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(Established as a University of Technology in the State of Maharashtra)
(Under Maharashtra Act No. XXIX of 2014)
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Detailed Syllabus
for
Third Year B. Tech program in Petrochemical Engineering

With effective from
Academic year July 2019-20

Teaching and Evaluation Scheme Third Year B. Tech. (Petrochemical Engineering)

Sr. No.	Code	Course title	Weekly Teaching hours			Evaluation Scheme			Credit
			L	T	P	MSE	CA	ESE	
Semester V									
1	BTCHC 501	Chemical Engineering Thermodynamics - II	3	1	-	20	20	60	4
2	BTCHC 502	Mass Transfer Operations - I	3	1	-	20	20	60	4
3	BTCHC 503	Chemical Reaction Engineering - I	3	1	-	20	20	60	4
4	BTID 504	Product Design Engineering - II	1	-	2	-	60	40	2
5	BTPCC 505	Petrochemical Engineering -II	3	-	-	20	20	60	3
6	BTCHE 506	Elective II A. Petroleum Refining and Petrochemicals B. Fuel Cell Engineering C. Nuclear Process Engineering D. Food Technology E. Chemistry of Petroleum Hydrocarbons	3	-	-	20	20	60	3
7	BTCHM 507	Mini Project III	-	-	2	-	30	20	1
8	BTCHL 508	Mass Transfer Laboratory – I	-	-	2	-	30	20	1
9	BTCHL 509	Chemical Reaction Engineering Laboratory – I	-	-	2	-	30	20	1
10	BTPCL 510	Petrochemical Engineering Laboratory - II	-	-	2	-	30	20	1
11	BTPCF 511	Field Training / Internship/Industrial Training Evaluations (of sem. IV)						50	1
		Total	16	3	10	100	280	470	25

Semester VI									
1	BTCHC 601	Mass Transfer Operations - II	3	1	-	20	20	60	4
2	BTCHC 602	Chemical Reaction Engineering - II	3	1	-	20	20	60	4
3	BTCHC 603	Process Economics and Project Management	3	-	-	20	20	60	3
4	BTPCC 604	Petrochemical Engineering - III	3	-	-	20	20	60	3
5	BTCHC 605	Plant Utilities and Plant Safety	3	-	-	20	20	60	3
6	BTCHE 606	Elective III A. Catalyst Science and Technology B. Polymer Science and Engineering C. Non-Newtonian Flow and Rheology D. Optimization Techniques E. Heat Transfer equipment Design	3	-	-	20	20	60	3
7	BTCHM 607	Mini Project IV	-	-	2	-	30	20	1
8	BTCHL 608	Mass Transfer Laboratory – II	-	-	2	-	30	20	1
9	BTCHL 609	Chemical Reaction Engineering Laboratory - II	-	-	2	-	30	20	1
10	BTPCS 610	Seminar	-	-	2	-	30	20	1
11	BTPCF 611	Field Training / Internship/Industrial Training (minimum 4 weeks which can be completed partially in first semester and second Semester or in at one time.)	Credits to be evaluated in VIIth Sem.						
		Total	18	2	8	120	240	440	24

Semester V

BTCHC 501 Chemical Engineering Thermodynamics – II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Calculate heat effects involved in industrial chemical processes
CO2	Determine thermodynamic properties of gaseous mixtures / solutions
CO3	Calculate Bubble-P & T, Dew-P & T for binary and multi-component systems
CO4	Calculate vapor-liquid equilibrium (VLE) composition for ideal and non-ideal systems
CO5	Determine equilibrium constant and composition of product mixture at given temperature and pressure

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	✓	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: Vapour/Liquid Equilibrium Introduction: The nature of equilibrium, the Phase Rule, Duhem's Theorem, VLE: Qualitative behaviour, Simple models for vapour/liquid equilibrium, VLE by modified Raoult's Law, VLE from K- value correlations.

Unit II: Solution Thermodynamics Theory: Fundamental property relation, The chemical potential and phase equilibria, Partial properties, Ideal gas mixtures, Fugacity and fugacity coefficient.

