	The Maharaja Sayajirao University of Baroda **Faculty: Technology and Engineering** **Department: Chemical Engineering** **Kalabhavan, Vadodara.** Email ID: head-chemengg@msubaroda.ac.in	**Academic Year 2025-2026**

Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – I Chemical

Year	I	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	II	CHL 12XXCS: PROCESS CALCULATION	**Hours**	56

COURSE OBJECTIVES:

CO1 Understanding basic calculations for properties required for different Unit operations and processes.

CO2 Apply principles of material balance and conservation equations to solve problems pertaining to Unit operations and processes.

CO3 Apply fundamentals of energy balance to solve problems pertaining to Unit operations and processes

CO4 Extend the fundamentals of material and energy balances to multiple unit operations and processes.

Units	Contents	Hrs.	COs
I	**Introduction:** Chemical Engineering and Chemical Industry, Unit Operations, Unit Processes and Process Flow Diagrams, Unit conversions and dimensional consistency	**4**	**CO1**
II	**Basic Calculations:** State properties: Molecular weight, compositions, density, vapor pressure etc. for gas, liquid, and solid systems. Thermal properties: Heat capacity, sensible heat, latent heat, heat of reaction, heat of solution, enthalpy calculations etc. for gas, liquid and solid systems. Different terminologies associated with safety Techniques of problem Solution: Analytical, Graphical and Numerical.	**11**	**CO1**
III	**Material Balances (Non-reactive systems):** Material balance equations based on conservation principle, Material balances for non-reactive processes (Unit Operations) including safety aspects.	**11**	**CO2**
IV	**Material balances (reactive Systems):** Fundamentals of yield, selectivity and Conversion, Excess and limiting reactant, Combustion of Coal, Ultimate and proximate analysis of coal and related safety aspects of fire and explosion.	**10**	**CO2**
V	**Energy Balances:** Energy balances for closed and open systems based on energy conservation principle., Energy balances for non-reactive processes	**13**	**CO3**

	(Unit Operations), Energy balances for reactive processes, coupled material and energy balances for single unit process, including safety aspects.		
VI	**Multiple Unit Processes:** Introduction to processes with multiple Units, Material balances on processes with recycle, purge, and bypass, Introduction to DOF analysis and solution strategy for multi-unit process.	**7**	**CO4**

REFERENCES	
1	Bhatt and Vora: Stoichiometry, 4^{th} /5^{th} Ed, Tata McGraw-Hill
2	D.M. Himmelblau and J. B. Riggs: Basic Principles and Calculations in Chemical Engineering, 8^{th} Ed, Prentice Hall.
3	R.M. Felder and R.W. Rousseau 'Elementary Principles of Chemical Processes' 3^{rd} Ed, John Wiley and Sons, 2000.
4	K.V. Narayanan and B. Lakshmikutty 'Stoichiometry and Process Calculations', 2^{nd} Edition, PHI, 2017

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – I Chemical

Year	I	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	II	CHL 12XXCS: THERMODYNAMICS AND ENERGY SYSTEM	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand Laws of Thermodynamics, properties, concept and application of entropy to analyse energy changes in systems.

CO2 Apply Laws of Thermodynamics to Heat and flow processes.

CO3 Compare and categorize various conventional and alternative energy sources and their operational principles.

CO4 Describe renewable energy technologies and their potential applications in sustainable energy systems

Unit	Contents	Hrs	COs
I	**Fundamentals and First Law of Thermodynamics:** PVT relationships and thermodynamic properties estimation, Safety aspects of pressure vessels and PVT relationships, Ideal gas concept, reversibility and thermodynamic processes, Joule-Thompson effect and First Law of Thermodynamics, Introduction to work horses of thermodynamics: Enthalpy, Internal Energy, Heat, and Work	10	CO1
II	**Second Law of Thermodynamics and Heat Engines:** Introduction, Carnot cycle, Heat engines, Concept Entropy, Ideal and lost work analysis.	7	CO1
III	**Applications of laws of Thermodynamics:** Application to Flow processes, Refrigeration, Safety and operation aspect in selection of refrigerant, Heat pump and liquefaction techniques, Production of Power from Heat: Steam Power plant, I.C. Engines, Gas turbines. Safety aspects related to above processes.	11	CO2
IV	**Introduction to Energy Systems and Conventional Energy Sources:** Definition and scope of energy systems, Global energy landscape and challenges, Energy forms, classifications, and conversion principles, Energy efficiency and conservation concepts, Hydroelectric, Thermal and Nuclear power plants including safety aspects.	7	CO3
V	**Renewable Energy Sources:** Solar energy systems, Wind energy technologies, Tidal and geothermal power	12	CO4

VI	**Alternative Energy Sources:** Hydrogen energy systems including safety aspects, fuel cells, Biomass and bioenergy systems, Emerging alternative energy prospects, Energy from waste technologies, Emerging clean energy technologies.	**9**	**CO3**

REFERENCES	
1	A.W. Culp 'Principles of Energy conversion' 2nd Ed, McGraw Hill, 1991,
2	M.M. El-Wakil 'Power Plant Technology'2nd Ed, McGraw Hill, 1985
3	J.M. Smith, H.C. Van Ness & M.M. Abbot 'Introduction to Chemical Engineering Thermodynamics', 7th Ed, McGraw Hill, 2004.
4	G. D. Rai 'Non – Conventional Energy Sources' 5th Ed., Khanna Publication, April 2011.
5	K. V. Narayana 'A Textbook of Chemical Engineering Thermodynamics' 2nd Ed, Prentice Hall India, January 2013.
6	S.P. Sukhatme and J.K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, McGraw Hill, 3rd Edition, 2008.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 13XXCS: CHEMICAL ENGINEERING THERMODYNAMICS	**Hours**	56

COURSE OBJECTIVES:

CO1 Understanding concept of non-ideality and its application to pure species.

CO2 Apply concept of residual and excess properties to gases and liquids.

CO3 Computation of phase equilibria for vapor, liquid, and solid based systems.

CO4 Evaluate chemical reaction equilibrium for homogeneous and heterogeneous reactions under various conditions.

Units	Contents	Hrs.	COs
I	Phase diagrams of pure species, Concept of non-ideality, Virial equations, Generalized correlations and Cubic EOS. Concept of Gibbs energy and Fundamental property relations, Maxwell's relations, Gibbs energy as a generating function, Phase equilibrium criterion and computation of vapour pressure	**12**	**CO1**
II	Residual properties, Concept of fugacity and its computation using different models for pure species. Partial molar properties, Gibbs-Duhem equation, mixing rules and computation of fugacity for mixtures	**8**	**CO2**
III	Concept of ideal solutions, Excess properties, Activity coefficient, Excess Gibbs energy models Parameter estimation/data reduction using graphical and regression analysis, Thermodynamic consistency tests	**8**	**CO2**
IV	Vapour Liquid Equilibrium: Criteria, General VLE and Modified Raoult's law Experimental methods for generating VLE data, Phase diagrams for binary systems. BUBLP, BUBLT, DEWP, DEWT, Flash calculations Concept of azeotropy and related calculations K-values and VLE calculations	**11**	**CO3**

V	Liquid-Liquid equilibrium: Phase diagrams for miscible, partially miscible, and immiscible liquid mixtures, mutual solubility, phase stability, criterion for LLE and related calculations.	**5**	**CO3**
VI	Criteria of chemical equilibrium, effect of P and T on equilibrium conversion (Xe) and equilibrium constant (K), methods of evaluation of K &Xe, Xe charts for Exothermic, Endothermic, Reversible, and irreversible reactions etc; Introduction to equilibrium conversion calculation under adiabatic and non-isothermal conditions, Introduction to liquid phase and heterogeneous reaction equilibria.	**8**	**CO4**

REFERENCES	
1	Smith, J. M.; VanNess, H.C.; Abbott, M.M. (2012). 'Introduction to Chemical Engineering Thermodynamics'. McGraw Hill.
2	K. V. Narayana 'A Textbook of Chemical Engineering Thermodynamics' 2nd Ed, Prentice Hall India, January 2013.
3	J. Elliott and C. Lira, 'Introductory Chemical Engineering Thermodynamics' 2nd Ed. Pearson Publisher, 2012.
4	J. M. Prausnitz, R. N. Lichtenthaler and E. G. De Azevedo, 'Molecular Thermodynamics of Fluid-Phase Equilibria' Prentice-Hall International, 1998.

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION~~ 1	**Credit**	4
Semester	II	CHL 14XXCS: CHEMICAL REACTION ENGINEERING – I	**Hours**	56

COURSE OBJECTIVES:

CO1 Understand different reaction mechanisms to develop and solve rate equations for constant and variable volume systems.

CO2 Design ideal reactors for series, parallel, and recycle systems along with multiple reactor configurations.

CO3 Apply RTD concepts to describe real-world reactor performance.

CO4 Apply RTD concepts to describe real-world reactor performance.

