

Figure: Pictorial representation of M.Tech., M.Tech.-PhD program in chemical engineering with specialization

M.Tech. Compulsory Courses

Advanced Transport Phenomena	*Advanced Reaction Engineering*	*Advanced Chemical Engineering Thermodynamics*	*Advanced Mathematical Methods in Chemical Engineering*	*Advanced Process Control and AI Applications*	*Multi-component Separation Processes*
• Review of Fluid Kinematics • Conservative Principles and Constitutive Laws • Coupled Transport Processes • Turbulence Modelling • Multiple parameter estimation • Transport Phenomena in Large Scale and Small Scale Systems	• Introduction to Advanced Reactors • Reaction Stability Analysis • Nonideal Reactors • Gas-solid and Liquid-solid Catalytic Reactions • Multiphase Reactors, Fluidised Bed Reactors • Packed Bed Reactors	• Review of Classical Thermodynamics • Adsorption Thermodynamics • Chemical Reaction Thermodynamics • Statistical Thermodynamics • Modelling of ideal gases and gas mixtures • Modelling of Crystals	• Introduction of vector space matric. • Contraction mapping • Eigenvalue problems • Partial differential equations • Special ODEs and adjoint operators • Solution of PDEs by different methods.	• Introduction to advanced process control; feed-forward control. • Multivariable control. • AI and IoT in control systems, • AI techniques in process monitoring, fault detection and diagnosis • Real time computer control of process equipment.	• Concepts • Multi-component Distillation • Liquid-liquid Extraction • Separation Processes involving Solid Phase • Crystallization, Drying • Case Studies

M.Tech. Electives (ME)
Program Electives

Group 1: Industry 4.0+Data Analytics

S. No.	Group	Courses Title	L-T-P	Credit
1	Industry 4.0+Data Analytics	Industrial Design	3-0-0	3
2		Chemometrics	3-0-0	3
3		Data Analytics in Process Modelling and Simulation	2-0-2	3
4		Computational Fluid Dynamics	3-0-2	4
5		Process Optimization	3-0-2	4
6		Process Engineering and AI Applications	2-0-2	3
7		Packaging of Electronic Devices – Polymeric materials & Chemical Technology	3-0-2	4
8		Nanocomposite Membrane Technology	3-0-0	3
9		Artificial Intelligence-1	3-0-0	3
10		Machine Learning-1	3-0-0	3
11		Introduction to IoT	1-0-0	1
12		Nano-sensors	3-0-0	3
13		Additive Manufacturing	3-0-0	3
14		Robotics	3-0-2	4
15		Sensors and IoT Lab	0-0-2	1
16		Industry 4.0: Applications in Manufacturing Systems	1-0-0	1

Group 2: Reactive Chemical Processing

S.No.	Group	Course Title	L-T-P	Credit
1	Reactive Chemical Processing	Molecular Modeling of Catalytic Reactions	3-0-0	3
2		Heterogeneous Catalysis and Catalytic Reactors	3-0-0	3
3		Characterization of Multiphase Reactors	3-0-0	3
4		Advanced Wastewater Treatment	3-0-2	4
5		Chemical Reactor Analysis	3-0-2	4
6		Selected Topics in Reactive Chemical Processing	3-0-0	3
7		Recent Advances in Reactive Chemical Processing	2-0-0	2
8		Current Topics in Reactive Chemical Processing	1-0-0	1

Group 3: Petroleum and Petrochemicals

S. No.	Group	Course Title	L-T-P	Credit
1	Petroleum and Petrochemicals	Petroleum Refinery Engineering	3-0-2	4
2		Petrochemical Technology	3-0-0	3
3		Petroleum Production Engineering	3-0-0	3
4		Petroleum Reservoir Engineering	3-0-0	3
5		Process Safety and Hazards	3-0-0	3
6		Environmental Impact Assessment	3-0-0	3
7		Hydrogen and Methanol Economy	3-0-0	3
8		Selected Topics in Petroleum and Petrochemicals	3-0-0	3
9		Recent Advances in Petroleum and Petrochemicals	2-0-0	2
10		Current Topics in Petroleum and Petrochemicals	1-0-0	1

Group 4: Additional program Electives

S. No.	Group	Courses	L-T-P	Credit
1	Additional Electives	Advanced Fluid Dynamics	3-0-0	3
2		Advanced Mass Transfer	3-0-0	3
3		Advanced Heat Transfer	3-0-0	3
4		Capillarity and wetting	3-0-0	3
6		Kinetics & Theory for Polymers	3-0-0	3
7		Catalytic Nanomaterials	3-0-0	3
8		Mechanics of Viscoelastic Materials	3-0-0	3
9		Structure & Property for Polymers	3-0-0	3

Detailed course contents

Program core

Title	**Advanced Transport Phenomena**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree in Chemical Engineering	Type	Compulsory
Prerequisite	None		

Objective

The instructor will:

1. Provide in-depth understanding of processes involving mass, energy, and momentum transport.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the fundamental aspects of transport phenomena at advanced level.
2. Develop an understanding and pursue graduate research in this area.

Contents

Introduction: Review of fluid kinematics, Control Volumes, Reynolds transport. (4 lectures)

Conservation Principles and constitutive laws: Mass, Momentum, Energy, Entropy; Phase interface conditions, Solutions methods for equations of change, steady and unsteady fluid flow, Creeping flow, Lubrication approximation, Boundary layer theorem. (12 lectures)

Coupled transport processes: Steady and Unsteady states phenomena, Forced convection heat and mass transport in confined/unconfined laminar flows, low Peclet and high Peclet approximations, buoyancy driven flows, Multi-component energy and mass Transport. (12 lectures)

Turbulence modelling: Characteristics of turbulent flows, length and time scales, energy cascade, Reynolds averaged transport equations, Phenomenological models, Kolmogorov hypotheses, universality and turbulence spectra. (10 lectures)

Transport phenomena in large-scale and small-scale systems: chemical reactors, micro-fluidic devices. (4 lectures)

Text Books

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, Cambrige University Pres.
3. Pope S. B., 2000, Turbulent Flows, Cambridge University Press.
4. Belfore, L. A., 2003, Transport Phenomena for Chemical Reactor Design, John Wiley & Sons.
5. Ramachandran, P. A. 2014. "Advanced Transport Phenomena", Cambridge University Press.

Online Course Material

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	**Advanced Reaction Engineering**	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	Compulsory
Prerequisite	None		

Objective

The Instructor will:

1. Impart knowledge of hydrodynamics and transport effects in multiphase reactors, to learn lower order model for prediction of their performance.
2. Introduce industrial reactors,
3. Provide methodology to design multiphase reactors for a few specific applications.

Learning Outcomes

The students are expected to have the ability to

1. In-depth understanding of hydrodynamics and transport effects in multiphase reactors.
2. Design multiphase reactors.

Contents

Introduction to advanced reactors: Review of reaction kinetics and ideal reactors, catalytic reactions, non-catalytic reactions (3 lectures)

Reaction Stability Analysis: Application of conformal mapping for identification of unique steady state and the criteria for the same; estimation of multiple steady states; phase diagram and Routh-Hurwitz criteria for stable steady state; linear stability analysis. (5 lectures)

Non-ideal reactors: Principles of non-ideal flow, central volume principle and RTD theorems, data analysis and interpretation; Models for non-ideal flow patterns, tanks-in-series (8 lectures)

Gas-Solid and Liquid-Solid Catalytic Reactions: Gas-solid reactions, Liquid-solid reactions, Non-isothermal reactions, Effectiveness factor; Various regimes of gas-absorption and reaction, Enhancement factor. (7 lectures))

Different reactors: Multiphase reactors, Fluidised bed reactors; Packed Bed Reactors. (5 lectures)

Design Labs (28 hrs)

1. Stability analysis
2. Reactor design: Tank in series
3. Design of mechanically agitated reactors
4. Bubble column reactor
5. Slurry bubble column reactor
6. Fluidised bed reactor
7. Trickle bed reactor
8. Non-catalytic heterogeneous reactor
9. Multi-phase reactor design
10. Packed bed reactor design
11. Two phase packed bed reactor
12. Three phase packed bed reactor

Text Books

1. Froment, G. F., K. B. Bischoff, 1990, *Chemical Reactor Analysis and Design*, John Wiley.
2. Doraiswamy, L. K. and D. Uner, 2013, *Chemical Reaction Engineering: Beyond the Fundamentals,* CRC Press.

Reference Book

1. Carberry, J. J., Varma, A., 1986, *Chemical Reaction and Reactor Engineering*, Marcell-Dekker

Online Course Material

1. Shankar, H.S., Advanced Chemical Reaction Engineering, NPTEL Course Material, Department of Chemical Engineering, IIT Bombay https://nptel.ac.in/courses/103/101/103101001/
2. Viswanathan, G.A., Chemical Reaction Engineering II, NPTEL Course Material, Department of Chemical Engineering, IIT Bombay, https://nptel.ac.in/courses/103/101/103101008/

Title	**Advanced Chemical Engineering Thermodynamics**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0 (2)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree in Chemical Engineering	Type	Compulsory
Prerequisite	None		

Objective

The Instructor will:

1. Provide in-depth knowledge about statistical thermodynamics and applications to simple gas systems, lattice structures and structure–property analysis of such systems.