Unit III: Solution Thermodynamics Theory: (continued) Fugacity and fugacity coefficient: Species in the solution, generalized correlations for the fugacity coefficient, The ideal solution, Excess properties.

Unit IV: Solution Thermodynamics Applications: Liquid-phase properties from VLE data, Models for the excess Gibbs energy, Property changes of mixing, Heat Effects of mixing processes.

Unit V: Chemical Reaction Equilibria: The reaction coordinate, Application of equilibrium criteria to chemical reactions, The standard Gibbs energy change and equilibrium constant, Effect of temperature on the equilibrium constants.

Unit VI: Chemical Reaction Equilibria: Relation of equilibrium constants to composition, Equilibrium conversions for single reactions, Phase rule and Duhem's theorem for reacting systems, Multi reaction equilibria, Fuel cells.

Text/Reference books:

- J. M. Smith, H.C. Van Ness, and M.M. Abbott, Chemical Engineering Thermodynamics, 6^{th}ed, Tata McGraw Hill edition, 2003.
- Y. V. C. Rao, "Chemical Engineering Thermodynamics", University Press 1997
- S. I. Sandler. "Chemical Engineering Thermodynamics", Wiley, New York, 1999.

BTCHC 502 Mass Transfer Operations – I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand Fick's law of diffusion
CO2	Determine diffusivity coefficient in gases and liquids
CO3	Determine mass transfer coefficients
CO4	Calculate rate of mass transfer in humidification
CO5	Select equipment for gas-liquid operations

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	-	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed syllabus

Unit I: Diffusion in fluids - Fick's Law of diffusion equimolecular counter diffusion, diffusion in stationary gas. Maxwell's low of diffusion. Inter phase mass transfer - Mass transfer equilibrium, diffusion between two phases. Local mass transfer coefficient, Local and average overall mass transfer coefficients. Simultaneous heat and mass transfer.

Unit II: Material balance – steady state co current and counter current processes stage wise and differential contacts. Number of theoretical stages.Stage efficiency Height of mass transfer units.

Unit III: Gas Absorption - Equilibrium solubilities of gases.Material balance for transfer of one component. Counter current multistage operations for binary and multi component systems. Continuous contactors, absorption with chemical reaction.

Unit IV: Liquid–liquid extraction - Calculations with and without reflux for immiscible and partially miscible system.
Leaching - Leaching single and multistage operations based on solvent free co ordinates.

Unit V: Adsorption and Ion-exchange- Types of adsorption; Nature of adsorption; Freundlich equation; Types of adsorption; Nature of adsorption; Freundlich equation; Stage wise and continuous adsorption. Stage wise and continuous adsorption.Theory of ion – exchange and its application to removal of ionic impurity.

Unit VI: Gas–Liquid operations - Sparged vessels (bubble columns), mechanically agitated vessels for a single phase and gas liquid contact liquid dispersed scrubbers, venturi scrubbers, wetted towers packed towers. Mass transfer coefficients for packed towers co-current flow of gas and liquid end effect and axial mixing.

Texts / References:

- R. E. Treybal, Mass transfer operations, 3ed ed. McGraw Hill, 1980.
- A. S. Foust et al. Principles of Unit Operations
- J. M. Coulson and J. F. Richardson, “Chemical Engineering”, Vol. 1 ELBS, Pergaman press, 1970
- J. M. Coulson and J. F. Richardson, “Chemical Engineering” Vol. 2 ELBS, Pergaman press, 1970

BTCHC 503 Chemical Reaction Engineering - I

Course Outcomes: At the end of the course, students will be able to:

CO1	Compare the performance of ideal and non-ideal reactors using E- and F-curves
CO2	Determine the mean residence time and standard deviation using residence time distribution (RTD) data
CO3	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model
CO4	Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer
CO5	Design fixed bed reactors involving chemical reactions with mass transfer
CO6	Determine internal and overall effectiveness factors

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO6	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed syllabus

Unit I: Mole Balances - Definition of the rate of reaction, General mole balance equation, Batch Reactors, Continuous-flow reactors, Industrial reactors

Unit II: Conversion and Reactor Sizing - Definition of conversion, Design equations, Applications of the design equations for continuous-flow reactors, Reactors in series

