Indian Institute of Technology Indore

Curriculum and Courses of Study for Bachelor of Technology in Chemical Engineering and Minor Programs

April 2025

[After incorporating decisions of 53rd meeting of the Senate held on April 23, 2025]

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Sections and Course structure of 1st year BTech (from AY 2023-24 onwards)

Section-A (CSE+CE+MEMS+ChE+EP)			
Semester-I	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1
IC 152	Makerspace	1-0-6	4
CS 103	Computer Programming	2-0-0	2
IC 151	Computer Programming Lab	0-0-3	1.5
NO 101	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-3-11**	**22.5**

Section-B (EE+ME+MC+SSE)			
Semester-I	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2
ChE 201	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1
CS 103	Computer Programming	2-0-0	2
IC 151	Computer Programming Lab	0-0-3	1.5
NO 101	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-2-5**	**18.5**

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
CH 105	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-3-2**	**18**

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
IC 152	Makerspace	1-0-6	4
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-4-8**	**22**

Curriculum of 2nd Year B. Tech. (Chemical Engineering)
From AY 2024-25 onwards (Batch admitted in and after AY 2023-24)

Semester III

Course Code	Course title	Weekly contact hours (L-T-P)	Credits
ZZ 2XX	Course – I, Minor program	X-X-X	3
MA 205	Complex analysis and	3-1-0	2
MA 207	Differential equations	3-1-0	2
ChE 201	Chemical Engineering Thermodynamics	2-1-0	3
ChE 203	Transport Phenomena	2-1-0	3
ChE 205	Materials Science for Chemical Engineers	2-1-0	3
ChE 207	Chemical Process Calculations	2-1-0	3
ChE 2XX	Department Elective -1	2-1-0	3
ChE 251	Heat and Mass Transfer Lab	0-0-2	1
ChE 255	Materials Characterization lab	0-0-2	1
	Total	**13-6-4 (25)**	**21/24**

Semester IV
From AY 2024-25 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course title	Weekly contact hours (L-T-P)	Credits
ZZ 2XX	Course – II, Minor program	X-X-X	3
MA 204N	Numerical Methods	2-1-0	3
ChE 202	Fluid Mechanics	2-1-0	3
ChE 204	Chemical Reaction Engineering	2-1-0	3
ChE 206	Separation processes	2-1-0	3
ChE 252	Fluid Mechanics lab	0-0-2	1
ChE 254	Reaction Engineering lab	0-0-2	1
ChE 258	Computational Chemical Engineering Lab -1	0-0-3	1.5
ChE 2XX	Department Elective II	x-x-x	3
ZZ 2XX	Institute elective I	x-x-x	3
Total		12-6-4 (22)	21.5/24.5

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3rd Year B. Tech. (Chemical Engineering)
From AY 2025-26 onwards (Batch admitted in and after AY 2023-24)

Semester V

Course Code	Course title	Weekly contact hours (L-T-P)	Credits
ZZ 3XX	Course – III, Minor program	X-X-X	3
ChE 301	Process modeling	2-1-0	3
ChE 303	Fluid Particle Systems	2-1-0	3
ChE 305	Biochemical Engineering	2-1-0	3
ChE 307	Process Dynamics and Control	2-1-0	3
ChE 351	Bioprocessing lab	0-0-2	1
ChE 353	Unit operations Lab	0-0-2	1
ChE 3XX	Department Elective - 3	2-1-0	3
ZZ 3XX	Institute open elective - 2	2-1-0	3
	Total	**12-6-4 (22)**	**20/23**

3rd Year B. Tech. (Chemical Engineering) - Semester VI
From AY 2024-25 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course title	Weekly contact hours (L-T-P)	Credits
ChE 3XX	Computer-Aided Process Equipment Design	2-1-0	3
ChE 3XX	Process Dynamics, Instrumentation & Control	2-1-0	3
ChE 3XX	Chemical Process Technology and Intensification	2-1-0	3
ChE 3XX	Plant Design and Economics	2-1-0	3
ChE 3XX	Process Control lab	0-0-2	1
ChE 3XX	Computer-aided chemical Engineering lab – 2	0-0-2	1
ChE 3XX	Department Elective – 4	2-1-0	3
ChE 3XX	Department Elective – 5	2-1-0	3
ZZ 3XX	Institute open elective -3	2-1-0	3
Total		14-6-4 (24)	23

4th Year B. Tech. (Chemical Engineering)
From AY 2026-27 onwards (Batch admitted in and after AY 2023-24)

Semester VII

Course Code	Subject Name	Weekly contact hours (L-T-P)	Credits
CHE 493	**B Tech Project (BTP)** 1. Student can do BTech project either outside the institute or within the institute under a supervision of an IIT Indore Faculty. 2. The choice is to be made latest by 30th April. 3. Last Date of Thesis submission: 1st week of Dec. 4. Last Date of Submission of Grades: 2nd week of Dec.	0-0-32	16
CHE 4XX	Internship-I		1
CHE 4XX	Internship-II		1
Total		0-0-32 (32)	18

Semester VIII

From AY 2026-27 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course title	Weekly contact hours (L-T-P)	Credits
CHE 4XX	Department Elective – 6	2-1-0	3
CHE 4XX	Department Elective – 7	2-1-0	3
ZZ 4XX	Institute open Elective - 4	2-1-0	3
ZZ 4XX	Institute open Elective - 5	2-1-0	3
ZZ 4XX	Institute open Elective - 6	2-1-0	3
Total		10-5-0 (15)	15

List of the Elective Courses for BTech in Chemical Engineering

ChE 208 : Process Data Analytics & Monitoring (2-1-0-3)
ChE 209 : Introduction to Soft Matter and Polymers (2-1-0-3)
ChE 211: Waste to Energy Conversion (2-1-0-3)
ChE 309 : Energy System and Sustainability (2-1-0-3)
ChE 311 : Heat Transfer Operations (2-1-0-3)\
ChE 402/602 : Process Optimization (2-1-0-3)
ChE 404/604 : Advanced Soft Matter (2-1-0-3)
ChE 406/606 : Heterogeneous Catalysis and Reactor Design (2-1-0-3)
ChE 408/608 : Computational Synthetic Systems Biology (2-1-0-3

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Structure of the Minor programs for AY 2024-25 onwards (For all UG batches admitted in and after AY 2023-24)

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Liberal Arts From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Astronomy From AY 2024-25 (Batch Admitted in and after AY 2023-24)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 203: Psychology HS 205: Sociology HS 221 Fundamentals of	AA 201: Introduction to Astronomy

				Linguistics HS 223 Language Variation: Culture and Society	
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 214: History of Indian Culture and Civilization HS 213: Cognitive Psychology HS 224 Contemporary Short Fiction HS 226 Sociology of Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 321: History of Modern Indian Business	HS 311: Life and Thought of Gandhi HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications
6TH : Minor 4			HS 325: Industrial Organization	HS 315: Sociology of Science and Technology HS 328 Philosophy and Film HS 330 Graphic Literature	

7th : (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)