Learning Outcomes

The students are expected to have the ability to:

1. To apply in-depth knowledge of chemical reaction thermodynamics,
2. Molecular perspective of equilibrium and states of materials,
3. Statistical thermodynamics and applications.

Contents

Prelude to Advanced Thermodynamics: Structure property relationships of matter, degree of freedom, equilibrium, review of classical thermodynamics, reversible and irreversible processes; Adsorption Thermodynamics; Chemical Reaction Thermodynamics. (9 lectures)

Statistical Thermodynamics: probability postulate, Ergodic hypothesis, Probability analysis and relating statistical properties to macroscopic properties. Microcanonical, Canonical and Grand Canonical Ensembles, Molecular interactions and force fields (8 lectures)

Modelling of ideal gases (monatomic, diatomic, polyatomic):, degrees of freedom and internal energy, specific heat capacity, entropy and free energy. Modelling of lattice gas.

Modelling of gas mixtures. (6 lectures)

Modelling of crystals: Perfect crystals, defects. Internal energy and heat capacity, Modelling of Adsorption, perturbation analysis. (5 lectures)

Text Book

1. Smith & Van Ness: Introduction to Chemical Engineering Thermodynamics, McGraw Hill, any edition from 4th – 7th.

Reference Books

1. Richard Elliot, Intro ductory Chemical Engineering Thermodynamics, Pearson Education, 2nd Edition, 2014
2. Terrel L Hill, Introduction to Statistical Thermodynamics, 1st Edition, Dover Publications,1988

Online Course Material

1. Kishore, N., Advanced Thermodynamics, NPTEL Course Material, Department of Chemical Engineering, IIT Guwahati https://nptel.ac.in/courses/103/103/103103162/

Title	**Advanced Mathematical Methods in Chemical Engineering**	Number	CLL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0
Offered for	M.Tech. and M.Tech.-Ph.D. Dual Degree	Type	Compulsory
Prerequisite	Knowledge of Engineering Mathematics		

Objective

To impart knowledge about advanced mathematical techniques in chemical engineering particularly analytical maths.

Learning Outcomes

A successfully completed course should enable the student to have fair knowledge of advanced mathematical methods in chemical engineering particularly analytical maths including eigenvalue problems and partial differential equations.

Contents

Introduction of vector space metric, norm, inner product space examples, onto, into, one to one function, completeness of space. (8 lectures)

Vectors: Linear combination of vectors, dependent/independent vectors, orthogonal and orthonormal vectors, gram-schmidt orthogonalization. *Contraction Mapping*: Definition; applications in chemical engineering; examples. Matrix, determinants and properties. (8 lectures)

Eigenvalue problem: Various theorems; solution of a set of algebraic equations; solution of a set of ordinary differential equations; solution of a set of nonhomogeneous first order ordinary differential equations (ivps), applications of eigenvalue problems: stability analysis; bifurcation theory; examples. (7 lectures)

Partial Differential Equations: Classification of equations; Boundary conditions; Principle of Linear superposition, *Special ODEs and Adjoint operators*: Properties of adjoint operator; sturm luiville theorem for eigenvalues and eigenfunctions. (5 lectures)

Solution of linear, homogeneous PDEs by separation of variables: Cartesian coordinate system & different classes of PDEs; cylindrical coordinate system; spherical coordinate system (8 lectures)

Solution of PDEs by different methods. (6 lectures)

Text Books

Pushpvanam S., Mathematical Methods in Chemical Engineering, Prentice Hall India Rice and Do, Applied Mathematics and Modeling for Chemical Engineers, John Wiley and Sons, Inc

Mickley, Sherwood and Reed, Applied Mathematics in Chemical Engineering, Tata McGraw-Hill

Reference Books

Verma, A. and Morbidelli, M., Mathematical Methods in Chemical Engineering Loney, N.W. Applied Mathematical Methods for Chemical Engineers, CRC Press **Online Course Material**

Advanced Mathematical Techniques in Chemical Engineering, https://nptel.ac.in/courses/103/105/103105106/

Title	**Advanced Process Control and AI Applications**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Compulsory
Prerequisite	Introductory course on process control		

Objective

The Instructor will provide knowledge about the advanced concepts in process control, enabling multi- variable control, system identification, AI techniques in process control and digital control with computer-aided case studies.

Learning Outcomes

The students are expected to have the ability to:

1. Have fair knowledge and understanding of the advanced concepts in process control and AI techniques in process control.

Contents

Review of classical feedback control & transfer function approaches, State-space models, Distributed parameter models (5 lectures)
Introduction to advanced process control; feed-forward control, ratio control, dead time compensation (4 lectures)

Multivariable control & relative gain array (4 lectures)
Internal model control (3 lectures)
Z-transforms & introduction to digital control (4 lectures)
State estimation & system identification (5 lectures)

Adaptive control, nonlinear control, intelligent control (4 lectures)
Model predictive control (3 lectures)

AI and IoT in control systems, Fuzzy controllers, neural network for controllers, AI techniques in process monitoring, fault detection and diagnosis (5 Lectures)

Real time computer control of process equipment, case studies & use of MATLAB control system toolbox & SIMULINK (5 lectures)

Text Books

1. Coughanowr D. R. and LeBlanc S., 2008, *Process System Analysis and Control*, 3rd Ed., McGraw Hill.
2. Ogunnaike B. A. and Ray W. H., 1994, Process Dynamics Modeling and Control, Oxford University Press.
3. T.E. Quantrille and Y.A. Liu, 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. Seborg D. E., Edgar T. F. and Mellichamp D. A., 2004, *Process Dynamics and Control*, 2nd Ed., John Wiley and Sons.
3. Bequette B. W., 2003, *Process Control – Modeling, Design and Simulation*, Prentice-Hall of India.

Online Course Material

1. Patwardhan, S.C., Advanced Process Control, NPTEL Course Material, Department of Chemical Engineering, IIT Bombay, https://nptel.ac.in/courses/103/101/103101003/

Title	**Multi-component Separation Processes**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-2 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Compulsory
Prerequisite	None		

Objective

The Instructor will:

1. Provide in-depth knowledge about the multi-component separation processes that are relevant to industries today.

Learning Outcomes

The students are expected to gain:

1. The understanding of multicomponent separation processes with relevant industry examples and case studies.
2. The detailed knowledge about liquid-liquid extraction, multi-component distillation, crystallization and drying processes

Contents

Concepts & Definitions: Basic separation techniques, Maxwell-Stefan equations and their applications, estimation of diffusion coefficients, interphase multicomponent mass transfer, industrial chemical processes, separation factor, mass transfer in laminar and turbulent flow, models for mass transfer, degrees of freedom, azeotropic systems, multiphase systems, cascade and hybrid systems (11 lectures)

Multi-component Distillation and Liquid-Liquid Extraction: McCabe–Thiele Graphical Method for tray towers and its extension, stage efficiencies, equipment for solvent extraction, Hunter–Nash graphical equilibrium-stage method, Theory and scale-up of extractor performance, Fenske–Underwood–Gilliland (FUG) method, Equation-Tearing Procedures, Newton–Raphson (NR) method, Inside-Out method, batch distillation (11 lectures)

Separation involving Solid phase: Crystallization, solid drying (6 lectures)

Design Labs (28 hours)

Design of a multi-component distillation column
Design of a liquid-liquid extraction unit
Design and development of a spray dryer
Spray drying of milk to get milk powder
Flash vaporization
Recovery of a protease inhibitor from an organic solvent via crystallization
Crystallization of p-xylene from a mixture with m-xylene
Separation by reverse osmosis
Micro-filtration
Separation of whey from cheese via ultrafiltration
Recovery of caustic from Hemicellulose via dialysis
Demineralization of water by ion-exchange

Text Book

1. Seader, Henley and Ropar (2011) Separation Process Principles, 3rd Edition Wiley.
2. Ross Taylor, R. Krishna, (1993) Multicomponent Mass Transfer, John Wiley & Sons.

Reference Books

1. Humphrey, J. L. and Keller, G. E., 1997, Separation Process Technology, McGraw- Hill, NY
2. Kister, H. Z., 1992, Distillation Design, McGraw-Hill.

Details of Elective Courses

Program Electives

Group 1: Industry 4.0+Data Analytics

Title	**Industrial Design**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Knowledge of Unit Operations, Fluid Mechanics		

Objective

The Instructor will:

1. Provide knowledge of design and engineering problems of piping in process industries.
2. Provide knowledge of Industry4.0 in chemical companies.

Learning Outcomes

The students are expected to have the ability to:

1. Have fair knowledge and understanding of the design and engineering problems of piping in process industries.
2. Contribute to Industry 4.0 related work in chemical companies.