Unit III: Rate-Law and Stoichiometry - Basic definitions, Approach to reactor sizing and design, Stoichiometric table, expressing concentrations in terms other than conversion, Reactions with phase change

Unit IV: Isothermal Reactor Design - Design structure for isothermal reactors, Scale up of liquid-phase batch reactor data to the design of a CSTR, Tubular reactors, Recycle reactors

Unit V: Collection and Analysis of Rate Data - Batch reactor data, Method of initial rates, Method of half-life, Differential reactors, Least square analysis

Unit VI: Catalysis and Catalytic Reactors - Catalysts, Steps in a catalytic reaction, synthesizing a rate law, mechanism and rate-limiting step, Design of Reactors for gas-solid reactions, Heterogeneous data analysis for reactor design

Texts / References:

- H. S. Fogler, "Elements of Chemical Reaction Engineering", 3rd Ed, New Delhi-Prentice Hall, 2001
- O. Levenspiel," Chemical Reaction Engineering" Willey Eastern, 3rd Ed., 2000
- J. M. Smith, "Chemical Engineering Kinetics", 3rd Ed., McGraw- Hill, 1988

BTID 504 Product Design Engineering - II

BTID504	PCC 8	Product Design Engineering	1-0-2	2 Credits

Teaching Scheme:	Examination Scheme:
Lecture-cum-demonstration: 1hr/week Design Studio/Practical: 2 hr/week	Continuous Assessment 1: 30 Marks Continuous Assessment 2: 30 Marks Final Assessment: 40 Marks

Pre-requisites: Product Design Engineering: Part-I (IVth Semester), Basic Knowledge of Mechanical, electronics, electrical, computer and Information Technology disciplines

Design Studio/Practical: 2 hr to develop design sketching and practical skills
Continuous Assessment: Progress through a product design and documentation of steps in the selected product design
End Semester Assessment: Product Design in Studio with final product specifications

Course Outcomes: At the end of the course, students will be able to

1. In-silico Design of product, detailing of components, Create prototypes
2. Devise the tests and Testing the prototypes
3. Prepare detail product specification sheet
4. Understand the product life cycle management

Detailed syllabus

Unit I: Testing and Evaluation- Prototyping, Design Automation, Product architecture, Prototype testing and evaluation, Working in multidisciplinary teams, Feedback to design processes, Process safety and materials, Health and hazard of process operations. Writing detail specifications of various building blocks of the product as per Standards; writing specifications for materials and various items of work;

Unit II: Embedded Engineering User Interface- Firmware and Hardware Design, UI programming, Algorithm and Logic Development, Schematic and PCB layout, Testing and Debugging.

Unit III: Manufacturing- Design models and digital tools, Decision models, Prepare documents for manufacturing in standard format, Materials and safety data sheet, Final Product specifications sheet, Detail Engineering Drawings (CAD/CAM programming), Manufacturing for scale, Design/identification of manufacturing processes. Systems of taking out quantities and estimating for all trades involved in construction of the product; preparation of Bill of Quantities (BOQ); Cost estimating for material and labor, valuation report preparation, and Budgeting for specific projects.

Unit IV: Environmental Concerns-Product life-cycle management, Disposal of product and waste.

Hands-on Activity Charts for Use of Digital Tools (Vth Semester)

Activity 1	Prototyping/Assembly	4
Activity 2	Testing and evaluation	3
Activity 3	UI Programming	3
Activity 4	PCB Layout, Testing and debugging	3
Activity 5	CNC Programming	3
Activity 6	CNC Programming with CAM software	3
Activity 7	Product market and Product Specification Sheet	3
Activity 8	Documentation for the product	2

Texts / References:

- Model Curriculum for "Product Design Engineer – Mechanical", NASSCOM (Ref. ID: SSC/Q4201, Version 1.0, NSQF Level: 7)
- Eppinger, S., & Ulrich, K.(2015). Product design and development, McGraw-Hill Higher Education.
- Green, W., & Jordan, P. W. (Eds.).(1999), Human factors in product design: current practice and future trends. CRC Press.
- Sanders, M. S., & McCormick, E. J. (1993), Human factors in engineering and design. McGraw-Hill Book Company.
- Roozenburg, N. F., & Eekels, J. (1995), Product design: Fundamentals and Methods (Vol. 2). John Wiley & Sons Inc.
- Lidwell, W., Holden, K., & Butler, J.(2010), Universal principles of designs, revised and updated: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design. Rockport Publication.