Syllabi
of

Chemical Engineering Courses

Course code	**ChE 201**
Title of the course	**Chemical Engineering Thermodynamics**
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	The course aims to provide students with an understanding of the fundamental principles of Thermodynamics targeted towards Chemical and Biological Processes.
Course Outcomes	● Appreciate the relevance and importance of thermodynamic principles. ● Application of Thermodynamic principles to chemical and Biochemical processes.
Course Content	**Module 1: Basic Concepts of Thermodynamics** Laws of Thermodynamics. Carnot's theorem, Concept of Entropy. Applications of first law to close and open systems; Thermodynamic cycles, PVT relations; Equations of state, S-R-K equation, Peng-Robinson equation. **Module 2: Thermodynamic properties of ideal and real fluids** Thermodynamic potentials, Maxwell's relations, Gibbs free energy as generating function; Residual properties; Heat, and work interconversion devices **Module 3.: Gibbs energy change calculations** Ideal gas mixtures, Fugacity of species in gaseous, liquid and solid mixtures: Predictive activity coefficient models, Combined equation of state and Excess Gibbs Energy model **Module 4: Phase Equilibria** Phase rule; Dew and bubble-point calculations; Flash calculations; Property estimation using VLE; Partial molar Gibbs energy and Gibbs-Duhem Equation; Phase equilibria in a multi-component system, Regular solution theory, Wilson equation, UNIFAC method, Thermodynamic properties of Reacting mixtures and the Heat of Reaction. **Module 5: Bio-Process Thermodynamics** Application of thermodynamic principles to biological systems and bioprocesses; Gibb's free energy change in bio reactions -

	photosynthesis, glycolysis, citric acid cycle; Thermodynamic analysis of osmosis, dialysis, Donnan equilibrium; Thermodynamic analysis of industrial bioprocesses
Suggested Books	**Textbooks** 1) J. M. Smith, H. C. Van Ness, M. M. Abbott, M. T. Swihart, Chemical Engineering Thermodynamics, McGraw Hill (2019), ISBN-13:978-9353168490 2) Y. V. C. Rao, Chemical Engineering Thermodynamics, 2nd Edition, University Press (2001), ISBN-13: 978-8173710483 **Reference books** 3) M. Ozilgen, E. Sorguven, Bio thermodynamics – Principles and Applications, CRC Press (2016), ISBN -13: 978-1466586093 4) R. J. Elliot, C. T. Lira, Introductory Chemical Engineering Thermodynamics, 2nd Edition, Prentice Hall, Pearson (2012), ISBN-13: 978-0136068549

Course code	ChE 202
Title of the course	Fluid Mechanics
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	The course aims to provide an introduction to the fundamental principles of fluid mechanics and their applications in the chemical engineering context.
Course Outcomes	• Basic understanding of fluid statics and dynamics • Analytical skills to solve various types of fluid flows
Course Content	**Module 1: Fundamental Concepts** Dimensions and Units, Fluid statics, vector and tensor analysis **Module 2: Fluid Flow Phenomena** Mass balance in a flowing fluid, differential momentum balance, equations of motion, laminar and turbulent flow, rheological properties of fluids, Poiseuille flow, boundary layers. **Module 3: Flow of Incompressible Fluids** Flow of incompressible fluids in pipes, Friction factor, Laminar flow of Newtonian and non-Newtonian fluids, Turbulent flow in pipes and closed channels, Effect of roughness, Friction factor chart, effect of fittings and valves, velocity heads, expansion and contraction losses. **Module 4: Introduction to Compressible Flow** Definitions and basic equations, Propagation of sound waves, isentropic, adiabatic and isothermal friction flow. **Module 5: Fluid Flow Measurement and Machinery** Transportation and metering of fluids. Fluid machineries: pumps, fans, blowers, compressors, measurement of flowing fluids. **Module 6: Flow past immersed objects** Drag and drag coefficients, Flow through packed beds, fluidization, sedimentation and rise of bubbles and drops

Suggested Books	**Textbooks** (1) R. W. Fox and A. T. McDonald, "Introduction to Fluid Mechanics", 8th ed., John Wiley & Sons (20011), ISBN: 978-81-265-1583-7 (2) R. B. Bird, W. E. Stewart, and E. N. Lightfoot, "Transport Phenomena", 3rd ed., John Wiley & Sons (2010), ISBN: 978-81-265-0808-2 (3) W. L. McCabe, J. C. Smith, and P. Harriott, "Unit Operations of Chemical Engineering", 4th ed., McGraw-Hill (2005), ISBN: 007-124710-6 **Reference Textbooks** (4) D. W. Green and R. H. Perry, "Perry's Chemical Engineers' Handbook",9th ed., McGraw-Hill (2018), ISBN: 0-07-142294-3

Course code	**ChE 203**
Title of the course	**Transport Phenomena**
Course Category	Core
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Objectives of the course	Understanding Mass, Momentum and Heat transfer in the context of Chemical Engineering Applications.
Course Outcomes	• Knowledge of fundamental principles underlying mass transfer, momentum transfer, and heat transfer. • Apply transport phenomena concepts to design of chemical processes and equipment. • Ability to formulate and solve mathematical models representing transport processes.
Course Content	**Module 1: Essential Mathematics and basic concepts** Vector and tensor analysis, Newton's law of viscosity, thermal conductivity and mechanism of energy transport, diffusivity and mechanism of mass transport, basic concept of classical momentum, heat, and mass transfer problems. **Module 2: Momentum Transport** Eulerian/Lagrangian motion, Reynolds transport theorem, Velocity distribution in laminar and turbulent flow, Fundamentals of boundary layer theory, Equations of continuity, Introduction to Navier - Stokes equation, Conservation of mechanical energy in fluids. **Module 3: Energy Transport** Temperature profiles in laminar and turbulent flow, Graetz problem with viscous dissipation, thermal boundary layer, conduction profile in solid under steady and unsteady conditions, equations of motion for free and forced convection. **Module 4: Mass Transfer** Basics of mass transport mechanism**,** shell balances of mass species diffusion under various driving forces, diffusion with chemical reaction, convective diffusion in dilute solutions, integral balances in momentum, heat, and mass transfer, concentration distributions in laminar flow; equation of continuity for a binary mixture and its application to convection-diffusion problems. concentration distributions under multiple variables.

	Module 5: Bio-Thermo-Fluidics and Transport Processes Fundamentals of momentum, heat, and mass transport as applied to biological systems; Rheology of Blood, Human body as a thermodynamic system, Fluid mechanical aspects of some diseases and organs.
Suggested Books	**Textbooks** 1) R.B. Bird, W. E. Steward, E. N. Lightfoot, Transport Phenomena, 2nd edition, John Wiley & Sons (2014), ISBN-13: 978-8126508082 2) J. L. Plawsky, Transport Phenomena Fundamentals, 4th edition, CRC Press (2020), ISBN-13: 978-1138080560 **Reference books** 3) P. A. Ramchandran, Advanced Transport Phenomena, Cambridge Univ Press (2014), ISBN-13: 978-0521762618 4) L.G. Leal, Advanced Transport Phenomena, Cambridge Univ Press (2007), ISBN-13: 978-0521849104