Contents

Transport of Solids: slurry transport systems, Correlations for various flow regimes. Conveying systems, solid gas flow pattern in different inclined pipe lines, Concept of saltation and choking velocities, pressure drop calculations, Design of pneumatic systems. (12 lectures)
Flow of Fluids: Frictional loss, resistance of fittings, valves and bends, carrying capacity of pipes and piping networks; Pressure drop and diameter calculations of pipe carrying steam, water, oil and gases; Optimum pipe diameter and network design. (9 lectures)

Pipes and Fittings: Standards, codes and practices; Wall thickness, tolerances, design of flanges and fittings, Flow regimes and piping design for two-phase flow; design of piping for reboiler and condenser systems. (6 lectures)
Strength and Failure of Materials: Stable and unstable deformation, plasticity, plastic instability, design assumptions, stress evaluation and design limits, codes and standards; Local components of pipe bends, branch connections and bolted flange connections. (8 lectures)

Simplified Methods for Flexibility Analysis: Thermal expansion loops, approximate solutions and flexibility analysis by model tests; Expansion joints and approaches for reducing expansion effects. (4 lectures)

Industry 4.0 in chemical companies: Digitalisation to improve its operational efficiency, Recycling, Sustainability aspects, AI in processing to automate knowledge. (3 lectures)

Text Book

1. Smith P., 2007, *Fundamentals of Piping Design: Drafting and Design Methods for Process Applications*, Gulf Publishing.
2. Quantrille T.E. and Liu Y.A., 1991, *Artificial Intelligence in Chemical Engineering*, Aademic Press.

Reference Books

1. Marcus R.D., 1990, Leung L.S., Klinzing G. E. and Rizk F., *Pneumatic Conveying of Solids*, Chapman and Hall
2. Nayyar M.L., 2000, *Piping Handbook*, 7th Ed., McGraw Hill
3. Boterman R. and Smith P., 2008, *Advanced Piping Design*, Gulf Publishing.
4. Deutsch D.J., 1980, *Process Piping Systems*, McGraw Hill

Online Course Material

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

Objective

The instructor will:

1. Impart knowledge of modern methods of analyzing chemical data.

Learning Outcomes

The students are expected to have the:

1. 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 leaning 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

Reference Books

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

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	**Computational Fluid Dynamics**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-2 (4)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Knowledge of Fluid Mechanics		

Objective

The Instructor will:

1. Provide an understanding of physical models to study hydrodynamics in engineering systems.

Learning Outcomes

The students are expected to have the ability to:

1. Interpret and understand the physical models to study hydrodynamics in engineering systems.

Contents

Introduction: Review of equations of change for transfer processes, Philosophy of computational fluid dynamics (CFD), simplified flow models such as incompressible, potential and creeping flow, flow classification. (5 lectures)

Grid Generation: Structured and unstructured grids, choice of suitable grid, grid transformation of equations, some modern developments in grid generation for solving engineering problems. (3 lectures)

Finite Difference Method (FDM): Discretization of ODE and PDE, approximation for first, second and mixed derivatives, implementation of boundary conditions, discretization errors, FDM applications to engineering problems (12 lectures)

Finite Volume Method (FVM): Discretization methods, approximations of surface integrals and volume integrals, interpolation and differential practices, implementation of boundary conditions, FVM application to engineering problems (11 lectures)

Special Topics and Case Studies: Flow and heat transfer in pipes and channels, square cavity flows, reactive flow, multiphase flow, rotary kiln reactors, packed and fluidized bed reactors, furnaces and fire systems, Overview of finite element method. (11 lectures)

CFD Design Lab (28 hrs)

Design Flow Models for:
- Incompressible flow
- Potential flow
- Creeping flow

Greed generation technique

Discretization methods for ODE and PDE

Application technique of Finite Volume Method

Surface and volume integrals

Text Books

1. Fletcher C.A.J., 1998, *Computational Techniques for Fluid Dynamics*, *Vol. 1: Fundamental and General Techniques,* Springer-Verlag.
2. Fletcher C.A.J., *Computational Techniques for Fluid Dynamics*, 1998, Vol. 2: Specific Techniques for Different Flow Categories, Springer-Verlag.

Reference Books

1. Anderson J.D., 1995, *Computational Fluid Dynamics*, McGraw Hill.
2. Ghoshdastidar P.S., 1998, *Computer Simulation of Flow and Heat Transfer*, Tata McGraw Hill.
3. Ferziger J.H. and Peric M., 2002, *Computational Methods for Fluid Dynamics*, 3rd Ed., Springer
4. Patankar S.V., 2004, *Numerical Heat Transfer and Fluid Flow*, Taylor and Francis.

Online Course Material

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

Title	**Process Optimisation**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-2 (4)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	knowledge of Chemical Engineering processes and Mathematics		

Objective

The Instructor will:

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

Learning Outcomes

The students are expected to:

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

Contents

Introduction: Optimization and calculus based classical optimization Techniques (4 lectures)
One Dimensional Minimization Methods: Elimination methods- equally spaced points method, Fibonacci method and golden section method; Interpolation methods- quadratic interpolation and cubic interpolation, Newton and quasi-Newton methods, Linear Programming (11 lectures)

Multivariable Non-Linear Programming: Unconstrained- Different methods for non-linear programming; Constrained- complex method, feasible directions method, GRG method, penalty function methods and augmented Lagrange multiplier method. (10 lectures)
Dynamic Programming: Multistage processes- acyclic and cyclic, sub-optimization, principle of optimality and applications. (6 lectures)

Geometric Programming (GP): Differential calculus and Arithmetic-Geometric inequality approach to unconstrained GP; Constrained GP minimization; GP with mixed inequality constraints and Complementary GP, Emerging Optimization Techniques: Genetic algorithm, simulated annealing, particle swarm and ant colony optimization. (11 lectures)

Process Optimisation Design Lab (28 hrs)
Solution of 1-D problems (4)
Linear programming problem (4)
Multi-variable nonlinear programming problem (4)
Dynamic programming problem (4)
Geometric programming problem (4)
Solution of case-studies problems (8)

Text Book

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

Reference Books

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

Online Course Material

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

Title	**Process Engineering and AI Applications**	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 on the issues and techniques involved in designing of large-scale chemical processes with multiple unit operations.
2. Impart knowledge about role of AI in process engineering.

Learning Outcomes

The students are expected to:

1. Have the fair understanding and knowledge about the issues and techniques involved in designing of large-scale chemical processes with multiple unit operations in industries.
2. Have the fair understanding about the role of AI in process engineering.

Contents

Introduction: History and Relation of Artificial Intelligence (AI) to Process Engineering; Knowledge Representation I- Predicate calculus and Semantic Networks; flow-sheet synthesis, concept of economic potential of batch, continuous and recycle reactors, expert system shells. (8 lectures)

Neural Nets and Inexact Reasoning: Introduction and application to process engineering, Blackboard Architecture. (4 lectures)

Reactors and separation systems: Guidelines for selection methods; Heat and energy integration by calculating demands and targets; distillation column sequencing; grand composite curve and utility targeting; steam and cooling water circuits; Problem solving using AI and process modelling tools. (12 lectures)

Process economics: cost estimation, annuities, tax, depreciation, profitability analysis, risk management (4 lectures)

Process Engineering Design Lab (28 hrs):

Flow sheet analysis (2)
Economic model and comparison of reactors: Batch and Continuous reactors: Batch and Recycle reactors, Continuous and recycle reactors (6)
Column sequencing and water circuits (6)
AI application in process equipment/ plant performance analysis (8)
Case studies on Chemical plant design (6)

Text Books

1. T.E. Quantrille and Y.A. Liu, 1991, Artificial Intelligence in Chemical Engineering, Academic Press.
2. Douglas J.M., 1988, *Conceptual Design of Chemical Processes*, NY: McGraw-Hill.
3. Smith R., 2005, *Chemical Process: Design and Integration*, 1st ed. West Sussex, UK: Wiley.

Reference Books

1. Seider, W. D., Seader,J.D. and Lewin, D.R., 2003, *Product and Process Design Principles: Synthesis, Analysis, and Evaluation*, 2nd ed. New York, NY: Wiley.
2. Edgar and Himmelblau, 1988, *Optimization of Chemical Processes,* New York, NY: McGraw Hill

Title	**Packaging of Electronic Devices – Polymeric materials** & Chemical Technology	Number	CHL7XX
Department	Chemical Engineering	L-T-P [C]	3-0-2
Offered for	MTech, MTech-PhD	Type	Elective
Prerequisite	Basic knowledge of polymeric materials		

Objectives

The Instructor will:

1. Impart knowledge about the current status as well as advancements for electronic packaging of devices along with process details and their relevance to Chemical Engineers. Empower scholars to pursue further career and self-learning in this area.

Learning Outcomes

The students are expected to have the knowledge about:

1. Various types of packages, levels of packaging and overall processes relevant to packaging starting from assembly to reliability.
2. Detailed know-how about the chemical manufacturing processes relevant to Electronic Packaging of devices.