BTPCC 505 Petrochemical Engineering – II

(Lubricants, Waxes and Specialty Chemicals)

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand details of lubricating oil, their specification and technology involved
CO2	Analyze and Evaluate re-refining of lube oil
CO3	Gain knowledge about type of waxes, their synthesis and end use
CO4	Understand different specialty chemicals in use in Petrochemical industry

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓								
CO2	✓	✓	✓	✓								
CO3	✓	✓	✓									
CO4	✓	✓	✓									

Detailed Syllabus:

Unit I: Lubricating oils, Specifications, characteristics, production, lube specialties, additives.

Unit II: Refining of lubricating oil - solvent, chemical and hydrogenation method, dewaxing DE asphalting etc. Re-refining of lubricating oil. Asphalt and asphalt specialties, Air blowing and emulsification techniques

Unit III: Waxes - Introduction, History of waxes and their applications, definitions, Classification- Natural, partially synthetic and fully synthetic wax.

Unit IV: Petroleum wax: Macro-crystalline wax (Paraffin wax), Microcrystalline wax (Micro waxes), Division into product classes of paraffin wax. Production of microwaxes, candles.

Unit V: Process for the manufacture of specialty chemicals such as synthetic lubricants, pore point depressant.

Unit VI: Process for manufacture of flow additive, oil field additives, Napthatic acid, anti-oxidants and other performance chemicals.

Reference Book:

- Peter H.Spitz; Petrochemicals 'The Rise of an Industry'
- Wiley Critical Content Petroleum Technology- Vol-2, Wiley Interscience Publication.

BTCHE 506 Elective II

A. Petroleum Refining and Petrochemicals

Course Outcomes: At the end of the course, the student will be able to:

CO1	State the composition of petroleum.
CO2	Understand the unit operations and processes in petroleum refining
CO3	Understand the technologies for conversion of petroleum refining products to chemical products
CO4	Select feed stock for conversion to products

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: Origin, formation and composition of petroleum- Origin and formation of petroleum, Reserves and deposits of world, Indian Petroleum Industry, composition of petroleum. **Petroleum processing data**: Evaluation of petroleum, thermal properties of petroleum fractions, important products, properties and test methods.

Unit II: Fractionation of petroleum- Dehydration and desalting of crudes, heating of crude-pipe still heaters, distillation of petroleum, blending of gasoline. **Treatment techniques**: Fraction-impurities, treatment of gasoline, treatment of kerosene, treatment of lubes.

Unit III: Thermal and catalytic processes- Cracking, catalytic cracking, catalytic reforming, Naphtha cracking, coking, Hydrogenation processes, Alkylation processes, Petrochemical Industry – Feed stocks

Unit IV: Chemicals from methane- Introduction, production of Methanol, Formaldehyde, Ethylene glycol, PTFE, Methylamines. **Chemicals from ethane-ethylene-acetylene**: Oxidation of ethane, production of Ethylene, Manufacture of Vinyl Chloride monomer, Vinyl Acetate manufacture, Ethanol from Ethylene, Acetylene manufacture, Acetaldehyde from Acetylene.

Unit V: Chemicals from C3, C4 and higher carbon atoms- Chemical from Propylene, manufacture of Isopropanol, manufacture of Acrylonitrile, production of Acrylic acid, polymers and copolymers of propylene, production of Phenol from cumene, production of Bisphenol-A, manufacture of maleic Anhydride, production of Acetic acid and production of Butadiene from Butane.

Unit VI: Synthesis gas and chemicals: Steam reforming of hydrocarbons, production of synthesis gas, SNG from Naphtha, Synthesis gas via partial Oxidation.