Course code	ChE 204
Title of the course	Chemical Reaction Engineering
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	The objective of this course is to study the kinetics of homogeneous and heterogeneous reactions and interpret the kinetic data to perform the design of chemical reactors.
Course Outcomes	• Ideal and non-ideal reactor systems • Design equations for isothermal and non-isothermal reactors. • Design methodology for multiple reactions.
Course Content	**Module 1: Kinetics of homogeneous reaction** Introduction to chemical reaction engineering, kinetics of homogeneous reactions, kinetic models, testing kinetic models, effect of temperature on reaction rates. Interpretation of batch reactor data, differential and integral methods of analysis of batch reactor data, half-life and fractional life methods. **Module 2: Ideal reactors and design for single and multiple reactions** Design of single homogeneous reactors: ideal reactors, design equations for ideal reactors, optimum reactor size problems, combination of ideal flow reactors, recycle reactor, autocatalytic reactions, series reactions, parallel reactions, series–parallel reactions **Module 3: Design of non-isothermal reactors** General graphical design procedure, steady state non–isothermal design of ideal reactors for single and multiple reactions, stability of reactor **Module 4: Non-Ideal Reactors and design of non-ideal reactor** Reasons for non–ideal flow, residence time distribution (RTD) functions, calculation of mean residence time and variance from the RTD data, limitation of RTD, Conversion in non–ideal reactors, tanks in series model, axial dispersion model. **Module 5: Heterogeneous reaction** Introduction to heterogeneous reactions, Classification of heterogeneous reaction, Introduction of non-catalytic fluid solid

	reaction, Shrinking core model, kinetics of solid catalyzed reactions, reaction and diffusion in porous catalysts, Thiele modulus and effectiveness factor.
Suggested Books	**Textbooks** (1) O. Levenspiel, Chemical Reaction Engineering, 3rd ed., John Wiley & Sons (2006), ISBN:9788126510009 (2) H. S. Fogler, Elements of Chemical Reaction Engineering, 3rd ed., Prentice Hall (2006), ISBN: 9780131278394 **Reference books** (3) J. M. Smith, Chemical Engineering Kinetics, 2nd ed., McGraw–Hill (1981), ISBN: 9780070665743

Course code	**ChE 205**
Title of the course	**Materials Science for Chemical Engineers**
Course Category	Elective
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Objectives of the course	The course aims to provide fundamentals of various classes of materials, microstructures, important properties, and their applications in various industries.
Course Outcomes	• Able to identify crystal structure and the important parameters. • Knowledge of key differences among various classes of engineering materials. • Understand the processing, structure, and properties relations of engineering materials.
Course Content	**Module 1**: Atomic bonding in solids and its influence on properties; Crystallography: Atomic Packing factor, Planar density, Linear density, Techniques for determining the crystal structure. Imperfections in crystalline solids and the characterization techniques **Module 2:** Gibbs phase rule, the transition from single to binary & multi-phase systems, Solidification principles: Nucleation and Kinetics, Solid Solution formation rules, a few important binary phase diagrams, Iron-Iron carbide phase diagrams, various classes of steels, Diffusion kinetics in materials **Module 3:** Mechanical properties of materials and the physics of deformation, strengthening mechanisms such as solid solution strengthening, Grain boundary strengthening, precipitation hardening, and failure in materials **Module 4:** Types, properties, and applications of polymeric, ceramic, and composite materials, Methods of fabrication of polymeric and composite materials. Viscoelastic properties, Kelvin-Voigt Model, Maxwell **Module 5:** Introduction to biomaterials, concept of biocompatibility, properties of biomaterials, bimetallic alloys, ceramic biomaterials, polymeric biomaterials.

Suggested Books	**Textbooks:** 1) W. D. Callister, Fundamentals of Materials Science and Engineering, John Wiley & Sons (2008), ISBN 13: 978-0470234631 2) M. Rubinstein, R. H. Colby, Polymer Physics, Oxford University Press, United Kingdom (2003), ISBN 13: 978-0-19-852059-7 **Reference Books:** 3) W. F. Smith, J. Hashemi, R. Prakash, Materials Science and Engineering, 4th Edition, McGraw Hill (2010), ISBN 13: 978-0073529240 4) Donald R. Askeland, Essentials of Materials Science and Engineering, 2nd edition, Wadsworth Publishing Co Inc. (2008), ISBN-13- 978-0495244462

Course code	ChE 206
Title of the course	Separation Processes
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	To introduce concepts, processes and equipments that are commonly utilized to separate different chemical and biological mixtures.
Course Outcomes	• Fundamental understanding of chemical engineering separation processes • Design of distillation equipments • Design of adsorption and stripping units • Introduction to separation processes employed in bioprocessing and biomanufacturing
Course Content	**Module 1: Fundamental concepts** Introduction to various chemical engineering separation equipments, Thermodynamics of Separation processes, Mass Transfer and Diffusion, Single Equilibrium Stages and Flash Calculations **Module 2: Absorption and stripping of mixtures** Equipment for Vapor-liquid separations, Design of packed tower, Counter-current multi-stage absorption, Absorption with chemical reactions, Adsorption processes, isotherms **Module 3: Distillation operations** Batch distillation, continuous fractionation, calculations with multiple feeds and withdrawals, MESH equations, McCabe-Thiele and Ponchon-Savarit Graphical Methods for trayed towers, Tray hydrodynamics and efficiencies, Multicomponent, multistage operations **Module 4: Liquid-Liquid extraction** Ternary phase diagrams, Examples of Solvent Extraction; Solvent Selection; Design Calculations.

	Module 5: Bioseparations Introduction to Bioseparations, Chromatography, Bioproduct Crystallization, Drying of Bioproducts, Electrophoresis, Membranes in Bioprocessing
Suggested Books	**Textbooks:** (1) J.D. Seader, E.J. Henley and D. Keith Roper, Separation Process Principles, 3rd ed, John Wiley & Sons (2013), ISBN 978-0470481837 (2) Treybal, R. E. Mass Transfer Operations. 3rd ed., McGraw-Hill (1980). ISBN: 9780070651760. (3) W. L. McCabe, J. C. Smith, and P. Harriott, "Unit Operations of Chemical Engineering", 4th ed., McGraw-Hill (2005), ISBN: 0071247106 **Reference books:** (4) Dutta, Binay K. Principles of mass transfer and separation processes. PHI Learning Pvt. Ltd., (2007), ISBN: 8120329902

Course code	**ChE 207**
Title of the course	**Chemical Process Calculations**
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Objectives the course	The course aims to provide students with an understanding of the fundamental principles of Material and Energy balances for Chemical and Biochemical Process Industries
Course Outcomes	• Basic knowledge of material and energy balances. • Applications of behavior of Solid, liquid, and gas to chemical and biochemical plants.
Course Content	**Module 1: Introduction to Material Balance** Principles of material balance and its calculation, material balance equation, balances on single and multiple unit processes without reaction, material balances on non-reactive processes, material balances on non-reactive processes with recycle and bypass, material balances on reactive processes, Solving linear simultaneous algebraic equations for applications in material balance and computer-based calculations. **Module 2. Properties of Gases and Liquids** State equation of ideal gas and non-ideal gases and calculation, Vapor-liquid equilibrium: bubble point, dew point calculations, phase envelope diagrams, saturation and humidity, Psychometric chart and its use, problem-solving Process of phase change: Condensation, vaporization. **Module 3. Energy Balance on Chemical Process Units** Mechanical energy balance: basic understanding, enthalpy balance without reaction, energy balances with multiple inlet and outlet streams, energy balances on reactive systems, energy balance with standard heat of reaction, enthalpy balances for heat of solution, computer-based calculations for energy balance. **Module 4. Combustion Calculations** Characteristics of solid, liquid, and gaseous fuels, combustion reaction, stoichiometric principles to calculate the theoretical air-fuel ratio for complete combustion, energy balance in combustion processes, and combustion efficiency.