Contents

Introduction to Electronic Packaging: Definitions, Need for Electronic Packaging, Levels of packaging, Types of packages, Introduction to Device generations, Introduction to device manufacturing process, Case studies, DFM, DFR, DFT (5 Lectures)

Flip Chip Packaging: History and details of process flow for flip-chip technology, Polymers for flip-chip technology (6 Lectures)

Advanced Packaging: Substrate manufacturing technology, Embedded die technology, core-less technology, wafer and panel level packaging, Polymers for Advanced Packaging, subtractive process, semi-additive process, additive process (12 Lectures)

Surface Mount Technology: BGA, LGA, PGA, SMT failures, Lead-free solder (3 Lectures)

Thermal Management: Need for thermal management, Heat Sinks, Novel thermal management technologies, Passives (6 Lectures)

Electronic Package Reliability: Thermal reliability, Mechanical reliability, Moisture sensitivity test, Pre-conditioning, Chemical resistance, Electrical reliability, HAST, B-HAST (10 Lectures)

Laboratory Experiments (28)

Shear-rheology of polymer dielectric for lamination processes1
Shear-rheology of polymer dielectric for lamination processes2
Structural analysis for polymer dielectrics for SEM1
Structural analysis for polymer dielectrics for SEM2
Structural analysis for polymer dielectrics for reliability via AFM1
Structural analysis for polymer dielectrics for reliability via AFM2
SEM analysis of mobile chip 1/SEM analysis of a mobile chip 2/SEM analysis of a mobile chip 3
SEM analysis of a television chip/ SEM analysis of a Air Conditioner chip
SEM analysis of an old generation chip (pre 1990s)

Textbook

1. Khandpur R. S., (2005), *Printed Circuit Boards Design, Fabrication, Assembly and Testing*, Tata McGraw Hill Education Private Limited India

Reference Books

1. Tummala R., (2019), *Fundamentals of Device and Systems Packaging: Technologies and Applications*, McGraw Hill

Online Course Material

1. Bhattacharya A, Electronic *Packaging & Manufacturing,* NPTEL Course Material, Department of Mechanical Engineering, Indian Institute of Technology Kharagpur, https://nptel.ac.in/courses/112105267/
   Mahesh G V, *An Introduction to Electronics Systems Packaging*, NPTEL Course Material, Department of Electrical Engineering, IISc Bengaluru, https://nptel.ac.in/courses/108108031/

Title	**Nanocomposite Membrane Technology**	Number	CHL8XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech.-Ph.D. Dual Degree and Ph.D.	Type	Elective
Prerequisite	Basic knowledge of Engineering and Chemistry		

Objective

The instructor will provide:

1. Fundamentals, synthesis and characterisation of nanocomposite membrane,
2. Different applications of nanocomposite membrane technology.

Learning Outcomes

The students are expected to have:

1. Comprehensive knowledge of fundamentals, synthesis and characterisation of nanocomposite membrane technology.
2. Its applications in different fields such as water treatment, gas separation etc.
3. Challenges and opportunities.

Contents

Introduction to nanocomposite membrane technology: Membrane types, membrane processes, transport theories. (8 Lectures)

Synthesis of nanocomposite membranes: Preparation techniques, homogeneous membranes, composite membranes, raw materials, processing methods. (6 Lectures)

Characterisation of nanocomposite membranes: Pore size, micrographic methods, spectroscopic methods, strength measurements. (6 Lectures)

Nanocomposite membranes in water treatment: Conventional nanocomposites, thin film nanocomposites, TFC with nanocomposite substrate. (7 Lectures)

Nanocomposite membranes in gas separation. (5 Lectures)

Challenges in processing of nanocomposite membranes. (5 Lectures)

Environment and safety issues. (5 Lectures)

Text Book

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

Reference book

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

Online Course Material

1. Mohanty, K., Membrane Technology, NPTEL Course Material, Department of Chemical Engineering, IIT Guwahati, https://nptel.ac.in/courses/103/103/103103163/

Title	**Artificial Intelligence-1**	Number	CSXXXX
Department	Computer Science and Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech. 1st Year, Ph.D. 1stYear	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. 1st Year, Ph.D. 1stYear	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	**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	**Nanosensors**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-0 [3]
Offered for	B. Tech, M. Tech and PhD	Type	Open Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide understanding about 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	**Additive Manufacturing**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3–0–0 [3]
Offered for		Type	Program Elective
Prerequisite			

Objectives

The Instructor will:

1. cover scientific as well as technological aspects of various additive, subtractive and formative rapid manufacturing processes.
2. cover wide range of contemporary methodologies/technologies and tools for rapid manufacturing.

Learning Outcomes

The students are expected to have the ability to:

1. appreciate process flow and working principles for various additive manufacturing processes
2. deal with challenges faced during additive manufacturing of components

Contents

1. Introduction: Mass production and customization, Classification of processes, process chain for AM (4 Lectures)
2. Data Preparation: Data formats, data conversion, data validity checks, data repair(4 Lectures)
3. Process Planning Stage: Slicing Algorithms, Part Depositions and Orientation, Direct Slicing, STEP related details (6 Lectures)
4. AM Processes: FDM of polymers, metals and ceramics, Laminated Object manufacturing, Shaped Deposition manufacturing, Sterolithography and liquid based systems, Laser Sintering technologies, 3-D Printing, Direct Metal Deposition, Electron and Laser beam technologies, Subtractive and Formative Rapid manufacturing processes (14 Lectures)
5. Rapid Tooling (2 Lectures)
6. Hybrid Processes (4 Lectures)
7. Process Selection, Applications, Capabilities and Challenges (8 Lectures)

Reference Books

1. Gibson, I, Rosen, D W, and Stucker, B, Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer
2. Hopkinson, N, Haque, R, and Dickens, P, Rapid Manufacturing: An Industrial Revolution for a DigitalAge: An Industrial Revolution for the Digital Age, Wiley
3. Bartolo,P J (editor),Virtual and Rapid Manufacturing: Advanced Research in Virtual and Rapid Prototyping, Taylor and Francis
4. Chua, C K, Leong, K F, Lim C S, Rapid Prototyping, World Scientific

Online Course Material:

1. https://nptel.ac.in/syllabus/112104156/

Title	**Robotics**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	3-0-2 [4]
Offered for	B. Tech (ME), M. Tech(AMD) and PhD	Type	Program Core
Prerequisite			

Objectives

1. To introduce fundamental aspects of modeling and control of robot manipulators.
2. To provide a brief of results from geometry, kinematics, dynamics, motion planning and control

Learning Outcomes

1. The course will equip students with theoretical and practical knowledge of robot modeling, programming and control.

Contents: Fractal 1: Robot Modeling [MEL7XX1] [1-0-0]

1. Rotational Transformations, Composition of Rotations, Parameterizations of Rotations, Rigid Motions, Homogeneous Transformations (2 lectures)
2. Forward and Inverse Kinematics – Kinematic Chains, Forward Kinematics: The Denavit-Hartenberg Convention, Inverse Kinematics, Kinematic Decoupling (4 lectures)
3. Velocity Kinematics – The Jacobian: Angular and Linear Velocity: The General Case, Derivation of the Jacobian, Analytical Jacobian, Singularities, Inverse Velocity and Acceleration (4 lectures)
4. Robot Dynamics: Equations of Motion, Kinetic and Potential Energy, Euler-Lagrange Equations, Properties of Robot Dynamic Equations, Recursive Newton-Euler Formulation (4 lectures)

Fractal 2: Motion Planning and Programming [MEL7XX2] [1-0-0]

1. Path and Trajectory Planning: Path vs. Trajectory, The Configuration Space, Path Planning Using Configuration Space, Potential Fields, Trajectory Planning, Point To Point Motion, Paths Specified by Via Points, Probabilistic Roadmap Planner (5 lectures)
2. Vision-Based Control: The Geometry of Image Formation, Camera Calibration, Camera Motion and Interaction Matrix, Image-Based Control Laws, Relation between End Effector and Camera Motions, Partitioned Approaches (4 lectures)
3. Robot Operating System (ROS): Basic ROS concepts, Writing RoS Programs, Log Messages, Graph Resource Name, Launch Files, Parameters, Services, Recording and Replaying Services (5 lectures)

Fractal 3: **Robot Control[MEL7XX3] [1-0-0]**

1. Sensors and Actuators: Joint Actuating Systems, Drives, Proprioceptive Sensors, Exteroceptive Sensors (3 lectures)
2. Linear Control: Feedback and closed-loop control, second-order linear systems, control of second-order systems, Control-law partitioning, trajectory-following control, disturbance rejection, continuous vs. Discrete time control, modeling and control of a single joint, architecture of an industrial-robot controller (3 lectures)
3. Nonlinear control: Nonlinear and time-varying systems, multi-input, multi-output control systems, control of manipulators, practical considerations, current industrial-robot control systems, lyapunov stability analysis, cartesian-based control systems, adaptive control (4 lectures)
4. Force Control: Interaction with Environment, Compliance Control, Impedance Control, Force Control, Hybrid Force/Motion control (4 lectures)

Laboratory Classes (12 exercises)

DH Parameters, Forward and Inverse Kinematics of Robot, Robot Trajectory Planning, Robot Operating System (ROS), Control of Robot through ROS, Path Planning, Vision Based control, Force Control

Reference Books

1. Saha S. K., Introduction to robotics. Tata McGraw-Hill Education
2. Spong M. W., Hutchinson, S., and Vidyasagar, M., Robot modeling and control. New York: Wiley.
3. O'Kane J. M., A Gentle Introduction to ROS, ISBN 978-1492143239
4. Craig J. J, Introduction to robotics: mechanics and control. Pearson/Prentice Hall.