Texts / References:

- B.K. Bhaskara Rao - Modern Petroleum Refining Processes - 3rd edition, Oxford & IBH Publishing Co. Pvt. Ltd., Jan. 1997.
- B.K. Bhaskara Rao - A Text of Petrochemicals - 2nd edition, Khanna Publications, 1998.
- W.L. Nelson - Petroleum Refinery Engineering; McGraw Hill Book Company

B. Fuel Cell Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	State the composition of Fuel Cell
CO2	Understand the unit operations and processes in Fuel Cell.
CO3	Understand the technologies for conversion of Fuel Cell products to chemical products
CO4	Select feed stock for conversion to products

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: Overview of Fuel Cells: What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.

Unit II: Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others.

Unit III: Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

Unit IV: Fuel cell process design: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, Fuel cell operating conditions: pressure, temperature, flow rates, humidity.

Unit V: Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modeling

Unit VI: Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal, Using renewable fuels for SOFCs

Texts / References:

- Hoogers G., Fuel Cell Technology Hand Book, CRC Press, 2003.
- Karl Kordesch& Gunter Simader, Fuel Cells and Their Applications, VCH Publishers, NY, 2001.
- Barbir, PEM Fuel Cells: Theory and Practice, 2nd Ed., Elsevier/Academic Press, 2013.
- Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications, 2003.
- O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, NY 2006.

C. Nuclear Process Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand radioactivity, nuclear fission and fusion.
CO2	Understand the interaction of alpha, beta particles and neutrons with matter
CO3	Understand neutron cycle, critical mass, reactor period and transient conditions
CO4	Understand engineering aspects of nuclear power production and environmental effects.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO2	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO3	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	✓	-	-	-	-	-

Detailed Syllabus:

Unit I: Nuclear Energy Fundamentals- Atomic structure and Radio isotopes, Nuclear fission and fusion, types and classification of nuclear reactors, nuclear fuels, other reactor materials, fuel processing flow sheet, chemical processes for nuclear power industries, separation of reactor products, nuclides.

Unit II: Nuclear Reactions and radiations- Radioactivity, interaction of alpha and beta particles with matter, decay chains, neutron reactions, fission process, growth and decay of fission products in a reactor with neutron burnout and continuous processing.

Unit III: Make up of reactor, reactor fuel process flow sheet, irradiation schemes, neutron balance, feed requirements and fuel burn up for completely mixed fuels with no recycle.

Unit IV: Nuclear Reactor theory- The neutron cycle, critical mass, neutron diffusion, the diffusion equation, slowing down of neutrons, reactor period, transient conditions and reflectors.

Unit V: Engineering Consideration of nuclear Power-Environmental effects: Introduction to nuclear power systems, Thermal-hydraulics: Thermal parameters: definitions and uses. Sources and distribution of thermal loads in nuclear power reactors. Conservation equations and their applications to nuclear power systems: power conversion cycles, containment analysis.

Unit VI: Thermal analysis of nuclear fuel, Single-phase flow and heat transfer, Two-phase flow and heat transfer.

Texts / References:

- Glasstone S and Alexender Seasonske, Nuclear Reactor Engineering, 3rd Edition, CBS publisher, USA, 1994.
- K. Sriram, Basic Nuclear Engineering, Wiley Eastern Ltd., 1990.
- W Marshall, Nuclear Power Technology, Vol I, II, and III, Oxford University Press, New York 1983.

D. Food Technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain techniques in food processing
CO2	Design process equipment to achieve the desired quality of food
CO3	Develop novel food processes that have a minimal effect on food quality
CO4	Design efficient controllers to maintain food quality

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus:

Unit 1:Introduction- General aspects of food industry, World food demand and Indian scenario, Constituents of food, Quality and nutritive aspects, Product and Process development, engineering challenges in the Food Processing Industry.

Unit 2:Basic principles- Properties of foods and processing theory, Heat transfer, Effect of heat on micro-organisms, Basic Food Biochemistry and Microbiology: Food Constituents; Food fortification, Water activity, Effects of processing on sensory characteristics of foods, Effects of processing on nutritional properties, Food safety, good manufacturing practice and quality Process Control in Food Processing.

Unit 3: Ambient Temperature Processing: Raw material preparation, Size reduction, Mixing and forming, Separation and concentration of food components, Centrifugation, Membrane concentration, Fermentation and enzyme technology, Irradiation, Effect on micro-organisms, Processing using electric fields, high hydrostatic pressure, light or ultrasound.