Suggested Books	**Textbooks** 1) D. M. Himmeblau, J. B. Riggs, Basic Principles and Calculations in Chemical Engineering, 4^{th} Edition, Pearson (2012), ISBN-13-978-0132346603 2) O. A. Hougen, K. M. Watson & R. A. Ragatz, Chemical Process Principles, Material and Energy Balances, Part I, John Wiley (2004), ISBN-13- 978-8123909530 **Reference books.** 3) G. V. Rekliatis, Introduction to Material and Energy Balances, John Wiley & Sons (1983), ISBN-13- 978-0471041313 4) R. M. Felder and R.W. Rousseau, Elementary Principles of Chemical Processes, 3rd Edition, John Wiley & Sons (2004), ISBN-13- 978-0471687573

Course code	ChE 208
Title of the course	Process Data Analytics & Monitoring
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 - 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the course	This course refers to techniques and tools for making inferences and decisions based on data from process systems. These technologies and techniques are increasingly used by the process industries to make better decisions about operations and supply chains for achieving operational excellence.
Learning Outcomes	• Understand the importance of data analytics in chemical engineering • Apply statistical and machine learning techniques for process data analysis • Develop the ability to build predictive and prescriptive models for process engineering applications and real-time monitoring.
Course Content	**Module 1** – Introduction to Chemical Process Data Analytics, Types of process data (continuous, batch, discrete) in chemical industry, data sources and data quality issues in chemical processes, Data visualization, normalization, scaling and time-series analysis. **Module 2** -Multivariate Statistical Process Control techniques, Principal Component Analysis (PCA), Partial Least Squares (PLS). **Module 3** - Types of learning problems: Supervised, Unsupervised, Classification and Clustering- (K-nearest neighbors, Logistic regression, Support vector machines, Decision trees, Random forests, Boosting), Regression – Simple Linear regression, Multiple Linear Regression), Neural Networks for soft sensing, cross-validation and performance evaluation metrics **Module 4** – Problem based learning through various Practical Applications and Chemical Engineering Case Studies, Fault detection and diagnosis.

Suggested Books	**Textbooks** (1) T. Agami Reddy, Gregor P. Henze, Applied Data Analysis and Modeling for Energy Engineers and Scientists, 1st ed., Springer (2011), ISBN: 9781441996138 (2) M. Gopal, Applied Machine Learning,2nd ed., McGraw Hill (2022), ISBN:9789353160265 **Reference books.** (3) S. Sridhar, M. Vijayalakshmi, Machine Learning, 1st ed., Oxford University Press (2021), ISBN: 9780190127275

Course code	**ChE 209**
Title of the course	**Introduction to Soft Matter and Polymers**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the course	The course aims to provide students with an understanding of the forces governing the assembly of various soft materials such as synthetic polymers, proteins, colloids, gels, liquids, etc. along with their unique physicochemical properties
Learning Outcomes	• Demonstrate a thorough understanding of the assembly of soft materials such as colloids and polymers. • Understand the structure-property relationship for a variety of soft matter systems • Gain an appreciation for biological systems as living soft matter
Course Content	**Module 1: Fundamentals of Soft Matter** Everyday soft matter; Forces governing the assembly of soft matter; Experimental characterization techniques for soft matter; Thermodynamics and mechanical properties, such as viscoelasticity, of soft materials. **Module 2. Colloids** Types of colloids, Brownian motion, Intermolecular forces between colloids, sols, gels, food colloids. **Module 3. Polymers** Polymer chemistry; Thermodynamics of polymer solutions; Phase separation of polymer solutions; Polymer gels. **Module 4. Biological soft matter** Membranes, DNA, proteins. Protein folding and crystallization; Intrinsically disordered proteins and phase separation.

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Suggested Books	**Textbooks** 1) I. W. Hamley, Introduction to soft matter, synthetic and biological self-assembling materials, Wiley, Germany (2007), ISBN13: 978-0470516102 2) M. Rubinstein & R. H. Colby, Polymer physics. Oxford University Press, United Kingdom (2003), ISBN: 978-0-19-852059-7 **Reference books**. 3) T. McLeish, Soft Matter, A Very Short Introduction, Oxford University Press, United Kingdom (2020), ISBN: 9780198807131 4) D. F. Evans, H. Wennerström, The Colloidal Domain, Where Physics, Chemistry, Biology, and Technology Meet, VCH Publishers Germany (1999), ISBN: 3-527-89525-6 5) K. Dill, S. Bromberg, Molecular Driving Forces, Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience., CRC Press, United States (2010), ISBN: 9781136672996

Course code	**ChE 210**
Title of the course	**Introduction to Metabolic Engineering**
Course Category	Department Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 - 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	This course will cover engineering principles to optimize metabolic processes for the biomanufacturing of pharmaceuticals, fuels, and chemicals.
Course Outcome	● Understand the principles and applications of metabolic engineering ● Construct and solve mathematical representations of metabolic networks ● Analyze metabolic pathways to quantify the production of industrially important fuels and chemicals
Course Syllabus	**Module 1: Basics of metabolic engineering** Overview of cellular metabolism: central metabolic pathways such as glycolysis, TCA cycle, pentose phosphate pathway, other important biosynthetic reactions; Applications of metabolic engineering in biomanufacturing: pharmaceuticals, chemical bioprocesses etc. **Module 2: Models for cellular reactions** Jacob Monod model, feedback regulation. Thermodynamics of metabolic reaction networks. Regulation of enzymatic activity and concentration, Control of transcription and translation; Systems biology approaches. **Module 3: Flux Balance Analysis** Law of mass action, Building stoichiometric matrix, Stoichiometric network analysis, Constraint-based modeling. Examples using computer code. **Module 4: Metabolic flux analysis** Steady state and pseudo steady state assumptions; Solve linear programming problems related to metabolic networks; Isotope-based flux analysis; Examples using computer code.

Suggested Books	**Textbooks:** 1. Gregory N. Stephanopoulos, Aristos A. Aristidou and Jens Nielsen Metabolic Engineering. Principles and Methodologies, Elsevier, 1998. ISBN: 978-0080536286 **Reference books**: 2. Alon U. An introduction to Systems Biology: Design Principles of Biological Circuits. 2007. Chapman & Hall/CRC (Taylor & Francis Group) London. ISBN: 978-1439837177 3. Networks: An Introduction by M.E.J. Newman, Oxford University Press, 2018. ISBN: 978-0199206650

Course code	**ChE 211**
Title of the course	**Waste to Energy Conversion**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the course	The course deals with the production of energy from different types of wastes through thermal, biological and chemical routes.
Learning Outcomes	• Fundamental knowledge and understanding of current thoughts and newer technology options along with their advances in the field of the utilization of different types of wastes for energy production. • Analyze case studies to understand the success and challenges of various Waste to Energy technology options.
Course Content	**Module 1: Introduction** The Principles of Waste Management and Waste Utilization. Waste Management Hierarchy and 3R Principle of Reduce, Reuse and Recycle. Waste as a Resource and Alternate Energy source. **Module 2. Waste Sources & Characterization** Waste production in different sectors such as domestic, industrial, agriculture, post-consumer, waste, etc. Classification of waste – agro-based, forest residues, domestic waste, industrial waste (hazardous and non-hazardous), Characterization of waste for energy utilization, waste selection criteria. **Module 3. Technologies for Waste to Energy** Biochemical Conversion: Energy production from organic waste through anaerobic digestion and fermentation. Thermo-chemical conversion techniques: Combustion, Incineration and heat recovery, Pyrolysis, Gasification, and other newer technologies. **Module 4. Case Studies** Success/failures of waste to energy; Global Best Practices in Waste to Energy Production Distribution and use.