Units	Contents	Hrs.	COs
I	Introduction to chemical kinetics, types of reactions, kinetics of homogeneous reactions, temperature dependency of reactions.	**05**	**CO1**
II	Formulation and analysis of simple and complex rate equations. Interpretation of rate data in constant and variable volume systems.	**11**	**CO1**
III	Introduction to reactor design, concept of ideal reactors, development of design expression for batch, tubular and stirred tank and semi-batch reactors, multiple reactor systems, reactors in series and parallel, recycle reactor.	**12**	**CO2**
IV	Multiple reactions, concept of selectivity, maximizing the desired product in series and parallel reaction system. Introduction to process design for some industrial reactors.	**10**	**CO3**
V	RTD and non-ideal reactor analysis, one parameter models for non-ideal reactor RTD and their equivalence, conversion calculations using RTD measurements. The use of RTD models for evaluation of reactor performance.	**10**	**CO4**
VI	Equilibrium conversions, heats of reaction and temperature, Optimum temperatures for isothermal and non-isothermal operations, product distribution and effect of temperature in multiple (complex) reactions. Evaluation of adiabatic and non-adiabatic reactor performance, thermal stability or reactors.	**08**	**CO3**

REFERENCES	
1	Levenspiel “Chemical Reaction Engineering”, 3rd Ed, John Wiley & Sons, 1999
2	Fogler H. S., ‘Elements of Chemical Reaction Engineering’, 4th Ed, Prentice Hall India, 2005.
3	Schmidt L., The Engineering of Chemical Reactions’, 2nd Ed, Oxford, 2008.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION~~	**Credit**	4
Semester	I	CHL 13XXCS: FLUID FLOW OPERATIONS	**Hours**	56

COURSE OBJECTIVES:

CO1 Understand fluid properties, pressure relationships, and hydrostatic behaviour.

CO2 Apply fundamental laws of fluid motion using energy and momentum balances.

CO3 Analyse flow in pipes, fittings, networks, and flow-measurement devices.

CO4 Analyse flow through pumps, packed beds, and industrial fluid-transport systems.

Units	Contents	Hrs.	COs
I	**Fluid Statics:** Nature of Fluid, Pressure concept, Hydrostatic Pressure, Barometric equation, Types of fluid, Types of Manometers, Continuous gravity Decanter, Centrifugal decanter, Examples based on manometer and decanters.	9	CO1
II	**Fluid Flow Phenomena:** Potential flow, Laminar & Turbulent flow, Reynolds number and experiment, Velocity gradient & Viscosity, Momentum flux, Kinematic viscosity, Newtonian and Non-Newtonian fluids with their Examples, Boundary layer separation & Wake formation. Mass velocity, Average velocity, Bernoulli's equation, Correction factor in Bernoulli's equation, Kinetic energy correction, Momentum energy correction, Correction for fluid friction	10	CO2
III	**Flow through Pipes and Channels:** Incompressible and Compressible fluids, Flow of Incompressible fluid in pipes, Hagen Poiseuille equation, friction factor, relation between skin friction parameters, relation, Velocity distribution in pipe, effect of roughness in friction, friction loss from sudden expansion, sudden contraction friction loss in fittings & valves. Compressible flow through pipes and nozzles. Fans, Blowers, Ejectors and compressors.	10	CO3
IV	**Flow measurement:** Classification and selection of flow meters, Variable head and Variable area meters including Notches and Weirs (Principle, Construction, Working, Installation, Merits & Demerits), Positive Displacement meters, Coriolis meters, Ultrasonic meters and various other quantity meters.	8	CO3
V	**Flow Through Solid:** Packed and Fluidized beds. Packed bed structure, Porosity and void fraction, Ergun equation, Pressure drop correlations, Industrial packed-bed systems, Design considerations. Examples associated.	9	CO4

VI	**Fluid Transportation and Moving machinery:** Pipes, tubes, pipe fittings, specification of Pipes & tubes (schedule number, BWG) Joining of pipes & tubes, Types of valves, steam Traps, devices for leakage prevention around Moving parts. Centrifugal Pump: Principle, Construction, Working, Installation, Uses, Capacity, Head developed, Efficiency, Work done, Cavitation & NPSH, Calculation of power consumption, Performance and characteristics curves, Head losses. Positive displacement Pumps.	**10**	**CO4**

REFERENCES	
1	W.L. Mc Cabe, J.C. Smith, P. Harriot, 'Unit Operations of Chemical Engineering' 7th Ed, McGraw Hill, 2006.
2	P.K. Kundu& I.M. Cohen 'Fluid Mechanics' 5th Ed, Academic Press, 2002
3	G.S. Sawhney 'Fundamentals of fluid mechanics', 2nd ed, I.K. International
4	J.M. Coulson & J.F. Richardson 'Chemical Engineering' Vol. I, 6th Ed, Elsevier, 2004.
5	R. K. Bansal, "A Textbook of Fluid Mechanics and Hydraulic Machines", Revised 9th Ed, Laxmi Publications, 2010.

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	II	CHL 14XXCS: HEAT TRANSFER OPERATION	**Hours**	56

COURSE OBJECTIVES:

CO1 Understand principles of heat conduction to solve problems in various geometries, including extended surfaces and insulation.

CO2 Apply fundamentals of convective heat transfer for steady state and unsteady state operations to design Heat Exchangers.

CO3 Apply the principles of Heat transfer with phase change for condensation and evaporation applications

CO4 Understand the role of radiation in engineering applications.

Units	Contents	Hrs.	COs
I	**Heat Transfer by Conduction** Fourier's Law, General differential equation for heat conduction, steady state analytical and numerical methods for flat, cylindrical and spherical geometry. Extended surface heat transfer, Insulation.	10	**CO1**
II	**Heat transfer by convection:** Free & forced convection, film & overall heat transfer coefficients, concept of convective resistances in series. Dimensional analysis of convection, physical significance of the dimensionless numbers. Laminar & turbulent flow heat transfers inside tubes & outside of tubes. Unsteady state heat Transfer.	10	**CO2**
III	**Heat exchangers:** Classification and selection, double pipe heat exchanger analysis, parallel and counter flow heat transfer, LMTD, design considerations, NTU method of heat exchanger analysis and design, Shell & tube heat exchanger calculations.	8	**CO2**
IV	**Heat transfer with phase change:** Regimes of boiling heat transfer, various correlations. Heat transfer during condensation, drop and film condensation, Nusselt's equation and its applications, condensation over tube banks.	9	**CO3**

V	**Heat transfer by radiation:** Laws of radiant heat transfer, concept of black body and grey body. Radiation between surfaces, view factors, radiation between reflecting surfaces, absorption and emission by gases, luminous & nonluminous gases, combined modes of heat transfer.	12	**CO4**
VI	**Evaporation:** Types of evaporators their classification and selection. Single effect and multiple effect evaporators, capacity and economy, feed arrangement to multiple effect evaporators. Evaporator calculations for single effects and multiple effects.	7	**CO4**

REFERENCES	
1	D. Q. Kern, "Process Heat Transfer", 5th Ed, McGraw-Hill, 1965
2	J. M. Coulson & J. F. Richardson "Chemical Engineering", Vol. I, 6th Ed, Elsevier, 2004
3	Y. V. C. Rao, "Heat transfer", 2nd Ed, 2001

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION /~~	**Credit**	4
Semester	I	CHL 13XXCS: MECHANICAL OPERATION	**Hours**	56

COURSE OBJECTIVES: -

CO1 Interpret particle size measurement techniques to analyse particle characteristics and size modification techniques.

CO2 Analyse bulk solid properties to identify optimize material handling and storage systems for industrial applications.

CO3 Describe mixing fundamentals and assess different mixer types for various industrial processes.

CO4 Apply knowledge of filtration, sedimentation and fluidization techniques to solve separation challenges in industries.

Unit	Contents	Hrs	COs
I	**Fundamentals of Particle Technology:** Introduction to particle technology, Characterization of solid particles (Size, Shape, Size distribution), Particle size measurement techniques, Particle population, Mixed particles, Specific surface of mixture, Screen analysis (Method of reporting screen analysis), Screening equipment, Capacity and effectiveness of screens.	**10**	**CO1**
II	**Size Modification:** Principles of comminution, Laws of crushing, Energy and power required for comminution, Size reduction equipment (Types, Selection criteria), Industrial processes for particle size enlargement, Size enlargement equipment and operation, Modern size modification technologies.	**7**	**CO1**
III	**Material Handling and Storage:** Properties of bulk solids (Angle of repose, Flow properties), Bulk storage systems, Storage in bins and silos (Design principles, Operation considerations), Hopper design and flow patterns, Mechanical conveying systems (Screw conveyers, Belt conveyers, Bucket elevators), Pneumatic conveying of solids, Safety considerations in material handling.	**11**	**CO2**
IV	**Mixing and Agitation:** Fundamentals of mixing, mixing of powders and pastes, Types of mixers (For cohesive solids, for non-cohesive solids), Mixing Index and quality assessment, Agitation and mixing of liquids, Basic stirred tank design, Types of impellers and selection, Flow patterns in mixing vessels, Power consumption calculations, Scale-up considerations, Equipment selection criteria.	**7**	**CO3**

V	**Filtration:** Principles of filtration, Types of filtration (Constant pressure filtration, Constant rate filtration), Filter cake characteristics (Compressible cakes, Incompressible cakes), Resistance factors (Cake resistance, Filter media resistance), Filter media and filter aids, Filtration equipment (Batch operations, Continuous operations), Selection criteria for filtration systems, Washing of filter cakes, Advanced filtration techniques.	**12**	**CO4**
VI	**Sedimentation and Fluidization:** Gravity settling fundamentals, Types of sedimentation (Batch sedimentation, Continuous sedimentation), Rate of sedimentation, Equipment design (Gravity clarifiers, Sorting clarifiers, Thickeners), Centrifugal sedimentation (Principles, Applications), Separation processes (Solid-gas separation, Liquid-solid separation), Fluidization fundamentals, Geldart classification of particles, Fluidization parameters (Minimum fluidization velocity, Pressure drops), Types of fluidization (Particulate fluidization, Bubbling fluidization), Industrial applications of fluidization.	**9**	**CO4**

REFERENCES	
1	Couper, J. R.; Penney, W. R.; Fair, J. R.; Walas, S. M. "Chemical Process Equipment - Selection and Design". 3rd ed., Butterworth-Heinemann (Elsevier), Massachusetts, 2012
2	Ludwig, Ernest E. - Applied Process Design for Chemical and Petrochemical Plants. Volume 1. 4th Edition. Gulf Professional Publishing. 2001.
3	Swain, A.K., Patra H., Roy G.K., "Mechanical Operations". Tata McGraw Hill Edu. Pvt. Ltd., New Delhi, 2011
4	Brown, G.G. - Unit Operations. John Wiley & Sons.
5	McCabe, W.L., Smith, J.C., & Harriott, P. - Unit Operations of Chemical Engineering. 7th Edition. McGraw-Hill Education. 2004.
6	Narayan, C.M., & Bhattacharya, B.C. - Mechanical Operations for Chemical Engineers. 1st Edition. New Age International Publishers. 2007.