Unit 4:Heat processing using steam, water and air- Blanching, Pasteurisation, Heat sterilization, Evaporation and distillation, Extrusion, Dehydration, Baking and roasting.

Unit 5:Heat processing by direct and radiated energy- Dielectric heating, Ohmic heating, Infrared heating.

Unit 6: Post Processing Applications Packaging- Coating or enrobing, Theory and Types of packaging materials, Printing, Interactions between packaging and foods, Environmental considerations.

Texts / References:

- Fellows P., Food Processing Technology: Principles and Practice, 2nd Edition, Woodhead Publishing, 2000.
- Toledo R, Fundamentals of Food Process Engineering, 3rd Edition, Springer, 2010.
- Singh, R.P. &Heldman, D.R., Introduction to Food Engineering, 3rd Edition, Academic Press, UK, 2001.
- Smith J.M., Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981

E. Chemistry of Petroleum Hydrocarbons

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand details of crude composition and their uses
CO2	Understand chemistry and technology of different reactions
CO3	Understand and analyze structure of catalyst
CO4	To know application of catalyst in petrochemical Industry

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓		✓								
CO2	✓	✓		✓								
CO3	✓	✓		✓								
CO4	✓	✓		✓								

Detailed Syllabus:

Unit I: Review of types of hydrocarbon groups present in petroleum and their structures, sulfur, nitrogen, oxygen and oregano-metallic compounds in petroleum

Unit II: Low and high molecular paraffin's, olefins, aromatics naphthenes and Diens, their thermodynamic stability and reactivity and their relationship with the performance characteristics

Unit III: Chemistry of certain reactions such as cracking, cyclization, dehydrogenation, hydrogenation, oxidation, nitration

Unit IV: Chemistry of certain reactions such as chlorination, alkylation, disproportionation, Trans alkylation, esterification and etherification

Unit V: Zeolite synthesis reactions, unit cell structure, classification, acidity, and basicity in Zeolites, cation exchange dealumination and isomorphus substitution principles

Unit VI: Applications of Zeolites in catalysis and in separation processes- a few case studies

Texts / References:

- N.N. Lebdev, Chemistry and technology of basic organic and petrochemical synthesis, Vol. 1 & 2 Mir publications, Moscow
- W.D. Breek, Zeolite Molecular sieve structure, chemistry and use, John Wiley & Sons, NY, 1974

BTCHM 507 Mini Project- III

The purpose behind the mini project is that the student should be exposed to more hands-on rather than merely theory. It is expected that the student (or a small group say, not more than two in a group, to be confirmed) will undertake to make a working model, a program, critics on technology evolution, experimental work, survey etc. which he will benefit from since he /she will be doing it first-hand. It should be related to chemical engineering field

BTCHL 508 Mass Transfer Laboratory – I

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine efficiency of steam distillation
CO2	Plot mutual solubility curve for acetone-methyl-iso-butyl-ketone and water
CO3	Determine the overall plate efficiency of sieve plate distillation
CO4	Verify Rayleigh's equation for batch distillation
CO5	Determine HETP and HTU for given packing for distillation of benzene-acetone mixture under total reflux
CO6	Determine the critical moisture content in drying

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	✓	-	✓	-
CO2	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO3	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO4	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO5	✓	-	✓	-	-	-	-	-	✓	-	✓	-
CO6	✓	-	✓	-	-	-	-	-	✓	-	✓	-

List of Practicals:

1. To determine the diffusivity of acetone in air
2. To determine the diffusivity of carbon tetra chloride in air
3. To study the absorption with chemical reaction in packed bed
4. To study multistage cross-current leaching operation for calcium carbonate, sodium hydroxide water system.
5. To draw equilibrium solubility diagram for an acetic acid, benzene, water. and benzene(C) system
6. To study liquid-liquid extraction in packed bed (HTU/NTU)
7. To study the physical absorption in packed bed (HTU/NTU)

BTCHL 509 Chemical Reaction Engineering Laboratory – I

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand and calculate activation energy for given reaction
CO2	Determine rate of reaction and parameter affecting the rate.
CO3	Understand kinetic of different reaction