Suggested Books	**Textbooks** 1) M. J. Rogoff and F. Screve, "Waste-to-Energy, Technologies and Project Implementation", Elsevier Store. William Andrew (2019), ISBN-13- 978-0128160794 **Reference books**. 2) G. C. Young, Municipal Solid Waste to Energy Conversion Processes - Economic Technical and Renewable Comparisons, Economic, Technical, and Renewable Comparisons, John Wiley and Sons. (2010), ISBN-13- 978-0470539675 3) J. H. Harker and J. R. Backhusrt, "Fuel and Energy", Academic Press Inc. (1997), ISBN-13- 978-0123252500 4) M.M. EL-Halwagi, "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science. (2014), ISBN-13- 978-9401084161

Course code	**ChE 251**
Title of the course	**Heat and Mass Transfer Lab**
Course Category	Core
Credit Structure	L - T - P - Credits 0 – 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the Lab	Introduce the students to the basics of heat and mass transfer
Learning Outcomes	• Understand the nuances in the experimental measurement in Heat and Mass transfer
Course Content	**List of representative experiments:** 1. Determine the unsteady state heat transfer by lumped capacitance. 2. Determine the heat transfer in the process of condensation and by free and forced convection. 3. Investigating the drying characteristics of a solid under forced draft condition 4. Examining the heat transfer in a Pin-Fin (by natural & forced convection) and the radiation heat transfer by the black body and the effect of hemisphere temperature on it 5. Evaluate the heat transfer through conduction in metal rods of different materials and Parallel flow/counter flow heat exchangers. 6. Demonstrate the super thermal conductivity of Heat pipe and compare its working with the best conductors. 7. Evaluate the critical flux in the Pool boiling apparatus using in-situ method 8. Operational principle of a Rotary dryer 9. Mass transfer operations in the water-cooling tower for different flow and thermodynamic conditions. 10. Dissolution characteristics of benzoic acid in water and aqueous solution of sodium hydroxide. 11. Adsorption in a packed bed for a solid-liquid system 12. Effect of temperature on the diffusion coefficient 13. Demineralization of water using two bed system

Suggested Books	Y. A. Cengel, A. J. Ghajar, Heat and Mass Transfer: Fundamentals and Applications, McGraw Hill; 6th Edition (2020), ISBN-13: 978-9390185283

Course code	ChE 252
Title of the course	Fluid Mechanics Lab
Course Category	Core
Credit Structure	L - T - P - Credits 0 – 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the Lab	To augment the principles learned in the theory component,and understand flow through various geometries as well as the functioning of flow measuring equipment.
Learning Outcomes	• Understand pressure loss occurring in various pipe fittings • Decide appropriate choice of pumping and flow measuring equipment for various applications • Basic understanding of flow visualization through the use of simulation packages.
Course Content	**List of representative experiments:** • Determination of viscosity using Stokes' law • Experiment to characterize the Reynolds-number-based transition from laminar to turbulent flow regime. • Experiment to understand pressure drop, by calculating equivalent length of pipe fittings. • Experiment for the calculation of friction in annulus of a circular pipe. • Use of a venturimeter and orifice meter for flow measurement in pipe flow. • Determining the performance characteristics of a centrifugal pump. • Determining the discharge coefficient for flow through a rectangular notch. • Flow visualization through Virtual Lab experiments.
Suggested Books	**Textbooks** (1) V. Gupta, S. K. Gupta, "Fluid Mechanics and Its Applications", New Age international Private Ltd (2015), ISBN:

	9788122439977 (2) F. M. White, "Fluid Mechanics",7th Ed., McGraw Hill (2022), ISBN: 9789355322043

Course code	ChE 254
Title of the course	Reaction Engineering Lab
Course Category	Core
Credit Structure	L - T - P - Credits 0 – 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the Lab	Introduce the students to the basics of reactors design
Learning Outcomes	• Understand the nuances in the chemical reactors
Course Content	**List of representative experiments:** • Determine the rate using iso-thermal batch reactor. • Study the reaction rate using semi-batch reactor • Determine the reaction rate for liquid phase reaction in a Continuous Stirred Tank Reactor (CSTR). • Calculate the rate of reaction for homogeneous reaction in a straight tube reactor. • Determine the reaction rate for homogeneous reaction in a coil tube flow reactor • Experiments with CSTR connected in series. • CSTR and Plug flow in series and parallel. • Determine Residence Time Distribution (RTD) in a CSTR. • Determine RTD in a Plug Flow Reactor (PFR). • Determine RTD in a Packed bed reactor
Suggested Books	**Textbooks:** (1) O. Levenspiel, Chemical Reaction Engineering, 3rd ed., John Wiley & Sons (2006), ISBN:9788126510009

Course code	**ChE 255**
Title of the course	**Materials Characterization lab**
Course Category	Core
Credit Structure	L - T - P - Credits 0 – 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Scope of the Lab	● Introduce the students to various mechanical, thermal and microstructure characterization techniques. ● Analysis of the data and establish a correlation between the structure and properties of various material systems
Learning Outcomes	● Evaluate the microstructure and mechanical properties of materials. ● Analyze the experimental data in terms of various empirical and phenomenological models. ● Able to design and conduct experiments to understand various properties of materials.
Course Content	**List of representative Experiments** (1) Determination of crystal structure of given metals using X-ray diffraction. (2) To determine the hardness of various materials (3) Determination of mechanical properties of different materials such as yield strength, elastic modulus, and strain hardening behavior. (4) To determine the microstructure of low, medium, and high-carbon steels (5) Determination of glass transition temperature of polymers and understanding the effect of rejuvenation. (6) Investigate the rheological properties of various polymers. (7) Determine the phase transformation temperature in steels and shape memory alloys. (8) Steady simple shear experiments to obtain the viscosity of polymer solutions. (9) Small Amplitude Oscillatory Shear (SAOS) experiments to measure storage and loss modulus of polymer solutions and blends.

Suggested Books	1) C. Suryanarayana, Experimental Techniques in Materials and Mechanics, CRC Press; 1st edition (2011) ISBN: 978-1439819043

Course code	ChE 402/602
Title of the course	**Process Optimization**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 - 3
Pre-requisite, if any	None
Scope of the course	Learning constrained and unconstrained optimization techniques and their implementations in Process Applications
Learning Outcomes	• Able to formulate optimization problems, identify objective functions and constraints, and classify optimization problems. • Apply linear programming to solve process optimization problems for maximum efficiency, productivity, and profitability. • Solve different class of optimization problems (both numerically and coding)
Course Content	**Module 1 - Introduction to Process Optimization**: Problem formulation, Convexity, Hessian and properties, Unconstrained single variable optimization-Line search, Trust region methods, inexact line search -AC, CC and WC conditions with examples **Module 2 - Unconstrained multivariable optimization techniques**- Steepest Descent, Newton Method, Quasi-Newton Method, Conjugate Gradient Method with example process applications **Module 3 - Constrained Optimization** – Active constraints, Lagrange Multipliers, KKT Matrix, Equality Constrained Quadratic Programming (ECQP) Problem, Inequality Constrained Quadratic Programming (ICQP) Problems, Active-Set Method, Successive Quadratic Programming Methods (SQP). **Module 4 - Linear Programming (LP) Problems** - formulation, simplex method, Primal and Dual Problems, Integer Programming basics.