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	II	CHL 14XXCS: MASS TRANSFER OPERATION – I	**Hours**	56

COURSE OBJECTIVES:

CO1 Understand the laws and theories related to mass transfer.

CO2 Apply fundamentals for selection of gas-liquid contactors and design of absorption column.

CO3 Explain the concepts of humidification and dehumidification for designing cooling towers.

CO4 Analyse various distillation techniques and apply design methods for the separation of binary mixtures.

Units	Contents	Hrs.	COs
I	**UNIT-I: Molecular diffusion in fluids** Stefan- Maxwell's diffusion equations Prediction of diffusion coefficients for gases and liquids.	**09**	CO1
II	**UNIT-II: Mass Transfer** Fundamentals of mass transfer, mass transfer coefficients, interphase mass transfer, mass transfer theories	**06**	CO1
III	**UNIT-III: Gas absorption** Gas- liquid equilibria, solvent selection criteria, analysis of absorption columns, graphical design of plate columns, Kremsers Soudres & Brown's method. Mass transfer analysis for design of packed absorption columns for gas absorption (HETP, HTU, NTU concept) Gas-liquid contacting equipments their classification and selection.	**09**	CO2
IV	**UNIT-IV: Humidification and dehumidification** Basic concepts, cooling towers and their classification and selection, cooling tower design by enthalpy potential method.	**07**	CO3
V	**UNIT-V: Distillation** Introduction to distillation. Vapor liquid equilibria. Distillation techniques viz. differential, flash, steam, fractionation, azeotropic and extractive distillation etc. vapor liquid contacting equipment their constructional and operational features and design aspects.	**09**	CO4

VI	**UNIT-IV: Analysis of binary distillation** Material and energy balance around a distillation column, concept of reflux, Lewis Sorel method of calculation, McCabe & Thiele method for determining number of ideal plates, feed stage location, optimum reflux ratio, condenser and reboiler heat duty, Ponchon & Savarit method for design of plate column. Concept of plate efficiencies. Distillation in packed columns.	**12**	CO4

REFERENCES	
1	Treybal R. E., "Mass-Transfer Operations", 3rd ed., McGraw-Hill, 1980
2	Geankoplis C. J., "Transport Processes and Separation Process Principles", 4th ed., Prentice-Hall India, 2003
3	Foust A. S., Wenzel L. A., Clump C. W., Maus L., Anderson L. B., "Principles of Unit Operations", 2nd ed., John Wiley & Sons, 1972
4	McCabe W. L., Smith J. C., Harriott P., "Unit Operations of Chemical Engineering", 7th ed., McGraw-Hill Education, 2006
5	Coulson J. M., Richardson J. F., "Chemical Engineering, Volume I", 6th ed., Elsevier, 2004
6	Coulson J. M., Richardson J. F., "Chemical Engineering, Volume II", 5th ed., Elsevier, 2003
7	Dutta B. K., "Mass Transfer", 2nd ed., Tata McGraw-Hill, 2006
8	Ananthraman N., Begum K. M. M. S., "Mass Transfer – Theory and Practice", 1st ed., Prentice-Hall India, 2011
9	Ludwig E. E., "Applied Process Design for Chemical and Petrochemical Plants, Volume II", 4th ed., Gulf Professional Publishing, 1994

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – II Chemical

Year	II	CORE ~~/ ELECTIVE / FOUNDATION~~ 1	**Credit**	4
Semester	II	CHL 14XXCS: PROCESS EQUIPMENT DESIGN – I	**Hours**	56

COURSE OBJECTIVES:

CO1 Understand the selection criteria for the material of construction and the fabrication techniques involved for chemical process vessels.

CO2 Design unfired pressure vessels including closures, flanges, and gaskets using appropriate codes.

CO3 Design tall vessels along with supports for various process equipment.

CO4 Implement SMPV rules and design considerations for storage and high-pressure vessels using standard practices.

Units	Contents	Hrs.	COs
I	**UNIT I: Corrosion, Materials of Construction and Fabrication technique** Corrosion: Fundamentals, types, and effect of different parameters, lining techniques, Selection of materials for process and ancillary equipment, Fabrication techniques, Fabrication drawings for process equipment, Testing of vessels (storage tanks and pressure vessels)	11	CO1
II	**UNIT II: Unfired Pressure Vessel** Design codes for unfired pressure vessels, Design of unfired process vessels subject to internal and external pressure, Types of closures and design aspects, Types of flanges and gaskets: selection and applications, Reinforcement of nozzles, manholes, and other openings	12	CO2
III	**UNIT III: Tall Vessels** Design considerations for wind loads and seismic activity, Eccentric load considerations, Vertical water testing requirements,	8	CO3
IV	**UNIT IV: Supports** Design of leg supports, Design of bracket supports, Design of saddle supports, Design of skirt supports for tall vessels.	8	CO3
V	**UNIT V: Storage Tanks**	9	CO4

	Design codes for storage tanks, Static & Mobile Pressure Vessel (SMPV) rules, Design of non-pressure storage vessels with fixed and floating roofs, Concept and qualitative description of storage tank design		
VI	**UNIT VI: High-Pressure Vessels** Design of monobloc vessels, Design of multi layered pressure vessels	8	CO4

REFERENCES	
1	L.E. Brownell and E.H. Young, 'Process Equipment Design', Wiley, 1959
2	B.C. Bhattacharya, 'Introduction to chemical equipment design – Mechanical aspects. CBS publishing Co., 2008
3	B.C. Bhattacharya and C.M. Narayanan, 'Computer aided design of chemical process equipment', New Central Book Agency, 1992.
4	M.V. Joshi and V.V. Mahajani, 'Process equipment design', 3rd Ed. Pressure vessel manual – Eugene 14th ed.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – III Chemical

Year	III	CORE / ~~ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 15XXCS: CHEMICAL PROCESS INDUSTRIES	**Hours**	56

COURSE OBJECTIVES: -

CO1 Identify key safety measures, utility systems, and raw materials used in paper, cement, and lime industries.

CO2 Describe the processes involved in the production of inorganic chemicals and fertilizers.

CO3 Outline the major processing techniques in petrochemical and organic chemical industries.

CO4 Explain the principles behind the production of industrial gases, coal-based chemicals, and pharmaceuticals.

Unit	Contents	Hrs	COs
I	**Industrial safety and utilities:** Introduction to MSDS (OSHA), NFPA. DM Water, Chilled Water, Thermic Fluid, Steam	**05**	**CO1**
II	**Pulp, Paper, Cement and lime industries:** Pulping techniques, paper making, paper machines, black liquor, recovery etc. Classification, types and manufacture cement and lime industries, etc.	**09**	**CO1**
III	**Inorganic and Fertilizer Industries:** Sulfuric, Nitric, Hydrochloric, Phosphoric acid, Soda ash, Caustic soda Introduction to fertilizers, Sources of NPK, Urea, Diammonium phosphate, triple super phosphate, Bio fertilizers	**14**	**CO2**
IV	**Organic and Petrochemical industries:** BTX (separation of xylene), Cyclohexane, ethylene, acetaldehyde, methanol, cumene, phenol, acetic acid, Formic acid & Oxo-alcohols, butyl ester, Ethanol from molasses and synthetic routes	**15**	**CO3**
V	**Industrial gases and coal-based industries:** Hydrogen, Ammonia, Oxygen & Nitrogen, Argon Partial oxidation/coal gasification, Coking	**06**	**CO4**

VI	**Pharmaceuticals, commodity and fine chemicals:** Introduction to pharmaceuticals: Paracetamol & Penicillin Dyes & H acid LAB and derivatives, (phosphate free detergents), Fat splitting, biodiesel, transesterification etc.	**07**	**CO4**

REFERENCES	
1	R.N. Shreve, 'Chemical Process Industries', 5th Ed, McGraw-Hill, 1997
2	C. Dryden, 'Outline of Chemical Technology',3rd Ed, TMH, 1974
3	J.A. Kent 'Riegel's Handbook of Industrial Chemistry'10th Ed., Springer Science & Business Media, 2003
4	Kirk and Othmer, 'Encyclopaedia of Chemical Technology', 5th Ed, 24 volumes, 2006.