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓			✓			-	-	-	-	-	-
CO2	✓	✓		✓			-	-	-	-	-	-
CO3	✓	✓		✓			-	-	-	-	-	-

List of Practicals:

1. Determine activation energy of acid catalysed hydrolysis of methyl acetate.
2. To study effect of concentration of reactant and temperature on the rate of reaction.
3. To determination of specific reaction rate of acid catalyzed hydrolysis of ethyl acetate
4. Determination of specific reaction rate of acid catalyzed hydrolysis of ethyl acetate by sodium hydroxide at 298 K
5. To study the reaction between potassium persulphate and iodide
6. Kinetics of hydrolysis of methyl acetate by strong acid.
7. To study saponification of ethyl acetate.
8. Study of Isothermal continuous stirred tank reactor

BTPCL510 Petrochemical Engineering Laboratory - II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand product tests methods and their significance
CO2	Perform experiment related to distillation, calorific value
CO3	Perform and analyze experimental results

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓		✓			✓					
CO2	✓	✓		✓			✓					
CO3	✓	✓		✓			✓					

List of Practicals:

1. To determine the Rams bottom Carbon Residue of given petroleum sample
2. To determine the Drop point of given petroleum product.
3. To determine the Conrandson carbon residue of given petroleum sample.
4. To determine the calorific value of given petroleum product by Bomb Calorimeter.
5. To determine the ASTM distillation curve for given petroleum product.
6. Determination of % aromatics in given petroleum sample by Aniline Point Method.
7. To study the method for determination of hydrocarbon type (PONA Analysis) in liquid
8. Petroleum product by Fluorescent Indicator Adsorption Method.
9. To study the method for determination of surface area of catalyst sample by BET technique.
10. To determine the penetration index of given grease sample
11. To determine the vaporization characteristics of given petroleum product by TBP distillation.

BTPCF 511 Field Training / Internship/Industrial Training Evaluations (of sem. IV)

Evaluation of the Internship / Industrial Training done in the end of IV^{rth} Semester.

Semester VI

BTCHC 601 Mass Transfer Operations – II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Select solvent for absorption and extraction operations
CO2	Determine number of stages in distillation, absorption and extraction operations
CO3	Determine the height of packed column in absorption, distillation and extraction
CO4	Calculate drying rates and moisture content for batch and continuous drying

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: Distillation - Vapour liquid equilibria, flash vapourisation, batch distillation, differential distillation.

UNIT II: Continuous fractionation - Binary systems, Mc-Cabe.Thiele and PonchonSavarit method calculations with multiple feeds and withdrawal

UNIT III: Humidification - Vapour liquid equilibrium, enthalpy for pure substances, vapour gas contact operation. Psychrometric charts and measurement of humidity
Dehumidification and Cooling Tower Design - Adiabatic and non adiabatic operations, evaporative cooling, cooling tower design and dehumidification methods.

UNIT IV: Drying - Drying equilibrium and rate of drying, drying operation batch and continuous number of transfer units.

UNIT V: Crystallisation - Theories of crystallisation nucleation and crystal growth. principles of supe saturation. Different types of crystallisers.

UNIT-VI: Special topics in separation: Types of membranes for osmosis and dialysis; Mechanism of solute/solvent rejection in the process; Design of R.O. and dialysis units; applications.

Texts / References:

- R. E. Treybal, Mass transfer operations, 3ed ed. McGraw Hill, 1980.
- J. M. Coulson and J. F. Richardson, "Chemical Engineering", Vol. 1 ELBS, Pergamon press, 1970
- J. M. Coulson and J. F. Richardson, "Chemical Engineering" Vol. 2 ELBS, Pergamon press, 1970

BTCHC 602 Chemical Reaction Engineering – II

Course Outcomes: At the end of the course, students will be able to:

CO1	Compare the performance of ideal and non-ideal reactors using E- and F-curves.
CO2	Determine the mean residence time & standard deviation using residence time distribution(RTD)
CO3	Analyze the performance of non-ideal reactors using segregation model, tanks-in series model and dispersion model
CO4	Understand the effect of velocity, particle size and fluid properties on rate of reactions controlled by mass transfer
CO5	Design fixed bed reactors involving chemical reactions with mass transfer
CO6	Determine internal and overall effectiveness factors