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Suggested Books	**Textbooks** 1. T. F. Edgar, D. M. Himmelblau, Optimization of Chemical Processes, McGraw-Hill International Edition, (1989). ISBN: 0070393591 **Reference books** 2. J. Nocedal, S. J. Wright, Numerical Optimization, Springer, (1999). ISBN: 0387303030

Course code	ChE 404/604
Title of the course	**Advanced Soft Matter**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Prerequisite, if any	None
Scope of the course	The course aims to use the principles of statistical mechanics to understand the properties of colloidal dispersions, polymeric solutions, and gels.
Course Outcomes	● Calculate the static and dynamic properties of colloidal dispersions, polymeric solutions and gels. ● Numerically solve the equations governing the dynamics of soft matter systems.
Course Content	**Module 1: Introduction and basic definitions** Probability and combinatorics, microcanonical and canonical ensembles, entropy and the Boltzmann Law, Partition function, Microscopic dynamics: Brownian motion, random walks, fluctuation-dissipation theorem, Smoluchowski equation, Langevin equation, time correlation function and response function. **Module 2: Polymer models and equilibrium properties** Ideal chain models, radius of gyration, distribution of end-to-end vectors, force-extension relationship, size measurement by scattering, structure factor, excluded volume and self-avoiding walks, osmotic pressure. **Module 3: Dynamics of polymeric solutions** Definitions of theta, poor and good solvents, Rouse model, Zimm model, Normal mode analyses, material functions, entangled polymer dynamics, dynamics of rod-like and liquid crystal molecules. **Module 4: Networks and Gelation** Branched chains, Gelation: concepts and definition, percolation theory, Mean-field model of gelation, gel point. **Module 5: Polymer kinetic theory and numerical implementation** Stochastic differential equations and connection to Smoluchowski/Fokker-Planck equations, stochastic calculus

	principles, Brownian dynamics simulations.
Suggested Books	**Textbooks** 1. K. A. Dill and S. Bromberg, Molecular Driving Forces, 2nd edition, Garland Science (2010), ISBN: 978-0815344308 2. M. S. Doi and S. F. Edwards, The Theory of Polymer Dynamics, Oxford University Press (1988), ISBN: 978-0198520337 3. M. Rubinstein and R. H. Colby, Polymer Physics, Oxford University Press (2003), ISBN: 978-0198520597 **Reference books** 4. R. B. Bird, C. F. Curtiss, R. C. Armstrong, O. Hassager, Dynamics of Polymeric Liquids: Vol 2, 2nd edition, John Wiley & Sons (1987), ISBN: 978-0471802440

Course code	ChE 406/606
Title of the course	**Heterogeneous catalysis and reactor design**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Pre-requisite, if any	Null
Course objective	• The course is intended to familiarize the students with concepts of gas-solid catalytic reactors • Concepts of catalysis kinetics and mechanistic aspects of catalysts • Design consideration of catalytic reactors
Course Outcomes	• To identify regions of mass transfer control and reaction rate control and calculate conversion • Predict the rate controlling step for the fluid - particle reactions • develop conceptual framework for designing catalytic reactors.
Course Content	**Module 1: Heterogeneous catalysis** Introduction to Catalysis, Catalysts, Physical properties of catalyst, surface area, void volume, solid density, pore volume distribution, Classification and preparation of catalyst, catalyst promoters. Catalyst inhibitors, Catalyst poisons, Nature and Mechanism of Catalytic reactions **Module 2: Solid Catalyzed reaction** Adsorption isotherms and rates of adsorption and desorption. Kinetic regimes, rate equations for surface kinetics, Pore diffusion, determining rate controlling step, experimental methods for finding rates, product distribution in multiple reactions **Module 3: Catalytic reactors** Catalytic reactions, introduction to LHHW (Langmuir-Hinshelwood-Hougen-Watson) and Eley Rideal kinetic model, introduction to Catalytic Reactors: Packed bed catalytic reactors, fluidized bed reactors, trickle beds, slurry reactors. **Module 4: Reactor design** Design concepts, Mass transfer correlations for various reactors, non-isothermal interphase effectiveness factor. Case study for industrial reactors design

Suggested Books	**Textbooks** 1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall (2006), ISBN: 978-0131278394. 2. Froment, G.B., and K.B. Bischoff, Chemical Reactor Analysis and Design, 2nd Ed., Wiley,(1990), ISBN:9780470565414 **Reference books** 3. J. M. Smith, Chemical Engineering Kinetics, 3rd ed, McGraw–Hill (1998), ISBN: 978-0070665743 4. O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons (2006), ISBN:978-8126510009

Course code	ChE 408/ 608
Title of the course	**Computational Synthetic Systems Biology**
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Pre-requisite, if any	None
Course objective	The objective of this course is to understand the fundamental principles of systems biology and its application to biological systems, and to investigate and analyze various biomolecular networks, including metabolic networks, signaling pathways, and gene regulatory networks.
Course Outcomes	At the end of the course, the student would be able to appreciate the need for taking a systems approach to biology and get familiarized with the mathematical and computational tools to approach biochemical systems
Course Content	**Module 1: Introduction to systems biology** Introductory and basic concepts in biology: central dogma, transcription, translation, enzymatic catalysis; Overview of systems biology-the need for a systems approach to biology, comparison with traditional biology, self organization in biological systems. **Module 2: Biological networks** Types of biological networks such as gene regulatory, signaling and metabolic networks. Metabolic networks and flux analysis; Analysis of large networks: Basic concepts of graph theory - degree distribution, clustering coefficient, pathlength, shortest path, Betweenness centrality; Random Networks - Erdös-Rényi Model**.** **Module 3: Mathematical modeling of biological networks** ODEs for modeling dynamic systems and parameter estimation; Stochastic modeling of gene expression and biochemical reactions: Chemical Master equations, Numerical simulations – Monte Carlo simulations (Gillespie algorithm) **Module 4: Enzyme kinetics** Inducer and repressor binding, Cooperativity and Inhibition, hill kinetics, Michaelis-Menten kinetics. **Module 5: Synthetic biology tools and techniques**

	Introduction to synthetic biology: principles, design-build-test cycle; synthetic gene circuits: oscillators, switches and logic gates; Synthetic pathways: metabolic engineering, bioproduction
Suggested Books	**Textbooks** 1. Alon U. An introduction to Systems Biology: Design Principles of Biological Circuits. Chapman & Hall/CRC (Taylor & Francis Group) London, (2007). ISBN: 1584886420 **Reference books** 2. Philip Nelson, Biological Physics: Energy, Information, Life. W. H. Freeman. (2007). ISBN: 978-0716798972 3. Newman, Mark. Networks: An Introduction. Oxford university press, (2018), ISBN: 978-0199206650

Course code	ChE 301
Title of the course	Process Modelling
Course Category	Core
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• To study the modeling of chemical engineering processes such as mixers, separators, and reactors. • To understand the classification of emerging models into steady/unsteady, linear/non-linear, and lumped/distributed models. • Understand and select the appropriate solution methods for each type of models arising in a variety of unit operations.
Course Outcomes	At the end of the course, students will be able to • Develop model building skills and computer aided solution skills, through application in chemical engineering systems. • Understand how general process simulators are built.
Course Content	**Module 1: Introduction** Introduction to engineered systems and their mathematical models. Classification of equation commonly arising in process engineering applications in the order of progressive complexity into linear and nonlinear algebraic equations (AE), dynamic, lumped models (ordinary differential equations-initial value problems, ODE-IVP), steady state 1-D distributed models (ordinary differential equations-boundary value problems – ODE-BVP), and dynamic, distributed models (partial differential equations, PDE) **Module 2: Steady state lumped models – (AE)** Separation processes: Stage-wise separation processes with applications in distillation, absorption. Transport processes: complex pipeline networks, steady state diffusion/conduction operations. Reaction processes: reaction and reactor networks. Sources of non-linearity arising in these models from thermodynamics, reaction kinetics models, advection processes. **Module 3: Unsteady lumped models: (ODE-IVP)** These are processes where spatial variation are ignored, but time

	variation is important. Typical applications in process engineering: thermometer systems, mixing tanks, transient mass & energy balance in reaction networks. Linearized models for process control applications. **Module 4: Steady state distributed models: (ODE-BVP)** These are models where spatial variation in one dimension is important leading to ordinary differential equations with boundary values. Transport processes: Blasius equation for boundary layers, fully developed flow in channels - Navier-Stokes equations. Separation processes: Two-film models. Heat-mass transfer and reaction process in one-Dimension (coupled ODE-BVP). Reaction processes: combined mass transfer and reaction in one-dimensional slab. models for combustion in 1D. **Module 5: Distributed-dynamic models: (PDE)** Transport phenomena: Developing flow in channels, Forced and natural convection heat transfer in pipes, Taylor-dispersion, mass transfer around submerged particles. Reaction engineering: Reaction-diffusion in catalyst pellets, packed bed reactor models.
Suggested Books	**Textbooks** 1. B. K. Dutta, "Mathematical Methods in Chemical and Biological Engineering," 1st edition, Apple Academic Press Inc. (2016), ISBN: 978-1482210385 2. S. Pushpavanam, "Mathematical Methods in Chemical Engineering", 1st edition, Prentice-Hall (1998), ISBN: 978-8120312623 **Reference books** 3. W.L. Luyben, "Process Modeling, Simulation, and Control for Chemical Engineering", 2nd edition, McGraw-Hill (2013), ISBN: 978-0070391604 4. M. M. Denn, "Process Modeling", 1st edition, Longman Higher Education (1986), ISBN: 978-0273087045