Self Learning Material

1. https://see.stanford.edu/Course/CS223A

Title	**Sensors and IoT Lab**	Number	**EEP7XX0**
Department	Electrical Engineering	L-T-P [C]	0–0–2 [1]
Offered for	M. Tech. 1st 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 Manufacturing Systems**	Number	MEL7XX0
Department	Mechanical Engineering	L-T-P-Th [C]	1-0-0 [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 Manufcturing 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

Group 2: Reactive Chemical Processing

Title	**Molecular Modelling of Catalytic Reactions**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Program Elective
Prerequisite	Basic knowledge of Chemical Kinetics		

Objectives:

The Instructor will:

1. Provide the knowledge in experimental and theoretical aspects of catalytic reactions, with primary emphasis on understanding of reaction mechanisms.
2. Introduce interesting recent trends in research and development of a heterogeneous catalyst, in which experimental results are inferred by quantum mechanical simulations, so as to develop a molecular level understanding of the catalytic reactions.

Learning Outcomes:

The students are expected to have the ability to:

1. Understand the experimental and theoretical aspects of catalytic reactions and recent trends in research and development of a heterogeneous catalyst, in which experimental results are inferred by quantum mechanical simulations.
2. Develop a molecular level understanding of the catalytic reactions.

Contents:

Principles of Molecular Heterogeneous Catalysis: Sabatier principle, Catalytic Cycle, Transition State Theory, Ensemble Effect, Defect Sites, Cluster-Size Effects, Metal-support Interactions, Structural Effects, Quantum Size Effects, Electron Transfer Effects, Bronsted-Evans-Polanyi Relations, Reactivity of Transition-Metal Surfaces. (8 lectures)

Kinetics of Catalytic Reactions: Adsorption, Desorption and Surface Reactions, Reaction on Uniform and Non-Uniform Surfaces, Structure Sensitive and Non-Sensitive reactions on Metals. (4 lectures)

Chemisorption & Quantum Chem: Chemical Bond, Bonding to Transition Metals, Chemisorption. (8 lectures)

Introduction to Density Functional Theory: Born–Oppenheimer approximation, Hartree-Fock Theory, Self-Consistent Field, Kohn-Sham Density Functional Theory, Bloch's Theorem and Plane Wave Basis Set. (6 lectures)

Computational Methods: Electronic Structure Methods, Potential Energy Surface, Exchange-Correlation Functional, Pseudo-Potential, Search for Transition State, Dimer Method, Nudged Elastic Band Method, Density of States. (8 lectures)

Molecular Modelling: Catalysis by Metals, Oxides, Sulfides and Zeolites. Aqueous Phase Heterogeneous Catalysis and Electrocatalysis. (8 lectures)

Text Book

1. Rutger A. van Santen, Matthew Neurock, *Molecular Heterogeneous Catalysis: A Conceptual and Computational Approach*, 1st edition (March 10, 2006), Wiley-VCH, ISBN: 978-3-527-29662-0

Reference Books

1. Chorkendorff, J. W. Niemantsverdriet, 2007, *Concepts of Modern Catalysis and Kinetics*, Wiley VCH, 2nd edition (22 August 2007), ISBN: 978-3527316724
2. David Sholl, Janice A Stecke, 2009, *Density Functional Theory: A Practical Introduction, Wiley-Interscience; 1 edition (April 13, 2009),* ISBN: 978-0470373170

3. M. Albert Vannice,2005, *Kinetics of Catalytic Reactions*, Springer; 2005 edition (August 24, 2005)
4. Wolfram Koch, Max C. Holthausen, 2001, *A Chemist's Guide to Density Functional Theory,* Wiley-VCH; 2 edition (July 11, 2001), ISBN: 978-3527303724
5. Michel Boudart, 1984, *Kinetics of Heterogeneous Catalytic Reactions*, Princeton University Press (1984), ISBN: 978-0691083476

Title	**Heterogeneous Catalysis and Catalytic Reactors**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic knowledge of Chemical Kinetics		

Objective

The Instructor will:

1. Impart knowledge about the basic concepts, detailed structures, preparation methods and reactivities of solid catalysts, its properties and relationship between the structures and reactivities.

Learning Outcomes

The students are expected to have the ability to:

1. Understand and gain knowledge of the detailed structures, preparation methods and reactivities of solid catalysts, its properties and relationship between the structures and reactivities.

Contents

Introduction to basic concepts (2 lectures)

Catalysis: Acid-base catalysis, application of catalyst functionality concepts for control of reaction selectivity and kinetic models, Properties of catalysts, reaction selectivity and kinetic models (10 lectures)

Steps in catalytic reaction: Adsorption, Kinetic models, intraparticle transport process, Selection and design of catalysts, Preparation and characterization of catalysts, Catalyst deactivation, various deactivation models, Optimal distribution of catalyst in a pellet (14 lectures)

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

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

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

Text Books

1. Sharma M.M. and Doraiswamy, *Heterogeneous Reactions,* Vol 1 and Vol II
2. Thomas, J.M., Thomas W.J., Principles and practice of heterogeneous Catalysis.

Reference Books

1. Bruce Gates , Catalytic Chemistry.
2. Morbidelli and Verma , Optimal distribution of catalyst in a pellet.
3. Ford M.E. and Marcel Dekker, Catalysis of Organic reactions.

Online Course Material

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

Title	**Characterization of Multiphase Reactors**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic knowledge of Chemical Kinetics		

Objective

The Instructor will:

1. Impart knowledge of modern characterization techniques useful for reaction engineering R&D and operation of chemical plants.
2. Introduce the students to analytical techniques, catalyst characterization techniques, and flow characterization techniques.

Learning Outcomes

The students are expected to have the ability to:

1. Have the understanding and knowledge of modern characterization techniques useful for reaction engineering R&D and operation of chemical plants.
2. Apply the analytical techniques, catalyst characterization techniques, flow characterization techniques, in real systems.

Contents

Characterization in Chemical Reaction Engineering: Introduction, Data Analysis and presentation, Data reporting methods, principles of measurement techniques (7 lectures)

Catalyst preparation and characterization: Principle of catalyst characterisation, determination of surface area and pore volume, pore size distribution of the catalyst, Understanding the surface morphologies and Chemical analysis of the catalyst (14 lectures)

Flow characterization in multiphase reactors: Introduction, Intrusive vs. Non-intrusive measurements, Pressure probes and voidage probes, data analysis and demonstration, Velocity measurement methods and demonstration (14 lectures)

Tomography methods: Introduction, gamma-ray tomography, electrical capacitance/ resistance tomography and demonstration (4 lectures)

Measurement of mass and heat transfer coefficients and demonstration (3 lectures)

Text Book

1. Chaouki, J., Larachi, F., & Dudukovic, M. P. (Eds.). (1997). *Non-invasive monitoring of multiphase*. Elsevier.

Reference Book

1. Perry's Chemical Engineer's Handbook 8th Edition

Title	**Advanced Wastewater Treatment**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-2 (4)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	None		

Objective

The instructor will:

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

Learning Outcomes

The students are expected to have the:

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

Contents

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

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

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

Advanced Treatment Processes: Membrane Filtration, microfiltration, ultrafiltration, nanofiltration, reverse osmosis and electrodialysis; wet air oxidation, adsorption and ion-exchange; wet-land and root-zone treatment of industrial and municipal wastes; design of sludge drying beds, thermal and biological processes for sludge and land fillings. membrane reactors, new technologies for wastewater disinfection. (12 lectures)

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

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

Title	**Chemical Reactor Analysis**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-2 (4)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic knowledge of Chemical Kinetics		

Objective

The Instructor will:

1. Provide in-depth knowledge of reaction kinetics and chemical reactors.

Learning Outcomes

The students are expected to have the ability to:

1. Have comprehensive knowledge of reaction kinetics and chemical reactors.

Contents

Introduction: Review of design of ideal isothermal homogeneous reactors for single reaction. (3 lectures)

Reactor design: Design of ideal isothermal reactors for multiple reactions. Definition of Residence time distribution (RTD), interpretation of the data, Flow models for non-ideal reactors – axial dispersion, N-tanks in series, and multi-parameter models, reactor diagnosis, influence of RTD and micro-mixing on conversion. (14 lectures)

Reactor operation: Adiabatic operations and non-adiabatic, optimal temperature, progression, hot spot in tubular reactor, auto-thermal operation and steady state multiplicity in continuously stirred tank reactor (CSTR) and tubular reactors, introduction to bifurcation theory. (13 lectures)

Multiphase catalytic reactors: Introduction, effectiveness factor, selectivity, catalyst deactivation, use of pseudo-homogeneous models for design of heterogeneous catalytic reactors (fixed and fluidized beds), Gas-liquid-solid reactors, hydrodynamics and design of bubble column, slurry and trickle-bed reactors. (12 lectures)

Design and Analysis Lab (28 hrs)

Design of isothermal reactors (2)
Residence time distribution (2)
Multiphase reactors (2)
Design method of different columns (2)
Continuously stirred tank reactor (4)
Tubular reactor (4)
Batch reactor (4)
Plug flow reactor (4)
Laminar floe reactor (4)

Text Books

1. Froment G.F. and Bischoff K.B., 1990, Chemical Reactor Analysis and Design, 2nd Ed., Wiley.
2. Fogler H.S., 2006, *Elements of Chemical Reaction Engineering*, 4th Ed., Prentice-Hall.
3. Levenspiel O., 1999, *Chemical Reaction Engineering*, 3rd Ed., Wiley.