	The Maharaja Sayajirao University of Baroda **Faculty: Technology and Engineering** **Department: Chemical Engineering** **Kalabhavan, Vadodara.** Email ID: head-chemengg@msubaroda.ac.in	**Academic Year 2025-2026**

Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	III	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 15XXCS: CHEMICAL REACTION ENGINEERING - II	**Hours**	56

COURSE OBJECTIVES:

CO1 Analyse the influence of mass transfer on reaction rates in heterogeneous non-catalytic systems and design fluid-fluid reactors.

CO2 Determine rate-limiting steps in fluid-solid non-catalytic reactions for reactor design.

CO3 Understand catalyst development and characterization and investigate the intrinsic kinetics in heterogeneous catalytic systems.

CO4 Design and optimize different types of industrial catalytic reactors.

Units	Contents	Hrs.	COs
I	Fundamentals of heterogeneous reacting systems, the influence of mass transfer on reaction rates, introduction and analysis of fluid-fluid systems, kinetic regimes, and rate analysis.	**08**	**CO1**
II	Classification and selection of fluid-fluid reactors based on reaction regimes. Design of fluid-fluid reactors.	**06**	**CO1**
III	Kinetics of fluid-solid non catalytic reactions, determination of rate determining steps, various models of gas solid reactions. Classification and design of non-catalytic fluid particle reactors.	**13**	**CO2**
IV	Non-Porous Catalysts: Fundamentals, Preparation, characterization, Kinetics and Deactivation.	**08**	**CO3**
V	Porous Catalysts: Fundamentals, Preparation, characterization, Kinetics and Deactivation.	**07**	**CO3**
VI	Design outline of fixed-bed, fluid-bed, trickle-bed and slurry reactors, isothermal and adiabatic operations. Selected case studies in design.	**14**	**CO4**

REFERENCES

1	Octave Levenspiel “Chemical Reaction Engineering”, 3rd Ed, John Wiley & Sons, 1999
2	H. Scott Fogler ‘Elements of Chemical Reaction Engineering’, 4th Ed, Prentice Hall India, 2005.

3	C.H. Bartholomew, R.J. Farrauto "Fundamentals of Industrial Catalytic Processes", 2nd Ed. John Wiley & Sons, 2006
4	J.M. Smith, 'Chemical Engineering Kinetics', 3rd Ed, McGraw-Hill, 1981
5	C.N. Satterfield 'Heterogeneous Catalysis in Industrial Practice 2nd Ed, McGraw-Hill 1993.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	III	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 15XXCS: MASS TRANSFER OPPERATIONS – II	**Hours**	56

COURSE OBJECTIVES:

CO1 Analyze liquid-liquid extraction processes by interpreting equilibrium diagrams and predicting separation performance of multistage extraction systems.

CO2 Examine leaching mechanisms and crystallization principles to evaluate mass transfer and separation efficiency in industrial processes.

CO3 Understand adsorption and ion exchange processes by analysing equilibrium considerations and separation techniques.

CO4 Predict drying behaviour and equipment performance based on material characteristics and process requirements

Units	Contents	Hrs.	COs
I	Liquid–Liquid extraction: Extraction equilibria and its graphical representation, tie line correlations, prediction of 1-1 equilibria. Stage wise & continuous contacting equipments their classification and selection, design of multistage counter current extraction with and without reflux.	**12**	**CO1**
II	Leaching: Principles and leaching equilibria, unsteady state & steady state operations, design of leaching systems, leaching equipment and systems.	**8**	**CO2**
III	Crystallization: Crystal geometry, solubility curves, supersaturation, theories of nucleation & crystal growth, calculation of yield, classification, and selection of equipment for solution crystallization, MSMPR crystallization model, melt crystallization.	**8**	**CO2**
IV	Membrane Separation Processes: Reverse osmosis, ultra-filtration, micro filtration, dialysis, per vaporation etc. concepts and analysis, flux equations, fouling and concentration polarization. Membrane modules their fabrication and design.	**10**	**CO3**
V	Adsorption & Ion exchange: Equilibrium considerations, stage wise adsorption and continuous contact adsorption. Fixed bed adsorption, scale up for constant pattern front, Thermal swing, and pressure swing adsorption. Counter current adsorption simulated moving bed. Chromatographic separations.	**9**	**CO3**

VI	Drying: Concepts, calculations of rate of drying, classification, and selection of drying equipment. Design of batch and continuous driers.	**9**	**CO4**

REFERENCES	
1	Don Green and Robert H. Perry, 'Perry's Chemical Engineers Handbook', 8th /9th Ed, Mc-Graw Hill, 2008
2	S.M. Walas 'Chemical Process Equipment' Butterworth- Heinemann, 1999.
3	E.E. Ludwig 'Applied Process Design of Chemical and Petrochemical Plants' 4th Ed, Vol. I, II, III, Gulf professional Publications, 1999.
4	Coulson and Richardson 'Chemical Engineering Design Volume 6' 4th ed., Elsevier Pub., 2014
5	J. D. Seader, Ernest J. Henley and D. Keith Roper 'Separation Process Principles' 3rd ed., John Wiley & Sons, 2015

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – II Chemical

Year	III	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 14XXCS: PROCESS EQUIMENT DESIGN – II	**Hours**	56

COURSE OBJECTIVES:

CO1 Design comprehensive piping system integrating single and two-phase flow considerations.

CO2 Evaluate the operational and design principles of separation equipment and their impact on process efficiency.

CO3 Compare different heat exchanger design methodologies to optimize thermal performance and energy efficiency.

CO4 Evaluate the performance of tray column for binary systems and column designs for efficient separation of multi-component mixtures.

Units	Contents	Hrs.	COs
I	Design of piping systems for single phase and two-phase flows, piping colours and codes. Selection and specifications of pipes, fittings, valves, pumps and compressors. PFDs, P and IDs	**12**	**CO1**
II	Principles of design of decanters, cyclone separators, Demisters	**09**	**CO2**
III	Design of the heat exchangers (Kern's method and Bell's method), condensers and reboilers.	**10**	**CO3**
IV	Principles of continuous contact vapor /gas - liquid equipment's. Design of Packed columns	**08**	**CO2**
V	Design of tray towers, Detailed design of trays and tray efficiencies	**09**	**CO4**
VI	Multi-component distillation, short cut methods, Distillation sequencing	**08**	**CO4**

REFERENCES

1	Don Green and Robert H. Perry, 'Perry's Chemical Engineers Handbook', 8th /9th Ed, Mc-Graw Hill, 2008
2	S.M. Walas 'Chemical Process Equipment' Butterworth- Heinemann, 1999.
3	E.E. Ludwig 'Applied Process Design of Chemical and Petrochemical Plants' 4th Ed, Vol. I, II, III, Gulf professional Publications, 1999.

4	Coulson and Richardson ‘Chemical Engineering Design Volume 6’ 4th ed., Elsevier Pub., 2014
5	J. D. Seader, Ernest J. Henley and D. Keith Roper ‘Separation Process Principles’ 3rd ed., John Wiley & Sons, 2015

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – III Chemical

Year	III	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	II	CHL 14XXCS: SAFETY HEALTH AND ENVIRONMENT	**Hours**	56

COURSE OBJECTIVES:

CO1 Classify industrial hazards and analyse fire and explosion indices while implementing preventive strategies to mitigate associated risks.

CO2 Conduct HAZAN and HAZOP studies to formulate risk assessment procedures and develop emergency response methods.

CO3 Interpret the impact of human activities on ecological cycles and propose mitigation strategies for pollution reduction and sustainability.

CO4 Compare various pollution control techniques and explain regulatory standards for air, water and solid waste.

Units	Contents	Hrs.	COs
I	**UNIT I: Chemical Industry Hazards and Toxicology** Types of hazards, accident statistics, and accident processes, Toxicology, industrial hygiene, and toxic release models	6	CO1
II	**UNIT II: Fires, Explosions, and Safety Design** Fire and explosion prevention, indices, and phenomena, Safety considerations in design, PESO rules, Factories Act, Plant layout, relief systems, static electricity, and noise pollution abatement	8	CO1
III	**UNIT III: Hazard Analysis and Risk Assessment** Hazard and operability studies, Analysis methods: What-if, Checklist, FMEA, FTA, ETA, Bow-Tie, Acceptable risk and safety properties	6	CO2
IV	**UNIT IV: Safety Procedures and Emergency Response** Personal and plant protective equipment, Emergency response and disaster management, Insurance, workers' safety, and public liability	6	CO2
V	**UNIT V: Environmental Science and Pollution Control** Ecological principles and natural resource management Atmospheric, hydrospheric, and climate cycles, Air pollution: Greenhouse effect, global warming, acts & legislations, Solid and nuclear waste management	14	CO3

VI	**UNIT VI: Water and Air Quality Management** GPCB & CPCB norms, air and water quality assessment, Air pollution control: Dust, mist, aerosol, toxic releases, SO_X & NO_X, Water pollution prevention and control techniques, Water and air pollution acts and legislations	**12**	**CO4**

REFERENCES	
1	Crowl and Louver 'Chemical Process safety: Fundamentals with Applications:' 3rd Ed., Prentice Hall, 2011
2	Valsaraj, 'Elements of environmental engineering' CRC press, 1998
3	Sanders, 'Chemical process safety' 3rd Ed, Elsevier, 2005.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	1.5
Semester	I	CHL 17XXLCS: COMPUTER AIDED DESIGN LABORATORY	**Hours**	-

COURSE OBJECTIVES: -

CO1 Apply spreadsheet tools to analyse chemical process data and perform engineering calculations.