Course code	ChE 303
Title of the course	Fluid Particle Systems
Course Category	Core
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• To study the physical mechanisms occurring in processes involving solid-fluid particles, formulating and solving mathematical descriptions of such processes. • To understand the design of solid-fluid particle systems.
Course Outcomes	The students will be able to • Understand fluid-solid interactions, governing equations, and transport phenomena. Analyze flow regimes in packed and fluidized beds. • Design and optimize equipment like cyclones, sedimentation tanks, and fluidized beds.
Course Content	**Module 1: Introduction of particulate sizes and shapes** Properties and handling of particulate solids: Characterization of solid particles, shape and size, mixed particle size analysis, specific surface of mixtures, average particle size, screen analysis and standard screen series. **Module 2: Size reduction of solids, transportation and storage** Principles of comminution, energy relationship in size reduction, power requirement, work index, equipment-crushers, grinders, ultra-fine grinders different types of conveyers and storage of solids **Module 3: Solid-fluid operation** Drag coefficient, free and hindered settling, Sink and float method, classifiers and thickness, cyclones, hydro-cyclones, centrifuges. **Module 4: Solid-fluid separation: Filtration** Theory of filtration and filtration equipment, Principles of Cake filtration: Pressure drop calculations, constant rate filtration, constant pressure filtration and principles of centrifugal filtration. **Module 5: Fluidization:** Minimum fluidization velocity, relevant particle properties, types of fluidization liquid- solid and gas-solid systems

Suggested Books	**Text books** 1. W. McCabe, J. C. Smith, P. Harriot, Unit Operations of Chemical Engineering, 7th Ed - McGraw Hill (2017). ISBN: 978-9355321084 2. A.K Swain, H Patra, G.K Roy, "Mechanical Operations", 2nd edition. McGraw Hill (2017). ISBN: 978-0070700222 **3.** D. Kunii, O. Levenspiel, "Fluidization Engineering", 2nd edition. Butterworth-Heinemann (1993), ISBN: 978-0409902334 **Reference books** 4. D.W Green, M.Z Southard, "Perry's Chemical Engineers HandBook", 9th edition, McGraw Hill (2019), ISBN: 978-0071422949 5. J.F. Richardson, J. H. Harker and J. R. Backhurst, Coulson & Richardson's Chemical Engineering Volume:2, 5th edition, Elsevier (2018). ISBN: 978-0750644457

Course code	ChE 305
Title of the course	Biochemical Engineering
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• To teach students about the fundamentals of biochemical engineering • Understand how biological systems can be harnessed to produce specific bioproducts
Course Outcomes	At the end of the course, the students would be able to: • Learn the basics of biochemistry, • Get a deep understanding of the design and operations of bioreactors.
Course Content	**Module 1: Introduction to Biochemistry and Microbiology** Review of Structure of cells, important cell types, cell fractionation; Lipids, Sugars and Polysaccharides, Nucleotides, RNA and DNA, Amino acids and Proteins, Structure of proteins; Hierarchy of cellular organization. **Module 2: Kinetics of Enzyme-catalyzed reaction** Enzyme-substrate complex and enzyme action, Michaelis-Menten kinetics, Two substrate reactions and cofactor activation, Modulation and regulation of enzyme activity, enzyme deactivation, Applications of enzyme catalysis, Immobilized enzyme technology, directed evolution of enzymes. **Module 3: Metabolic stoichiometry and energetics** Thermodynamic principles, metabolic reaction coupling with examples, photosynthesis, biosynthesis of small molecules and macromolecules, Metabolic organization and regulation, Stoichiometry of cell growth and product formation. **Module 4: Design and Analysis of biological reactors** Ideal bioreactors: Fed-batch reactors, enzyme-catalyzed reactions in CSTRs, Ideal plug-flow tubular reactor; Reactor dynamics: dynamic

	models, stability; Reactors with nonideal mixing: mixing times in agitated tanks, residence time distributions, models for non-ideal reactors, mixing-bioreaction interactions. Sterilization reactors, Multiphase bioreactors. Fermenter design and operation. Instrumentation and control in bioreactors, bioprocess economics with specific examples.
Suggested Books	**Text books** 1. J.E Bailey and D.F Ollis, "Biochemical Engineering Fundamentals", 2nd edition McGraw Hill (2017), ISBN: 978-0070701236 2. S. Katoh, J. Horiuchi, F. Yoshida, "Biochemical Engineering: A textbook for Engineers, Chemists and Biologists", 2nd ed. Wiley-VCH (2015), ISBN: 978-3527684984 **Reference books** 3. P. F. Stanbury, A. Whitaker, J.H Stephen, "Principles of Fermentation Technology", 2nd Edition. Butterworth-Heinemann, (2016) ISBN: 978-0080999531. 4. D. S. Clark. H.W. Blanch, "Biochemical Engineering", 2nd Edition, Taylor and Francis (1997), ISBN 978-0824700997

Course code	ChE 307
Title of the course	Process Dynamics and Control
Course Category	Core
Credit Structure	L - T - P - Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• To impart knowledge about the dynamics and control strategies for linear and non-linear processes along with control instrumentation.
Course Outcomes	At the end of the course, the students would be able to • Develop and analyze dynamic models of chemical processes. • Design and tune different types of controllers to implement process control strategies. Analyze process stability and performance under disturbances. • Select and integrate appropriate sensors and actuators for process monitoring and control.
Course Content	**Module 1: Introduction to Process Dynamics** First Principles model development, linearization and transfer function models, Process dynamics for first, second and higher order systems for various input signals, effect of poles, zeros and time delays on system response, Empirical models from data. **Module 2: Stability Analysis and controller design** Introduction to feedback control objectives, PID (Proportional Integral Differential), control, analysis of closed loop systems: stability (Routh-Hurwitz test), root locus, PID Tuning methods, and controller performance evaluation (ISE, IAE, ITAE) **Module 3: Process control measurement and final control element** Principles of measurement for various process parameters (Temperature, pressure, flow, level, and composition), types of sensors and transmitters (RTDs, thermocouples, flow meters, etc.), actuators and control elements (valves, pumps), on-off control, valve gains.