Reference Books

1. Doraiswamy L.K. and Sharma M.M., "Heterogeneous Reactions Analysis. Vol. 1: Gas-Solid and Solid-Solid Reactions", Wiley.
2. Doraiswamy L.K. and Sharma M.M., "Heterogeneous Reactions Analysis. Vol. 2: Gas-Solid and Solid-Solid Reactions", Wiley.

Title	**Selected Topics in Reactive Chemical Processing**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech. / M.Tech.-Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by the instructor		

Objective

The instructor will provide:

1. In-depth coverage on specific topics within the reaction engineering domain, as determined by the instructor(s) and declared to students before or at the time of registration.

Learning Outcomes

The students are expected to have:

1. the in-depth knowledge in specific topic within the reaction engineering domain.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Recent Advances in Reactive Chemical Processing**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0 (2)
Offered for	M.Tech./ M.Tech.- Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by instructor		

Objective

The instructor will provide:

1. Focussed and modular coverage on multiple topics of current interest in Reaction Engineering. The topics to be covered will depend on the instructor, but will relate to advanced research level material.
   (To be taken by students specifically interested in the corresponding areas of research.)

Learning Outcomes

The students are expected to have

1. the in-depth insight in the corresponding area of research.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Current Topics in Reactive Chemical Processing**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	1-0-0 (1)
Offered for	M.Tech. / M.Tech.- Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by the instructor		

Objective

The instructor will provide:

2. In-depth coverage on current topics in the area of reaction engineering, as determined by the instructor(s) and declared to students before or at the time of registration.

Learning Outcomes

The students are expected to have:

2. the in-depth knowledge in specific topic in the field of reaction engineering and apply the knowledge in the field of reaction engineering to specific areas of research.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Group 3: Petroleum and Petrochemicals

Title	**Petroleum Refinery Engineering**	Number	CHL7XX
Department	Chemical Engineering	L-T-P (C)	3-0-2 (4)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Knowledge of Mass Transfer		

Objective

The Instructor will provide:

1. Thorough understanding in the area of petroleum oil processing and new trends in refinery operations.

Learning Outcomes

The students are expected to have:

1. comprehensive knowledge of petroleum oil processing and new trends in refinery operations.

Contents

Prelude to Petroleum Refinery Engineering: Composition of petroleum, range of refinery products (6 lectures)

Processes in Petroleum Refinery Engineering: Catalytic cracking, Delayed coking, hydrogenation and hydrocracking, Isomerization, Alkylation and Polymerization, Pyrolysis of Naptha and light hydrocarbons (14 lectures)

Design in Petroleum Refinery Engineering: Design of crude oil distillation column, Furnace design (12 lectures)

Lube oil manufacturing (4 lectures)

Energy conservation and new trends in petroleum refinery operations (6 lectures)

Design Lab (28 hours)

Crude Oil Distillation Column Design
Components Design
Catalytic cracking unit
Furnace Design
Problem on energy conservation
Waste heat utilization
Efficiency enhancement
Pollution reduction
Wealth from waste
Recycling and reuse

Textbook

1. Nelson, Wilbur L. (1958), *Petroleum refining engineering*, McGraw-Hill, New York

Reference Books

1. Watkins, Robert N. (1979) *Petroleum refinery distillation*, Gulf Publishing Company, Book Division, Houston TX
2. Meyers, Robert Allen, and Robert Allen Meyers, (2004) *Handbook of petroleum refining processes*, New York: McGraw-Hill
3. Speight, James G., and BakiOzum (2001) *Petroleum refining processes.* CRC Press
4. Edmister, Wc, and B. I. Lee, (1961) *Applied Hydrocarbon Thermodynamics*, Gulf Pub. Co.,Houston
5. Daubert, T. E., and R. P. Danner. *API technical data book-petroleum refining*. American Petroleum Institute (API), Washington DC (1997)

Online Course Material

1. Pant, K.K. and Kunzru, D., Petroleum Refinery Engineering, NPTEL Course Material, Department of Chemical Engineering, IIT Delhi and Department of Chemical Engineering, IIT Kanpur, https://nptel.ac.in/courses/103/102/103102022/

Title	**Petrochemical Technology**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic knowledge of Chemical Engineering		

Objective

The Instructor will:

1. Provide comprehensive knowledge and understanding in the area of petrochemicals and new trends in petrochemical industries.
2. Focus on the conventional processes in downstream petrochemical industries, particularly oil derivatives, polymers, materials, detergents and synthesis gas derivatives. New innovations in the petrochemicals sector will be highlighted.

Learning Outcomes

The students are expected to have:

1. good understanding of petrochemicals and new trends in petrochemical industries, as well as conventional processes in downstream petrochemical industries, particularly oil derivatives, polymers, materials, detergents and synthesis gas derivatives.

Contents

Introduction: Composition of petroleum, laboratory tests, refinery products. (5 lectures)
Petrochemical industries: Indian Scenario. (1 lecture)
Feed stocks for petrochemical Industries. (2 lectures)
Introduction to Catalytic cracking, Catalytic reforming, Delayed coking, Hydrogenation and Hydrocracking, Isomerization, Alkylation and Polymerization. (4 lectures)
Purification of gases, Separation of aromatics by various Techniques. (4 lectures)
Petrochemicals from Methane. (2 lectures)
Petrochemicals from Ethane – Ethylenes – Acetylene. (3 lectures)
Petrochemicals from C3, C4 and higher Hydrocarbons. (3 lectures)
Synthetic Gas Chemicals. (1 lectures)
Polymers from Olefins. (5 lectures)
Petroleum Aromatics. (3 lectures)
Synthetic Fibers, Rubber , Plastics and Synthetic Detergents. (3 lectures)
Energy conservation in petrochemical Industries. (1 lecture)
Pollution control in Petrochemical Industries. (2 lectures)
New Trends in petrochemical Industry. (1 lecture)
Planning and commissioning of a petrochemicals complex. (2 lectures)

Text Books

1. Hatch, Lewis Frederic, and Sami Matar, 1981, *From hydrocarbons to petrochemicals*, Gulf Publishing Company, Book Division, 1981.
2. Meyers, Robert, and Robert Allen Meyers, eds., 2005, *Handbook of petrochemicals production processes*. McGraw-Hill.

Reference Books

1. Spitz, Peter H. *Petrochemicals: the rise of an industry*. New York: Wiley, 1988.
2. Articles related to new trends in Petrochemical Industries published in various Chemical Engineering journals.

Title	**Petroleum Production Engineering**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic knowledge of Chemical Engineering Concepts		

Objective

The Instructor will:

1. Provide in-depth understanding of oil production engineering concepts, well drilling, well completions, artificial lift mechanism, how to find a non-performing well in a reservoir, finding the remedy using well logging and well stimulation.

Learning Outcomes

The students are expected to:

1. Have understanding of oil production engineering concepts, well drilling, well completions, artificial lift mechanism, finding a non-performing well in a reservoir, finding the remedy using well logging and well stimulation.

Contents

Introduction to oil reservoirs. (3 Lectures)
Basic reservoir engineering concepts (porosity, permeability, darcy's law) (3 Lectures)
Different drive mechanisms of reservoir, different artificial lifts used in the wells. (4 Lectures)
Basic concepts of production engineering (tests run in wells to evaluate performance, parameters defining flow in a well). (5 Lectures)
IPR (inflow performance curve), VLP (vertical lift performance), Vogel equation, flow in pipe. (5 Lectures)
Well analysis tools (4 Lectures)
Problem identification and remediation in well. (6 Lectures)
Logging and well stimulation techniques. (6 Lectures)
Production well simulation or Sand control and horizontal wells. (6 Lectures)

Text Book

Michael J. Economides, A. Daniel Hill and Christine Ehlig-Economides, *Petroleum Production System*, PTR Prentice Hall, Inc, New Jersey, 1994.