CO2 Create custom VBA modules for solving recurring chemical engineering problems.

CO3 Analyse the performance parameters of pumps, columns using DWSIM tools.

CO4 Translate process flow diagrams into comprehensive P&ID drawings following industrial standards.

Unit	Contents	Hrs	CO
1	Students will be assigned computational / simulation exercises to be worked out using flow sheet simulators with special emphasis on property estimation and process optimization.	**-**	

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - I***	**Credit**	4
Semester	I	CHL 17XXCS: ADVANCES IN SEPARATION SCIENCE	**Hours**	56

COURSE OBJECTIVES: -

CO1 Describe the structure of separation processes and features of isotope separation.

CO2 Understand principles of membrane processes and extractive separations.

CO3 Discuss advanced separation techniques and different electrical separation methods.

CO4 Illustrate chromatographic separation principles and their applications in various processes.

Unit	Contents	Hrs	CO
1	**UNIT I: Fundamentals of Separation Processes** Structure of separation processes, Definitions of separation and separative work, Characterization of concentration distribution, Morphology of separation processes, Adsorptive bubble separation techniques: principles, application, and design	7	CO1
2	**UNIT II: Membrane Processes and Extractive Separations** Membrane processes: classification, principles, applications, and design, Extractive separations using liquid membranes, reverse micelles, and microemulsions	12	CO2
3	**UNIT III: Advanced Separation Techniques** Melt crystallization, Zone refining, Short path distillation, Reactive distillation, Supercritical extraction	11	CO3
4	**UNIT IV: Electrical Separations** Electrophoresis, Electrodialysis, Protein purification using isoelectric focusing in gels, Field flow fractionation	10	CO3
5	**UNIT V: Chromatographic Separations** Chromatographic separation principles, Applications and scale-up, Separations based on simulated moving beds, Affinity chromatography	9	CO4

6	**UNIT VI: Novel Separations** Features of separation of isotopes using novel separation techniques	**7**	**CO1**
REFERENCES			
1	Wankat, Phillip C. Rate-Based Separation. Elsevier, 2005.		
2	King, Cary Judson. Separation Processes. 2nd ed., McGraw-Hill, 1980.		
3	Li, Norman N., editor. Recent Developments in Separation Science. Vol. I-V, CRC Press, 1980		

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - I***	**Credit**	4
Semester	I	CHL 17XXCS: COLLOID AND SURFACE SCIENCE	**Hours**	56

COURSE OBJECTIVES: -

CO1 Describe particle characteristics and transport properties in colloidal systems.

CO2 Understand surface phenomena and interfacial properties in colloidal systems.

CO3 Examine electrical and stability aspects of colloidal dispersions.

CO4 Implement colloidal science concepts in industrial applications.

Unit	Contents	Hrs	CO
1	**Introduction to Colloidal Systems** Nature of colloidal dispersions, Scope and variables, Particle size and shape	8	CO1
2	**Transport Properties and Surface Phenomena** Transport properties of suspensions, Sedimentation and diffusion, Liquid surfaces and interfaces, Surface tension and contact angle, Surface energies	11	CO2
3	**Surfactant Solutions and Interfaces** Colloidal structures in surfactant solutions, Micellar phase diagrams, Adsorption from solution, Langmuir and Blodget films	9	CO2
4	**Dispersions and Electrical Properties** Rheology of dispersions, Electrical charges in dispersions, Forces between particles, Electrokinetics and zeta potential	10	CO3
5	**Colloidal Stability** DLVO theory, Electrostatic stability, Polymer-induced stability, Emulsions and foams, Microemulsions	9	CO3
6	**Industrial Applications** Surface coating industry, Pharmaceutical applications, Enhanced oil recovery, Other industrial applications	9	CO4

REFERENCES

1	Hiemenz P. C., Rajagopalan R., "Principles of colloid and surface chemistry", 3rd ed., Marcel Dekker, 1997
2	Handbook of Colloid and Interface Science, Vol. 1-4, De Gruyter, 2017
3	Birdi, K. S, "Handbook of surface and colloid chemistry", 4th ed., CRC Press, 2016

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - I***	**Credit**	4
Semester	I	CHL 17XXCS: CATALYSIS: SCIENCE & TECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand fundamental principles and historical development of catalysis science.

CO2 Analyse mechanisms of homogeneous, heterogeneous, and enzyme catalysis.

CO3 Design catalytic reactors considering mass transfer and deactivation effects

CO4 Implement catalytic solutions for environmental applications.

Unit	Contents	Hrs	CO
1	**Basics of Catalysis:** Emergence of catalysis science & technology, a brief history importance of catalysis and catalyst technology, Foundation catalytic phenomena & principles.	7	CO1
2	**Homogeneous and Enzyme catalysis:** Elementary steps in homogeneous catalysis, metal complex catalysis in liquid phase, liquid exchange dissociation &coordination, oxidative addition, reductive elimination, insertion, and migration. Structure/Activity relationships, steric effects. A symmetric homogeneous catalysis, industrial examples, homogeneous catalysis without metals, cleric acid/base catalysis, organoclays, Essentials of enzyme catalysis –Michaelis – Menten reaction, scaling up homogeneous catalysis, catalyst recovery & recycle, Hybrid catalysts.	9	CO2
3	**Heterogeneous Catalysis:** Concept of active site model catalyst systems, real catalysts, promoters, modifiers, poisons, preparation of solid catalysts, selection of support catalyst characterization. Surface characterization, temperature programmed techniques, spectroscopy & microscopy, selected care studies.	10	CO2
4	**Catalytic Reactor Design:** The LHHW model, general behaviour of catalyst particles & pellets, heat and mass transfer aspects, Thiele modulus and effectiveness factor. Choice of	10	CO3

	reactors in lab and plants collection & analysis of data from lab. Reactors. Fundamentals of catalytic reactor design, selected care studies.		
5	**Catalyst Deactivation:** Causes and mechanism of deactivation, prevention and regenerative treatment of catalyst decay, selected care studies. Optimal distribution of catalyst in a single pellet. Optimal distribution of catalyst in a reactor.	**11**	**CO3**
6	**Environmental Catalysis:** *Mobile sources:* Automotive gasoline catalytic converters, catalytic abatement of emissions from diesel engines, Trends in emission control for mobile sources. *Stationary sources:* Catalytic reduction of NOX catalytic oxidation of VOC emissions, catalytic oxidation of CO emission, Kinetics & reactor design for CO & VOC oxidation.	**9**	**CO4**
REFERENCES			
1	Thomas J. M., Thomas W. J., "Principles and Practice of Heterogeneous Catalysis", 2nd ed., Wiley-VCH, 2014		
2	Rothenberg G., "Catalysis: Concepts and Green Applications", Wiley-VCH, 2006		
3	Froment G. F., Bischoff K. B., De Wilde J. "Chemical Reactor Analysis and Design", 3rd ed., Wiley, 2010.		

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Name of the Programme: B.E. Chemical
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Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - I***	**Credit**	4
Semester	I	CHL 17XXCS: PETROLEUM ENGINEERING	**Hours**	56

COURSE OBJECTIVES: -

CO1 Examine petroleum exploration strategies and the potential of unconventional hydrocarbon resources.

CO2 Explain the characteristics of reservoirs and behaviour of hydrocarbon systems.

CO3 Understand drilling techniques, production methods, and enhanced oil recovery processes.

CO4 Apply various methods to assess reservoir performance and deliverability.

Unit	Contents	Hrs	CO
1	**UNIT I: Petroleum Resources and Exploration** Hydrocarbon resources and petroleum supply scenario, Prospecting for petroleum, Exploration methods, Reserve appraisals and petroleum management	8	CO1
2	**UNIT II: Reservoir Characteristics** Classification of reservoirs, Phase behaviour of hydrocarbon systems, Reservoir fluid properties, Properties of reservoir rocks, Flow through porous media, Mechanism of entrapment and mobilization of oil in porous media	10	CO2
3	**UNIT III: Drilling and Well Analysis** Drilling techniques, Well logging methods, Basin modelling	9	CO3
4	**UNIT IV: Reservoir Performance Analysis** Reservoir deliverability, Material balance calculations, Volumetric analysis, Decline curve analysis, Inflow performance relationship	10	CO4
5	**UNIT V: Production and Enhanced Recovery** Production techniques, Enhanced oil recovery techniques (Chemical, miscible and thermal methods), Reservoir management techniques, Safety aspects in petroleum production	12	CO3

6	**UNIT VI: Alternative Hydrocarbon Resources** Natural gas, Coal bed methane, Gas hydrate, Shale oil	**7**	**CO1**
REFERENCES			
1	James Speight, The Chemistry and Technology of Petroleum, 5th ed., CRS Press.		
2	Boyun Guo, William C. Lynos, Ali Ghalambor, Petroleum Production Engineering: A Computer Assisted approach. Gulf Publication.		

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - II***	**Credit**	4
Semester	I	CHL 17XXCS: CARBON BLACK TECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Identify raw materials and testing requirements for carbon black production.

CO2 Demonstrate understanding of carbon black production processes.

CO3 Identify instrumentation and control systems in carbon black plant to implement maintenance protocols.

CO4 Apply sustainable practices in carbon black manufacturing using case studies.