	Module 4: Frequency response and advanced control strategies frequency response using Bode and Nyquist plots, control design techniques, design criteria, time and frequency domain techniques, model based design, tuning, advanced control strategies- cascade and feed forward, introduction to multivariable control, controller implementation through discretisation.
Suggested Books	**Textbooks** **(1)** D.E. Seborg, T.F. Edgar, D. A. Mellichamp, "Process Dynamics and Control", 4th edition John Wiley and Sons, (2021), ISBN: 978-9354248429 **(2)** D. R Coughanowr. S. LeBlanc, "Process System Analysis and Control", 3rd edition., McGraw Hill. (2008), ISBN: 978-0073397894 **Reference books** **(3)** G. Stephanopoulos, "Chemical Process Control – An Introduction to Theory and Practice", 4th edition Prentice-Hall of India. (2015), ISBN: 978-9332549463 **(4)** C. D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson Education (2005), ISBN (978-0131194571)

Course code	ChE 309
Title of the course	Energy Systems and Sustainability
Course Category	Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 - 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
course	The course aims to provide students with an understanding of the Global Energy scenario along with the critical aspects of Sustainability in this connection.
Learning Outcomes	• Understanding of the present global energy systems, why sustainable energy matters and • How to achieve the transition to low-carbon energy systems in order to meet the global energy demand in a clean, safe and sustainable way.
Course Content	**Module 1: Introduction of Energy Systems and Sustainability** Overview of the present energy systems and its sustainable development. Exploration of why sustainable energy system matters. Comparison of different perspectives or factors that may shape energy systems into the immediate future. **Module 2: Primary Energy** The common feature of all the primary energy sources is that they are naturally occuring energy stores or energy carriers. Global primary energy sources: Fossil fuels, Biomass, Nuclear, Wind power, Solar and other renewables, environmental impact. **Module 3.: Energy Usage** Primary, final and useful energy. The expanding uses of energy: Domestic or residential, Industry, Transport and services. International comparisons: Energy and GDP and expanding uses of electricity. Efficiency of energy utilization. The expanding horizon of hydrogen energy – production, storage and utilization. **Module 4.: Cost of Energy** Energy Costing, Affordability and fuel poverty. Investment in Energy. Energy Security and Diversity of supply. Imbalances between supply and demand of energy. Encouraging energy efficiency with fuel taxes. New Energy technologies and economics of scale. Pattern of changes in energy cost in developed and developing economy.

	Module 5.: Environmental and Heath impact of Energy Use Classification of the impact of energy use: scale, source and public concern. Air quality related impacts. Accidents across the fuel chains: coal, oil & gas, hydro power, wind power, nuclear power, biomass; Global warming, climate change and related issues. **Module 6.: Towards Sustainable Energy Future** Cleaning up fossil fuels, decarbonization, reducing energy demand, harnessing renewable energy, increased use of nuclear power; Hydrogen, the fuel of the future.
Suggested Books (Text Books, Reference Books)	**Text book** 1. B. Everett, S. Peake, J. Warren, "Energy Systems & Sustainability: Power for sustainable future", 3rd Edition, Oxford, (2021), ISBN 978-0198767640 **Reference books** 2. B.M Albert, J. Dee, "Energy Unlimited: Four Steps to 100% Renewable Energy", 1st Edition, Barbara Albert (2017), ISBN 978-0994577702 3. T. B. Johansson, H. Kelly, A.K.N. Reddy, R. H. William, "Renewable Energy- Sources for fuels and Electricity" 2nd edition, Island Pr (1992), ISBN 978-1559631396

Course code	ChE 311
Title of the course	Heat Transfer Operations
Course Category	Elective
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	Basics of transport phenomena
Course objective	• To understand and model heat transfer processes in chemical engineering plants and utilize the concepts for designing heat transfer equipment.
Course Outcomes	At the end of this course, students will be able to: • Set up and solve mathematically model heat transfer problems; and • Design and analyze the performance of heat exchangers and evaporators
Course Content	**Module 1: Conduction** General conduction equation in orthogonal coordinate systems, steady-state and transient heat conduction, conduction with thermal energy generation, Lumped Capacitance Method. **Module 2: Convection** Heat transfer correlations for natural and forced convection, thermal boundary layer, internal and external forced convection in laminar and turbulent flow. **Module 3: Boiling, Condensation and Evaporation** Regimes in pool boiling, correlations in film and drop condensation, single- and multi-effect evaporators. **Module 4: Heat Exchangers** Overall heat transfer coefficient, LMTD correction factor, fouling factor, Effectiveness-NTU method, types of heat exchangers: double-pipe, shell-and-tube, spiral and plate, extended surface, compact. **Module 5: Radiation and Extended Surfaces** Radiative heat exchange between surfaces, view factor, different types of fins, heat transfer through a fin, fin efficiency.

Suggested Books	**Textbooks** (1) F. P. Incropera and D. P. DeWitt, “Fundamentals of Heat and Mass Transfer”, 5^{th} edition, Wiley India Pvt Ltd (2007), ISBN: 978-8126512614 (2) A. M. Flynn, T. Akashige and L. Theodore, “Kern’s Process Heat Transfer”, 2^{nd} edition, Wiley (2019), ISBN: 978-1119364825 **Reference Textbooks** (3) J. P. Holman and S. Bhattacharya, “Heat Transfer”, 10^{th} edition, McGraw-Hill (2017) ISBN: 978-0071069670 (4) C. J. Geankoplis, “Transport Processes and Separation Process Principles”, 4^{th} edition, Pearson Education India (2015), ISBN: 978-9332549432

Course code	ChE 353
Title of the course	Unit Operations Lab
Course Category	Core
Credit Structure	L - T - P - Credits 0– 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• The objective of this course is to teach students about the experimental techniques and tools employed in chemical industries
Course Outcomes	• Design a mixed tank, calculate its power requirements • Characterize particles and bulk solids through basic techniques such as average particle size and settling velocity • Describe the operation of filter processes and types of filters used to perform solid-liquid separations

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Course Content	List of representative experiments • Determine the average particle size of a given mixture using different methods. • Determine the size reduction ratio of particles through an experiment with a jaw crusher. • Determine the size reduction ratio and critical speed through an experiment with a ball mill. • Analyze the settling characteristics of slurry. • Examine solid-fluid separation using a cyclone separator. • Examine solid-fluid separation using a centrifuge. • Explore the operation of a plate and frame filter press. • Explore the operation of a rotary vacuum filter. • Explore the operation of a belt conveyor.
Suggested Books	**Reference book** 1. J.F. Richardson, J. H. Harker and J. R. Backhurst, Coulson & Richardson's Chemical Engineering Volume:2, 5th edition, Elsevier (2018). ISBN: 978-0750644457

Course code	ChE 351
Title of the course	Bioprocessing Lab
Course Category	Core
Credit Structure	L - T - P - Credits 0– 0 – 2 – 1
Name of the Concerned Department	Chemical Engineering
Pre-requisite, if any	None
Course objective	• To teach students about the experimental techniques and tools employed in bioprocessing labs and industries
Course Outcomes	At the end of the course, the students will be equipped with: • techniques and instrumentation employed in bioprocessing, • scale-up of biochemistry in large bioreactors
Course Content	List of representative experiments • Isolation of microorganisms from soil samples. • Isolation of colonies and preparation of monocultures; scale up from agar plate to shake flask culture. Preparation of axenic cultures for long-term storage in glycerol stocks • Large-scale production of intracellular product (ethanol /pectinase) from batch fermentation in 5 L and 20 L

	bioreactors • Separation of cells and media residues from broth by using microfiltration • Separation/concentration of product from cleaned broth by using ultrafiltration • Preparation of product for long-term storage using lyophilization • Medium-scale production of extracellular product using batch Fermenters of 5 L and 20 L. • Microfiltration and bioseparations for separation of cells from broth and separation of product from the cells. • Michaelis-Menten enzyme kinetics by using pectinase enzymes
Suggested Books	**Reference book** (1) J.E Bailey and D.F Ollis, “Biochemical Engineering Fundamentals”, 2nd ed. McGraw Hill (2017), ISBN: 978-0070701236.