Title	**Petroleum Reservoir Engineering**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic Knowledge of Chemical Engineering Concepts		

Objective

The Instructor will:

1. Provide in-depth understanding of petroleum reservoir engineering from basic model to production forecast.

Learning Outcomes

The students are expected to:

1. Have the knowledge of petroleum reservoir engineering, recovery mechanism and reservoir simulation.

Contents

Introduction of oil reservoirs/ static model and dynamic model. (2 lectures)
Rock properties: porosity, permeability, compressibility, wettability, capillary pressure, relative permeability, building a reservoir description. (6 lectures)
Fluid properties: formation volume factor, gas oil ratio, viscosity, tests for oil characterization. (6 lectures)
Oil in place numbers, definition of reserves, resources, different methods of reserves estimation, material balance for hydrocarbon reservoirs (3 lectures)
Pressure transient analysis. (4 lectures)
Recovery mechanisms 1. Primary: solution gas drive, gas cap drive, water drive. (4 lectures)
Recovery mechanisms 2. Secondary: gas injection, water flooding, Buckley-Leverett theory. (4 lectures)
Recovery mechanisms 3. Tertiary recovery: chemical methods, thermal methods. (4 lectures)
Production forecasts. (4 lectures)
Reservoir simulations. (5 lectures)

Text Book

1. Dake, L.P., 2020, *Fundamentals of reservoir engineering*, (Reprint edition), Elsevier.

Reference Books

1. Larry, W. Lake, 1996, *Enhanced Oil Recovery*, Prentice Hall
2. Buckley, S. E. and Leverett, M. C., 1942, *Mechanism of fluid displacement in sands*, Trans. AIME, 146, 107-116

Title	**Process Safety & Hazards**	Number	CHL7XX
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech., M.Tech-Ph.D. Dual Degree	Type	Programme Elective
Prerequisite	Basic Knowledge of Chemical Engineering		

Objective

The Instructor will:

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

Learning Outcomes

The students are expected to have the ability to:

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

Contents

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

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

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

Handling Chemicals and toxicity: Control of toxic chemicals, Storage and handling of flammable and toxic chemical, Runway reactions, Relief system risk and hazards management, Design to prevent Fires and Explosions, Miscellaneous Design for preventing Fires and Explosion. (8 lectures)

Hazards Identification: checklists, Surveys, Hazard and Operability Studies (HAZOP), Safety reviews. Risk Assessment, Hazard models and risk data. Tackling disasters, plan for emergency. Risk management routines, Emergency shutdown systems, Role of computers in safety, Prevention of hazard human element, Technology and process selection. (8 lectures)

Text Books

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

Reference Books

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

Online Course Material

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

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	M.Tech., M.Tech.-Ph.D. Dual Degree	Type	Elective
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; evolution of EIA; historical development of EIA; forecasting environmental changes; strategic environmental assessment; water sensitive environment; ISO provisions; environmental clearance procedure. (11 lectures)

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

EIA regulations; TOR for EIAs; environmental indices; environmental legislation; EIA at regional level, sectoral level, and policy level; sustainable development; Environmental Management Plan (EMP). (11 lectures)

Future strategies and EIA case studies. (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

1. Dubey, B.K., Introduction to Environmental Engineering and Science, NPTEL Course Material, Department of Civil Engineering, IIT Kharagpur, https://nptel.ac.in/courses/127105018/

Title	**Hydrogen and Methanol Economy**	Number	CH7XX0
Department	Civil Engineering	L-T-P [C]	3-0-0
Offered for	MTECH, MTECH-PhD Dual Degree	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 view point 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 Lectures)

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

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

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

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

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	**Selected Topics in Petroleum and Petrochemicals**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	M.Tech. / M.Tech.- Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by the instructor		

Objective

The instructor will provide:

1. In-depth coverage on specific topics in the area of Petroleum and Petrochemicals.

Learning Outcomes

The students are expected to have:

1. the in-depth knowledge in specific topic in the area of Petroleum and Petrochemicals.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Recent Advances in Petroleum and Petrochemicals**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	2-0-0 (2)
Offered for	M.Tech./ M.Tech.- Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by instructor		

Objective

The instructor will provide:

1. Focussed and modular coverage on multiple topics of current interest in the area of Petroleum and Petrochemicals. The topics to be covered will depend on the instructor, but will relate to advanced research level material.
   (To be taken by students specifically interested in the corresponding areas of research.)

Learning Outcomes

The students are expected to have

1. the in-depth insight in the corresponding area of research and apply the knowledge in the corresponding area of research.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Title	**Current Topics in Petroleum and Petrochemicals**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P (C)	1-0-0 (1)
Offered for	M.Tech. / M.Tech.-Ph.D. Dual Degree	Type	Elective
Prerequisite	To be declared by the instructor		

Objective

The instructor will provide:

1. In-depth coverage on current topics in the area of Petroleum and Petrochemicals.

Learning Outcomes

The students are expected to have:

1. the in-depth knowledge in specific topic in the field of Petroleum and Petrochemicals and apply the knowledge to specific areas of research.

Contents

The topics may be further updated according to the instructor.

Textbook

Relevant Textbook and/or research papers to be announced by the instructor.

Reference Books

Relevant Textbook and/or research papers to be announced by the instructor.

Group 4: Additional program Electives

Title	**Advanced Fluid Dynamics**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	An introductory course on Fluid Mechanics		

Objectives

The Instructor will:

1. Provide knowledge about boundary layer theory, turbulent boundary layer, modelling of turbulent flow, nonnewtonian fluid and fluidization phenomena.

Learning Outcomes

The students are expected to gain:

1. Understanding of boundary layer theory, turbulent boundary layer, modelling of turbulent flow, nonnewtonian fluid, fluidization phenomena.
2. Understanding of design aspects of fluidization.

Contents

Momentum theorem: Equations of change, ideal flow, Eulers equations of motion, velocity potential, rotational and irrotational flow; Navier-Stokes equation, poiseuille flow, creep flow and Couette flow. [8 Lectures]

Boundary layer: Boundary layer theory, integral momentum analysis, turbulent boundary layer, turbulence and mixing, universal velocity profile. [8 Lectures]

Stability analysis: Stability analysis of laminar flow, Orr-Sommerfield solution, transition to turbulence, detailed modeling of turbulent flow. [8 Lectures]

Laminar and turbulent flow: Non-newtonian fluid, rheological characteristics, consistency measurement, viscometric flow, pipe and annular flow, pipeline design equations. [8 Lectures]

Fluidization: The phenomena of fluidization and its industrial application, characteristics of particles, principle of fluidization and mapping of various regimes, two phase theory of fluidization, bubbles in fluidized bed, entrainment. fast fluidized bed. mixing, segregation and gas dispersion. heat and mass transfer in fluidized bed, solid-liquid fluidized bed and three phase fluidized bed, design of fluidized bed reactors. [10 Lectures]

Textbook

1. Kundu, P.K. and Cohen, I.M. (2016) *Fluid Dynamics*, Academic Press.
2. Muralidhar, K. and Biswas, G. (2005) *Advanced Engineering Fluid Mechanics*, Alpha Science

Reference Books

1. Deen, W.M., (2011) *Analysis of Transport Phenomena*, 2nd ed., Oxford.
2. Bird, R. B., Stewart, W. E. and Lightfoot, E. N., (2002) *Transport Phenomena*, 2nd ed, Wiley.
3. Kunni, B. and Levenspiel, O. (1991) *Fluidization Engineering*, Elsevier

Online Course Material

1. Advanced Fluid Mechanics, https://nptel.ac.in/courses/112/105/112105218/

Title	**Advanced Mass Transfer**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	An introductory course on Mass Transfer		

Objectives

The Instructor will:

1. Provide in-depth knowledge about multi-component distillation, minimum reflux ratio, total reflux, product distribution, flash vaporization, etc.

Learning Outcomes

The students are expected to gain:

1. Understanding of multi-component distillation, minimum reflux ratio, total reflux, product distribution, flash vaporization, etc.

Contents

Multicomponent mass transfer: Multicomponent distillation, determination of key components at minimum reflux ration by the method of Shiras. [8 Lectures]

Minimum reflux ratio by Underwoods method; Fenske equation for total reflux and computation of product distribution; Flash vaporization of feed to the distillation column; Rigorous methods of Lewis-Matheson, Thiele-Geddes, bubble point, sum rates method, Naphthali-Sandholm method. [10 Lectures]

Absorption with chemical reaction. [8 Lectures]

Simulation of cascade processes. [8 Lectures]

Recent developments in mass transfer and separation processes. [8 Lectures]

Text Book

1. Ross Taylor, R. Krishna, (1993) *Multicomponent Mass Transfer*, John Wiley & Sons.
2. Seader, Henley and Ropar (2011) Separation Process Principles, 3rd Edition Wiley.

Reference Books

1. Humphrey, J. L. and Keller, G. E., (1997), *Separation Process Technology*, McGraw- Hill, NY
2. Kister, H. Z., (1992), *Distillation Design*, McGraw-Hill.

Online Course Material

https://nptel.ac.in/courses/103/103/103103035/
https://nptel.ac.in/courses/103/104/103104046/
https://nptel.ac.in/content/syllabus_pdf/103103034.pdf

Title	**Advanced Heat Transfer**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	An introductory course on Heat Transfer		

Objectives

The Instructor will:

1. Provide in-depth knowledge about steady and unsteady state conduction in one-, two- and three-dimensional cases, forced convection, radiation heat transfer concepts, boiling heat transfer, liquid metal heat transfer etc.

Learning Outcomes

The students are expected to gain:

1. Understanding of about steady and unsteady state conduction in one-, two- and three-dimensional cases, forced convection, radiation heat transfer concepts, boiling heat transfer, liquid metal heat transfer etc.
2. Design of compact heat exchangers.

Contents

Conduction: General equation of change of energy. Steady and unsteady state conduction in one-, two- and three-dimensional cases. Finite difference method for steady and unsteady conduction. [8 Lectures]

Forced convention heat transfer: Analytical and semi- analytical solutions. Equations for velocity and temperature in vertical and horizontal planes for cylinders and spheres. [8 Lectures]

*Radiation heat transfer: C*oncepts. Angle factor calculations. Network method of analysis for radiation exchange. Radiation calculation through gases and vapors. [8 Lectures]

Design of compact heat exchangers. [4 Lectures]

Boiling heat transfer, liquid metal heat transfer. [8 Lectures]

Selected advanced topics on heat transfer. [6 Lectures]

Textbook

1. Ozisik, M.N., [2013], *Boundary Value Problems of Heat Conduction*, Dover Publications
2. Ghoshdastidar, P.S., [2012], *Heat Transfer*, Oxford Press.