Unit	Contents	Hrs	CO
1	**Introduction- Raw material, Quality and Testing:** CB Feedstock, Supporting Feedstock, Additives, Paper Bag, LDPE Bags, CB nomenclature, CB Characteristics, Testing of CB, Rubber Properties, Testing apparatus, Process reliability, Safety Health and Quality standards, QC tools.	9	CO1
2	**CB Process:** Reactors, Air preheater, Waste heat boiler, oil preheater, PFD, P&ID, Quench tower, Primary Bag filter, conveying system and operation, Palletization system and Operation, Combustor, Dryer, Purge Gas filter, Silo and Packing machine.	13	CO2
3	**Instrumentation:** Introduction to Control system and speed drives, PLC, DCS	7	CO3
4	**Plant Maintenance:** Refractory, Lubricants, Bearings, Equipment drive components, Gears, Tools, Packings, Welding, Forklift, Equipment alignment	12	CO3
5	**CB Specialty Grades:** Specialty Black and Testing, Rubber application, Rubber Products, Non-Rubber application, Material handling, International Regulations/legislations	8	CO1
6	**Sustainability and Case studies:**	7	CO4

REFERENCES			
1	Donnet J. B., “Carbon Black: Science and Technology”, 2nd ed., Routledge, 1993.		
2	Neal R. O., Perrott G. St. J., “Carbon Black – Its Manufacture, Properties and Use”, Forgotten Books, 2018		
3	Sanders I. J., Peeten T. L., “Carbon Black: Production, Properties & Uses”, NSP, 2011		

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Name of the Programme: B.E. Chemical
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Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - II***	**Credit**	4
Semester	I	CHL 17XXCS: GREEN TECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Describe the fundamentals and importance of green technology in industrial ecology.

CO2 Explain cleaner production strategies and green solvent.

CO3 Explain waste minimization techniques and sustainable industrial practices.

CO4 Understand green nanotechnology principles and sustainable materials.

Unit	Contents	Hrs	CO
1	**Introduction to green technology**: Definition of Green Technology and its Importance, History and evolution of green technology, advantages and disadvantages of green technologies, factors affecting green technologies, Role of Industry, Government and Institutions, introduction to industrial Ecology and its role in green technology	**8**	**CO1**
2	**Cleaner Production:** Definition, Importance, Principles of Cleaner Production and its Benefits, Strategies and Techniques in Cleaner Production, Cleaner Production Assessment & Implementation, Policies, Regulations, and Standards, Case Studies and Practical Applications	**9**	**CO2**
3	**Green Solvent:** Introduction, Types, properties, applications, Challenges and Future Prospects, Kamlet-Taft Methodology, Rating of solvents, LCA, Bio-based solvents	**10**	**CO2**
4	**Sustainable Waste Minimization & Pollution Prevention:** Waste Treatment and Valorisation in the Chemical Industry, Zero Liquid Discharge (ZLD) and Closed-Loop Systems, Green Separation Processes: Membrane Separation, Supercritical Extraction, Case Studies on Industrial Waste Management	**10**	**CO3**

5	**Sustainable Waste Minimization & Pollution Prevention:** Waste Treatment and Valorisation in the Chemical Industry, Zero Liquid Discharge (ZLD) and Closed-Loop Systems, Green Separation Processes: Membrane Separation, Supercritical Extraction, Case Studies on Industrial Waste Management	**10**	**CO4**
6	**Sustainable Waste Minimization & Pollution Prevention:** Waste Treatment and Valorisation in the Chemical Industry, Zero Liquid Discharge (ZLD) and Closed-Loop Systems,Green Separation Processes: Membrane Separation, Supercritical Extraction, Case Studies on Industrial Waste Management	**9**	**CO3**

REFERENCES

1	Kumar A., Singh H., Kumar N., "Renewable Energy and Green Technology: Principles and Practices", CRC Press, 2021
2	Yhaya M. F., Tajarudin H. A., Ahmad M. I., "Renewable and Sustainable Materials in Green Technology", Springer International Publishing, 2018
3	Kothari D. P., Singal K. C., Ranjan R., "Renewable Energy Sources and Emerging Technologies", Prentice Hall India Learning Private Limited; 2nd ed., 2011
4	Shankar U., "Handbook of Green and Sustainable Nanotechnology Fundamentals Developments and Applications", Springer, 2023
5	Kerton F. M., Marriott R., "Alternative Solvents for Green Chemistry", RSC publishing, 2009.

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - II***	**Credit**	4
Semester	I	CHL 17XXCS: PROCESS PLANT OPERATION	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand maintenance concepts and safety management systems in process plants.

CO2 Analyse operation aspects for process plant equipments.

CO3 Understand troubleshooting techniques for processes and utility systems.

CO4 Apply operational knowledge to manage plant utilities and auxiliary systems.

Unit	Contents	Hrs	CO
1	**Introduction** Concept of maintenance, Types of maintenance, theory of failure Accident Record keeping, Modern Management & maintenance techniques, Permit system.	7	CO1
2	**Heat Exchangers** Overview of industrial Heat exchangers, Critical issues associated with Heat Exchangers. Construction, working & operation aspect including start up, shut down, troubleshooting & maintenance.	9	CO2, CO3
3	**Columns** Overview of industrial Column, Column commissioning operations, Critical issues associated with Column. Construction, working & operation aspect including start up, shut down, troubleshooting & maintenance.	13	CO3
4	**Water services** *Cooling water*: working & operation aspects (including start up, shut down & trouble shooting & maintenance) of Cooling Water System and associate equipment (i.e. Cooling Tower, Spray Ponds… etc.) *DM Water*: working & operation aspects (including start up, shut down & trouble shooting & maintenance) of DM Water System.	10	CO3

5	**Air & Steam services** *Steam system:* Classification of steam their application, advantages and disadvantages, Problems associated with steam systems and their identification, steam trap failure. *Instrument Air:* production, quality specification, Problems associated with the systems and their identification.	**11**	**CO3**
6	**Miscellaneous services** *Flare System*: working & operation aspects (including start up, shut down & trouble shooting & maintenance) of Flare System *Boiler System*: Waterside, Fireside and general failure mechanism, start up, shut down and maintenance of boiler.	**6**	**CO4**

REFERENCES

1	Norman Lieberman, "Troubleshooting Process Operations", PennWell Books, 2009
2	D. B. Dhone, "Plant Utilities", Nirali Prakashan, 2017
3	Sathiyamoorthy Manickkam, "Chemical Plant Utilities", Lap Lambert Academic, 2016
4	T. M. Cook and D. J. Cullen, "Chemical Plant and Its Operation: Including Safety and Health Aspects", 2nd SI Ed, Pergamon Press, 1985
5	Keith Mobley, Lindley Higgins , Darrin Wikoff, "Maintenance Engineering Handbook", McGraw-Hill, 2008
6	Safe and Efficient Plant Operation and Maintenance Edited by Richard Green staff of chemical Engg. Mc. Graw Hill, New York.
7	Martin Killcross, "Chemical and Process Plant Commissioning Handbook: A Practical Guide to Plant System and Equipment Installation and Commissioning", 1st Ed, Butterworth-Heinemann, 2011

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE - II***	**Credit**	4
Semester	I	CHL 17XXCS: SOLID WASTE MANAGEMENT	**Hours**	56

COURSE OBJECTIVES: -

CO1 Classify different types of solid waste and their sources and Apply suitable reprocessing and processing technologies.

CO2 Implement composting methods along with recycling and disposal techniques for solid waste.

CO3 Apply plastic waste utilization in road construction and address related challenges.

CO4 Analyse the economic and ecological aspects of plastic waste reprocessing.

Unit	Contents	Hrs	CO
1	Introduction to Waste, its bifurcation and countrification – Sources, Production, Global and Indian Context. Current industry positions on solid waste and management.	**7**	**CO1**
2	Paper and Metal: Sources, production, reprocessing technology and other processing technology.	**9**	**CO1**
3	Plastics: Management, Control, Recycling, and Disposal. 3'R and other Techniques.	**8**	**CO2**
4	Organic and Inorganic Material: Composting and other techniques.	**10**	**CO3**
5	Waste Management Practices – Use of Plastic waste in roads, issues and challenges	**12**	**CO3**
6	Plastics waste reprocessing economic and ecological aspects.	**10**	**CO4**

REFERENCES

1	William A., Worrell P., Vesilind A., "Solid Waste Engineering", 2nd ed., CL-eng., 2011
2	Kreith F., Tchobanoglous G., "Handbook of Solid Waste Management", 2nd ed., 2002
3	Nicholas P., "Handbook Of Solid Waste Management and Waste Minimization Technologies", Butterworth-Heinemann, 2003

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE – III***	**Credit**	4
Semester	II	CHL 18XXCS: BIOTECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand the fundamental principles of biotechnology including basic microbiology and recombinant DNA technology.

CO2 Explain the concepts of enzyme kinetics and cell culture kinetics to analyze production processes.

CO3 Apply the principles of transport phenomena in bioprocess systems including aeration, agitation, media sterilization, and air fertilization.

CO4 Design and analyse methods for bioreactor, downstream processing, and industrial biotech products.

