Annexure 43.4

Curriculum of BTech Program
in
Chemical Engineering
(from AY 2023-24 onwards)

2^{nd} Year B. Tech. (Chemical Engineering)

Semester III

Course Code	Course title	Weekly Contact Hours (L-T-P)	Credits
ZZ XXX	Course – I, Minor program	X-X-X	3
MA 205	Complex analysis	3-1-0 (Half Semester)	2
MA 207	Differential equations	3-1-0 (Half Semester)	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 (23)	21/24

Semester IV

Course Code	Course title	Weekly Contact Hours (L-T-P)	Credits
ZZ 2XX	Course – II, Minor program	X-X-X	3
MA 204	Numerical Methods	2-0-2	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 2XX	Department Elective – 2	2-1-0	3
ZZ 2XX	Institute open elective – 1	2-1-0	3
ChE 252	Fluid Mechanics lab	0-0-2	1
ChE 254	Reaction Engineering lab	0-0-2	1
ChE 256	Computational Chemical Engineering Lab -1	0-0-3	1.5
Total		12-5-9 (24)	21.5/24.5

Departmental core 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 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 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 and Maxwell Models. 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 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, 4th 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

Departmental Labs

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	1) 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 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

Department electives

Course code	ChE 209
Title of the course	Introduction to Soft Matter and Polymers
Course Category	Elective
Possible instructors	Prof. Gaurav, Prof. Kailasham
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.
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

Suggested 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