Reference Books

3. Incropera, F. P. and Dewitt, D. P. [2006] *Fundamentals of Heat and Mass Transfer,* Wiley
4. Muralidhar, K. and Sundarrajan, T. [2003] *Computational Fluid flow and heat Transfer,* Alpha Science.

Online Course Material

2. Advanced Heat Transfer, https://nptel.ac.in/courses/103/105/103105052/

Title	**Capillarity and Wetting**	Number	CH7LXX
Department	Chemical Engineering	L-T-P (C)	3-0-0 (3)
Offered for	As prescribed for 700 level course	Type	Elective
Prerequisite	Basic course on Fluid dynamics		

Objective

The Instructor will:

1. Provide the knowledge about fundamentals of capillarity and wetting phenomena and help the students to understand many small scale phenomena occurring in nature.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basic concept of capillarity and wetting (Young Laplace law, Young equation, lubrication equation, Stokes equation);
2. Understand and apply the physical principles of static and dynamic wetting;

Contents

Introduction, scope and applications (1 Lecture)
Fundamentals (Molecular) of interaction force and interfacial tensions (2 Lectures)
Derivation of the fundamental equations of Young and Laplace (3 Lectures)
Wetting and molecular forces (disjoining pressure) (4 Lectures)
Wetting in external fields (2 Lectures)
Thin film flows and lubrication (5 Lectures)
stability and Instability analysis (Rayleigh Plateau, Rayleigh Taylor) (8 Lectures)
Contact line dynamics (5 Lectures)
Dewetting phenomena (4 Lectures)
Surface tension-driven flows (4 Lectures)
Basics of electrowetting (4 Lectures)

Text Book

1. Pierre-Gilles de Gennes, Francoise Brochard-Wyart, David Quere, 2003, *Capillarity and Wetting Phenomena,* Springer Science and Business Media, New York USA.

Reference Books

1. Pierre Lambert, 2013, *Surface Tension in Microsystems: Engineering Below the Capillary Length,* Springer.
2. Dieter Langbein, 2002, *Capillary Surfaces: Shape — Stability — Dynamics, in Particular Under Weightlessness,* Springer.

Online Course Material

1. Bhaskarwar A. N., *Interfacial Engineering*, NPTEL course material, Department of Chemical Engineering, Indian Institute of Techonology Delhi, https://nptel.ac.in/courses/103102016/

Title	**Principles of Electrochemical Engineering**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0 (3)
Offered for	B.Tech.	Type	Program Elective
Prerequisite	Basic knowledge of Thermodynamics		

Objectives

The Instructor will:

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

Learning Outcomes

The students are expected to have the ability to:

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

Contents

Basic Principles: Introduction to electrochemistry and fundamentals, Nernst equation, Electrode kinetics, Volta and Galvani potentials, electrochemical potential, electrochemical equilibrium, Enthalpy and Gibbs free energy calculation, solvation energy, ionic equilibrium. (6 lectures)

Cell potential: Electrochemical cell, standard electrode potential, Butler-Volmer formulation, Tafel equation, Pourbaix diagram, Activity Coefficients, Donnan potential, reversible electrode, Born model for ion-solvation energy, Batteries and Cell Chemistries. (7 lectures)

Ion-ion interactions and ionic transport: Debye-Huckel theory, activity coefficient of ionic solution, ion pair, Bjerrum theory and Fuoss theory, migration, extended Nernst-Planck equation, electrochemical mobility and its relation with diffusivity, Stokes-Einstein equation, ionic conductivity, transport number, Kohlrausch law. (12 lectures)

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

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

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

Textbook

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

Reference Books

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

Online Course Material

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

Title	**Kinetics & Theory for Polymers**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	Program Elective
Prerequisite	An introductory knowledge of polymers		

Objectives

The Instructor will:

1. Provide details on kinetics and theories relevant to polymer reactions as well as crystallization.

Learning Outcomes

The students are expected to:

1. Gain knowledge about the variety of reaction mechanisms for polymerization and their kinetics
2. Learn about the theories of polymer crystallization and it's kinetics

Contents

Polymerization reactions and classification [3 lectures]

Kinetics of Step Polymerization: polymerization reactions, Carothers theory for linear step polymerization, Statistical theory for linear step polymerization, Kinetics of step polymerization, Carothers theory for gelation, Statistical theory for gelation, Validation of theories [12 lectures]

Kinetics of Free Radical Polymerization: Reaction kinetics, polymerization processes, kinetics of living and ATRP polymerization [9 lectures]

Kinetics of Ionic Polymerization: Kinetics of cationic polymerization, kinetics of anionic polymeirzation [4 lectures]

Kinetics of Copolymerization: Reaction and kinetics [6 lectures]

Kinetics in Polymer Crystallization: Kinetics and mechanism, melting in semicrystalline polymers [8 lectures]

Textbook

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

Reference Books

1. Odian G., (2004) Principles of Polymerization, 4th Edition, Wiley Interscience

Title	**Catalytic Nanomaterials**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	Basic knowledge of Chemical Reaction Engineering		

Objectives

The Instructor will:

1. Provide knowledge about the nano-materials in catalysis applications

Learning Outcomes

The students are expected to:

1. Gain knowledge about the advancements in catalytic materials and their applications

Contents

Introduction: Nano materials in catalysis, nanomaterials' impact on catalysis, tailoring properties of nanocatalysts,controlling active sites on nano materials, applications. [9 lectures]

Nano-catalyst based Technologies and Catalysis: Fuel Cell, exhaust catalysts, gas sensors, photocatalysis. [10 lectures]

Nanocatalysis: catalysis by nanostructured metal particles, size-selective Fischer-Tropsch nanocatalyst, nano-catalyst precursors, dendrimer based nanocatalysts, olefin hydrogenation, nano-catalyst for heterogeneous catalysis. [14 lectures]

Synthesis of Nano-catalyst in Supercritical fluids: Properties of supercritical fluids, nanopowder catalysts synthesis in SCFs, supported nano-catalysts in SCFs, supercritical microfluidics for nano-catalyst synthesis. [9 lectures]

Textbook

1. Serp P., Philippot K., (2013) Nanomaterials in Catalysis, Wiley

Title	**Mechanics of Viscoelastic Materials**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	Basic knowledge of polymers or viscoelastic materials		

Objectives

The Instructor will:

1. Provide detailed knowledge of viscoelasticity and it's applications in various areas.

Learning Outcomes

The students are expected to:

Gain understanding of viscoelasticity, models for viscoelasticity and various viscoselastic materials.

Get motivated to pursue further studies and research in the area of visco-elasticity.

Contents

Viscoelasticity: Introduction, creep and relaxation, anelastic materials, examples, Mechanical models, Boltzmann superposition principle, dynamic mechanical testing, transitions and polymer structure, entanglements [6 lectures]

Constitutive Relations: Predicting response of linear viscoelastic materials, fading memory, relation between creep and relaxation and corresponding functions, time-temperature superposition, 3D linear constitutional equation, dielectric relaxation, adaptive and smart materials, non-linear viscoelasticity [10 lectures]

Dynamic Behavior of Linear Solids: Internal friction, linear dynamic response function, Kramers Kronig relation, hysterisis, lumped and distributed systems, wave propogation and attenuation, non-linear materials [8 lectures]

Linear Viscoelasticity and Viscoelastic Materials: Concepts, spectra, interrelations among spectra, theory of viscoelasticity, relaxation in amorphous and crystalline polymers, aging, piezo electric polymers, metals, ceramics, biological materials [20 lectures]

Textbook

1. Lakes R.S., (2009) Viscoelastic Materials, Cambridge University Press

Online Course Material

1. Deshpande, A., Rheology of Complex Materials, NPTEL Course Material, Chemical Engineering, IIT Madras, https://nptel.ac.in/courses/103/106/103106131/

Title	**Structure & Property for Polymers**	Number	CHL7XX0
Department	Chemical Engineering	L-T-P [C]	3-0-0
Offered for	BTech, MTech, PhD	Type	PE
Prerequisite	An introductory course on polymers for BTech, None for MTech		

Objectives

The Instructor will:

1. Provide knowledge about various structures in polymers and it's relation with the mechanical and thermal properties

Learning Outcomes

The students are expected to gain:

1. Understanding of structure-property for various polymeric systems
2. Understanding of thermal transition and deformation mechanisms in polymers

Contents

Introduction: Outline of the course, review of basics of polymers, polymerization reactions and classification [2 lectures]

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

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

Deformation in Polymers: Elastic deformation, stress-strain relationship, polymer chain deformation, crystal moduli, elastic deformation in semicrystalline polymers, yield and crazing – necking and its mathematical treatment, yield criteria, mechanisms, plastic deformation [9 lectures]

Viscoelasticity: Introduction, examples, Mechanical models, Boltzmann superposition principle, dynamic mechanical testing, transitions and polymer structure, t-T superposition, entanglements [9 lectures]

Polymer Composites: Matrix and fillers, composition, elastic deformation, fracture, packing, experiments, nanocomposites [5 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/