Unit	Contents	Hrs	CO
1	Introduction to Biotechnology. Basic microbiology and recombinant DNA technology	**7**	**CO1**
2	Kinetics of enzyme catalysis including immobilized enzyme technology	**8**	**CO2**
3	Kinetics of substrate utilization product formation and biomass production in cell culture.	**10**	**CO2**
4	Transport phenomena in Bioprocess systems. Aeration/Agitation/Media sterilization/Air fertilization.	**11**	**CO3**
5	Design and analysis of bioreactors and Downstream processing techniques	**11**	**CO4**
6	Industrial Biotech products – Ethyl alcohol based on various substrates including lignocelluloses. Penicillin citric Acid, SCP, Bio-fertilizers, Baker's yeast – other modern biotech products.	**9**	**CO4**

REFERENCES

1	Bailey, Ollis, "Biochemical Engineering",2nd ed., McGraw – Hill, 1986.
2	Young M., "Comprehensive biotechnology", Vol 1 to 5, Elsevier, 1984.
3	Belter, Cussler, Hu, "Bio separations", Wiley, 1988.

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE – III***	**Credit**	4
Semester	II	CHL 18XXCS: NANOTECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Describe the fundamental concepts and historical development of nanotechnology.

CO2 Explain the properties of nanostructured materials and their size dependence.

CO3 Outline various synthesis and characterization methods for nanomaterials.

CO4 Identify applications of nanotechnology in chemical industry.

Unit	Contents	Hrs	CO
1	Nanotechnology foundations: Definition, historical perspective, effects of nanoscience and nanotechnology in various fields	**6**	**CO1**
2	Properties of nanostructured materials: Shape and size dependent properties, colour, melting point, density of states, band gap, magnetism etc.	**9**	**CO2**
3	Synthesis of nanoparticles: Top down and bottom-up approaches, Nano particles via colloids, micelles, vesicles, polymers, crystalline and zeolite hosts. Mechanical attrition, high energy ball milling.	**11**	**CO3**
4	Characterization techniques of nanostructured materials: Scanning electron microscopy, Transmission electron microscopy, scanning tunnelling microscopy, atomic force microscopy, X-ray diffractometer, spectroscopy, UV-Vis, Raman, EDX, AES etc.	**12**	**CO3**
5	Fabrication: Crystal growth, epitaxy, lithography, etching, masking, MEMs	**9**	**CO3**
6	Applications relevant to the chemical industry: Catalysis, fuel cells, coatings, nanocomposite polymers, fluid inks, dyes, block copolymers and dendrimers.	**9**	**CO4**

REFERENCES

1	Klabunde K. J., "Nanoscale materials in Chemistry", Wiley Interscience, 2001.
2	Poole J., Owens S., "Introduction to Nanotechnology", Wiley, 1998
3	Rao C. N. R., "Chemistry of Nanomaterials", Wiley, 2007

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE – III***	**Credit**	4
Semester	II	CHL 18XXCS: PETROCHEMICAL TECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Explain petrochemical feedstocks and cracking processes for olefin production.

CO2 Demonstrate production processes for C1-C5 based petrochemicals using various unit operations.

CO3 Understand production and separation techniques for aromatic petrochemicals.

CO4 Apply clean technology concepts for sustainable petrochemical operations.

Unit	Contents	Hrs	CO
1	Scope of Petrochemical industry in India, Feedstock for petrochemicals	**6**	**CO1**
2	Naphtha cracking/Gas Cracking – separation and purification of cracker products (olefins and diolefins)	**11**	**CO1**
3	Production and purification of synthesis gas. C1 based petrochemicals (methanol, formaldehyde, acetic acid etc.) acetylene	**9**	**CO2**
4	C2 – C5 based Petrochemicals from various unit processes like oxidation, dehydrogenation, chlorination, oxychlorination, ammoxidation, hydration, dehydration, nitration, polymerization etc.	**11**	**CO2**
5	Aromatics production, isolation of aromatics, separation of C8 aromatics. Benzene derivatives, ethylbenzene, styrene etc, xylene derivatives, phthalic anhydride, terephthalic acid, dimethyl terephthalate etc.	**11**	**CO3**
6	Miscellaneous aspects of petrochemical production: Safety and Health aspects, environmental aspects, Clean Technologies & sustainability, Future beyond Petroleum.	**8**	**CO4**

REFERENCES

1	Mall I. D., “Petrochemical Process Technology”, Macmillan Publishers India Ltd., 2007
2	Gupta O. P., Saikat M., “Elements of Petrochemical Engineering”, Khanna Publishing House, 2018
3	Speight J. G., “Handbook of Petrochemical Processes (Chemical Industries)”, CRC Press, 2019
4	Lahiri C. R., Biswas D., “Petrochemical Industries”, CBS publishers and distributors, 2020

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	~~CORE~~ / ELECTIVE / ~~FOUNDATION~~: ***ELECTIVE – III***	**Credit**	4
Semester	II	CHL 18XXCS: POLYMER PROCESSING	**Hours**	56

COURSE OBJECTIVES: -

CO1 Apply the principles of polymer functionality and structure-property relationships to select appropriate polymers for specific applications

CO2 Understand the morphological and rheological behaviour and heat and mass transfer principles of polymers to predict their flow characteristics during processing.

CO3 Compare different moulding techniques to select the most suitable method for a given application

CO4 Develop strategies to optimize polymer processing parameters for improved product quality.

Unit	Contents	Hrs	CO
1	Basic aspects of Polymers: Functionality, types, structure-property relationship, processing fundamentals, processing aids and additives.	**6**	**CO1**
2	Morphology, rheology, and flow of polymers.	**11**	**CO2**
3	Heat and mass transfer in polymer systems, mixing of polymers, mixing equipments	**10**	**CO2**
4	Extrusion of polymers, extrusion equipment, calendaring.	**10**	**CO3**
5	Moulding of polymers: Blow, compression, transfer, rotational and injection moulding techniques, analysis and equipments.	**10**	**CO3, CO4**
6	Other processing techniques: Sheet forming, fiber spinning, pultrusion, techniques and equipments.	**9**	**CO4**

REFERENCES

1	Gupta B. R., "Polymer Processing Technology", Asian Books Pvt. Ltd, 2008
2	Tadmor Z., Gogos C. G., "Principles of Polymer Processing", John Wiley and Sons, 1979

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Name of the Programme: B.E. Chemical
Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 17XXCS: INSTRUMENTATION AND PROCESS CONTROL	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand the principles of measurement and instrumentation for various process variables.

CO2 Analyse the dynamic behaviour of systems using Laplace transforms.

CO3 Evaluate the stability and performance of closed-loop control systems using various analytical methods.

CO4 Implement advanced control strategies and understand the principles of digital control systems.

Unit	Contents	Hrs	CO
1	**UNIT I: Introduction to Process Instrumentation** Basic concepts and Qualities of Measurements, Units and Standards of Measurements. Instrumentation symbols and labels.	5	CO1
2	**UNIT II: Instruments for measurement** Instruments for measurement of process variables such as, temperature, flow, liquid level, Pressure.	12	CO1
3	**UNIT III: Dynamics of first order system** Block diagram representation of control loop. Overview of Laplace transforms for solving differential equations, Forcing functions, Dynamics of first order system, transient response to different forcing functions, linearization of nonlinear models.	8	CO2
4	**UNIT IV: Dynamics of higher order system** Inherently second order systems, Dynamics of manometer, viscus dampener and pendulum system, Concept of damping coefficient, First order systems in series, transient response to different forcing functions.	9	CO2
5	**UNIT V: Analysis and design of feedback control system** Incentive, Design aspects and hardware elements for chemical process control, Concept of feedback control, Types of feedback controllers (P, PI, PID, servo, regulatory), stability analysis of feedback systems, design of feedback control system using frequency response techniques. Final Control Element. Block diagram reduction.	12	CO3

6	**UNIT VI: Advanced control strategies** Control system with multiple loops, feedforward and ratio control, adaptive control system, Computer aided control, elements of computer aided measurements and control, computer aided process control architecture and software, Real-time operating systems, Introduction to Programable logic controllers and distributed control systems.	10	CO4

REFERENCES	
1	Coughanowr D, Leblanc S, 'Process systems analysis and control' 2nd Ed, McGraw-Hill, 1991.
2	Stephanopoulos, G. 'Chemical Process Control: An introduction to theory and practice', Pearson, 2015
3	Vyas R.P., "Process Dynamics and Control", Denett & Co, 2015
4	Sidkar D.C., "Instrumentation and Process Control", Khanna Publishers, 2007
5	Singh S. K., "Industrial Instrument & Control", McGraw-Hill, 3rd ed., 2010

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	CORE / ~~ELECTIVE~~ / ~~FOUNDATION~~	**Credit**	4
Semester	II	CHL 18XXCS: MODELLING SIMULATION AND OPTIMIZATION	**Hours**	56

COURSE OBJECTIVES: -

CO1 Develop mathematical models for chemical processes and understand their classification.

CO2 Apply simulation methods to solve model equations and use spreadsheets and SCILAB for process simulation.

CO3 Formulate optimization problems for chemical processes and classify optimization methods.

CO4 Apply advanced optimization techniques including global optimization methods to solve complex problems.

Unit	Contents	Hrs	CO
1	Role of Modelling, Simulation and Optimization (MSO) in process design – Synthesis Analysis,	**4**	**CO1**
2	Modelling: Introduction, Classification of process models, Model Building, Characteristics of mathematical models.	**11**	**CO1**
3	Simulation: Analytical and Numerical methods for solving model equations, Accuracy and error analysis, Approaches to Process Simulation, Commercial simulators.	**8**	**CO2**
4	Optimization Introduction: Optimization problem and its formulation, General approach for solution, Objective functions, Classification of Optimization problems and methods.	**9**	**CO3**
5	Optimization techniques: -Continuity, convexity and conditions for maxima / minima -Analytical methods: Direct search (without constraints) Lagrangian Multiplier (with constraints), Calculus of Variation. -Newton and quasi-Newton methods for single and multivariable search -Linear (LP) and nonlinear (NLP) programming with constraints -Mixed Integer Programming: MILP and MINLP -Global Optimization Techniques	**19**	**CO4**

6	Applications of modelling simulation and optimization to chemical processes and equipment. Fluid flow, heat Transfer, separations, reaction systems and reactors etc. Use of spreadsheets and DWSIM for Simulation and Optimization.	**5**	**CO1**
REFERENCES			
1	Edgar, Himmelblau, Lasdon, "Optimization of Chemical Process" McGraw-Hill, 1990		
2	Babu, "Process Plant Simulation". Oxford, 2005		
3	Ramiez, "Computational methods for process simulation", Butterworth, 1992.		
4	Ravindran A., "Engineering Optimization- Methods and Applications" 2nd ed., John Wiley & Sons,2006.		

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Name of the Programme: B.E. Chemical
Type of the Programme: S.S. of B.E. – IV Chemical

Year	IV	CORE / ~~ELECTIVE~~ / ~~FOUNDATION~~	**Credit**	4
Semester	II	CHL 18XXCS: PETROLEUM REFINERY ENGINEERING	**Hours**	56

COURSE OBJECTIVES: -

CO1 Outline growth of Indian petroleum refineries along with understanding of crude oil evaluation, testing and lube oil refining processes.

CO2 Describe secondary refining processes and natural gas processing.

CO3 Explain primary crude processing methods and product treatment techniques.

CO4 Understand Catalytic cracking, Catalytic Reforming and hydrocracking processes.

Unit	Contents	Hrs	CO
1	Development of Petroleum Refining industry in India. Crude evaluation and Testing of refinery products.	**6**	**CO1**
2	Primary processing of crude, preparation, atmospheric and vacuum distillation, flow sheets process, conditions, and Equipment. Treatment of petroleum products. Hydrodesulphurization.	**12**	**CO3**
3	Catalytic cracking, Catalytic Reforming and hydrocracking. Principles, feedstocks, catalysts, and hardware	**15**	**CO4**
4	Vis-breaking, coking, isomerization, alkylation, polymerization and Extraction of aromatics	**9**	**CO2**
5	Refining of Lube distillates: Deasphalting, solvent extraction, dewaxing etc. Production of bitumen, waxes, and greases	**7**	**CO1**
6	Processing natural and associated gases.	**7**	**CO2**

REFERENCES

1	Speight J., "The Chemistry and technology of petroleum", 2nd ed., Marcel Dekker, 1991
2	Meyers R. A., “Handbook of Petroleum refining processes”, 3rd ed., McGraw-Hill, 2004.
3	Bhaskarrao B. K., "Modern Petroleum Refining Processes", Oxford and IBH, 1984

सत्यं शिवं सुन्दरम्	**The Maharaja Sayajirao University of Baroda** **Faculty: Technology and Engineering** **Department: Chemical Engineering** **Kalabhavan, Vadodara.** Email ID: head-chemengg@msubaroda.ac.in	**Academic Year 2025-2026**

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Year	IV	CORE / ~~ELECTIVE~~ / ~~FOUNDATION~~	**Credit**	4
Semester	II	CHL 18XXCS: PROCESS SYNTHESIS AND ECONOMICS	**Hours**	56

COURSE OBJECTIVES: -

- **CO1** Apply process synthesis techniques for efficient process workflows and optimize reactor networks.
- **CO2** Develop heat exchanger networks for efficient heat integration in production processes.
- **CO3** Analyse the critical path in project scheduling and batch process scheduling to reduce cycle time and improve productivity.
- **CO4** Design and estimate cost-effective process systems by considering economics.

Unit	Contain	Hrs	CO
1	Introduction, role of process synthesis in process design, hierarchy of synthesis steps. Synthesis Tree approaches for synthesis, heuristics for process synthesis. Project engineering, plant location, plant layout and utilities.	**8**	**CO1**
2	Attainable Regions and reactor networks: Concepts and implementation techniques, reactor – separator – recycle network.	**8**	**CO1**
3	Heat & Power integration: Heat Exchanger Networks –Stream matching, heat loops and minimum heat exchangers. Heat integration in Distillation trains. Minimum energy requirement targets and pinch analysis	**8**	**CO2**
4	Project scheduling. Scheduling of batch processes. Optimization of cycle time and number of units. CPM/PERT, identification of critical path & critical activities.	**7**	**CO3**
5	Project cost estimation and cost of production estimation. Interest, investment costs, depreciation, profitability, criteria cash flow diagram, cost indices.	**7**	**CO4**
6	Economics of selecting alternatives and replacement cost, economy of scale, marginal cost, break even analysis and optimization. Inventory Control, taxes and insurance, legal aspects, liabilities, patent indemnity etc.	**7**	**CO4**

REFERENCES

1	Smith R., "Chemical Process Design and Integration", Wiley, 2005.
2	Biegler, Grossmann, Westerberg, "Systematic Methods of Chemical Process Design", Prentice Hall, 1997.
3	Seider, Seader, Lewin, "Product and Process Design Principles", 2nd Ed., Wiley 2004.
4	Peters, Timmerhaus, "Plant design and economics for chemical engineers", 4th Ed., McGraw-Hill, 1991.
5	Kharbanda O. P., "Process Plant and Equipment Cost Estimation", Craftsmen book Co., 1979

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Type of the Programme: F.S. of B.E. – IV Chemical

Year	IV	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 17XXCS: POLYMER SCIENCE AND TECHNOLOGY	**Hours**	56

COURSE OBJECTIVES: -

CO1 Understand polymer classification, structure-property relationships, and molecular weight determination along with fractionation techniques.

CO2 Explain various polymerization mechanisms, techniques, and manufacturing processes for common plastics.

CO3 Illustrate the manufacturing and processing methods for rubbers, fibres, and plastics.

CO4 Assess the mechanical behaviour of polymers through standardized testing methods.

Unit	Contain	Hrs	CO
1	Introduction & Basic Concepts, Polymer based industries and feed stocks. Classification of Polymers. State of polymer, structure property relations and transition temperatures. Polymer solutions and determination of Molecular Weight, polymer fractionation.	**8**	CO1
2	Chain polymerization: Mechanism and kinetics; copolymerization. Condensation polymerization, coordination polymerization, Techniques of polymerization.	**10**	CO2
3	Plastics–Materials & some typical manufacturing process, (poly olefins, PVC, PS, PMMA, Epoxy resins etc.).	**10**	CO2
4	Rubbers and fibres, materials and their manufacturing processes.	**12**	CO3
5	Processing of plastics and rubbers.	**8**	CO3
6	Testing of polymers.	**8**	CO4

REFERENCES

1	F.W. Billmeyer, Textbook of Polymer Science, 3rd Ed, Wiley, 1984
2	C.E. Carraher, Introduction to polymer chemistry, Traylor and Francis, 2007
3	Gowariker, "Polymer Science", 2nd ed., New Age int. pub., 2015

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Year	IV	CORE ~~/ ELECTIVE / FOUNDATION 1~~	**Credit**	4
Semester	I	CHL 17XXCS: TRANSPORT PHENOMENA	**Hours**	56

COURSE OBJECTIVES: -

CO1 Analyse the fundamentals of transport phenomena and fluid dynamics in chemical engineering processes.

CO2 Apply shell momentum and energy balance techniques to solve flow problems.

CO3 Analyse convective heat transport and develop solutions for heat transfer problems.

CO4 Examine the analogies between momentum, heat, and mass transfer in various media.

UNITS	Contain	Hrs	CO
1	**UNIT I: Fundamentals of Transport Phenomena and Fluid Dynamics** Role of transport phenomena in chemical engineering, Fluid classification and transport properties, non-Newtonian fluids and two-parameter models, Lagrangian and Eulerian concepts of motion, Control volume approach and mass balances in various coordinate systems	**10**	CO1
2	**UNIT II: Momentum Transport and Shell Balance** Shell momentum balance approach and applications, Equation of motion and its applications	**8**	CO2
3	**UNIT III: Fluid Dynamics and Turbulence** Boundary Layer theory and von Karman's analysis, Exact solutions using stream functions, Turbulence concepts, mixing length hypothesis, Universal velocity profile and applications	**12**	CO3
4	**UNIT IV: Energy Transport** Shell energy balance approach and applications, Convective heat transport, Asymptotic solutions of typical flow problems	**8**	CO3
5	**UNIT V: Mass Transport and Diffusion** Fick's law of diffusion, Differential balances in mass transfer, Critical analysis of mass transfer correlations, Mass transfer theories	**9**	CO4

6	**UNIT VI: Analogies** Convection-diffusion problems in homogeneous and heterogeneous media, Analogy between momentum, heat, and mass transfer	**9**	CO4
REFERENCES			
1	Bird Stewart and Lightfoot, 'Transport Phenomena' 2nd Ed, Wiley, 2002		
2	Welty, Wicks, Wilson &Rorer 'Fundamentals of Momentum heat & mass transfer, Wiley, 2001.		