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	-	-	✓	-	-	-	-	-
CO6	✓	✓	✓	✓	-	-	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: Multiple Reactions - Maximizing desired product in parallel reactions, Maximizing desired product in series reactions, Stoichiometric table using fractional conversion

UNIT II: Multiple reactions in PFR and CSTR- An alternative approach to using fractional conversion

UNIT III: Non elementary Reaction Kinetics - Fundamentals, Searching for a mechanism, polymerization, enzyme reaction fundamentals, Bioreactors

UNIT IV: External Diffusion Effects on Heterogeneous Reactions - Mass transfer fundamentals, Binary diffusion, External resistance to mass transfer, The shrinking core model

UNIT V: Distribution of Residence times for Chemical Reactors - General Characteristics, Measurement of RTD, Characteristics of RTD, RTD in ideal reactors, Reactor modeling with RTD, Zero-parameter models

UNIT VI: Models for non-ideal reactors - One-parameter models; tank-in-series model, dispersion model

Texts / References:

- H. S. Fogler, "Elements of Chemical Reaction Engineering", 3rd Ed, New Delhi-Prentice Hall, 2001
- O. Levenspiel," Chemical Reaction Engineering" Willey Eastern, 3rd Ed., 2000

- J. M. Smith, “Chemical Engineering Kinetics”, 3rd Ed., McGraw- Hill, 1988

BTCHC 603 Process Economics and Project Management

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze alternative processes and equipment for manufacturing a product
CO2	Design plant layout and engineering flow diagrams
CO3	Perform economic analysis related to process design
CO4	Evaluate project profitability

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	-	-	-	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	✓	-	✓	-	✓	-
CO3	-	-	✓	✓	✓	-	-	✓	✓	-	-	-
CO4	-	-	✓	✓	✓	-	-	✓	-	-	-	-

Detailed Syllabus

UNIT I: Capital cost estimation in chemical industries, different methods of calculation of fixed costs. Capital Investment and working Capital.

UNIT II: Time value of money, types of interest, investment costs, annuities, perpetuity and capitalized costs, discounted cash flow analysis

UNIT III: Taxes and insurance, depreciation, amortization and obsolescence in chemical industries, types of depreciation methods, breakeven point analysis

UNIT IV: Discussion on projects , causes for time and cost overruns, project evaluation and assessment of project profitability, organization of project engineering.

UNIT V: Optimum process design with examples, project development and commercialization, plant location and layout, selection of plant capacity.

UNIT VI: Project engineering management, project scheduling and its importance, use of CPM/PERT techniques.

Texts / References:

- M. S. Peters and K. D. Timmerhaus, "Plant Design Economics for Chemical Engineers", 5th Ed., McGraw-Hill, New York - 2003.
- V. W. Uhl and A. W. Hawkins, "Technical Economics for Chemical Engineers", AIChE - 1971.
- J. Modes and Philips, "Project Engineering with CPM and PERT", Rein Hold.
- Choudhary, “Project Management”
- Jelen, “Cost and Optimization Engineering”

BTPCC 604 Petrochemical Engineering -III
(Petroleum Refinery Engineering)

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand working types and calculate heat duty for pipe still heaters
CO2	Understand the equilibrium of multicomponent systems
CO3	Design distillation column for multicomponent system
CO4	Understand different types of distillation column ,and to do inter-conversion of data

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓								
CO2	✓	✓	✓	✓								
CO3	✓	✓	✓	✓								
CO4	✓	✓	✓	✓								

Detailed Syllabus:

Unit I: Heating of crude oil through exchangers. Pipe still heaters, their types and constructional features, estimation of heat duty, combustion calculation and heat transfer area in different parts in pipe still heater. Calculations of pressure drop and stack height.

Unit II: Flash distillation, Dew point and Bubble point calculations, temperature and concentration profile in a distillation column.

Unit III: Multicomponent distillation, Calculation of number of stages in distillation, Key component concept, Comparison between multicomponent distillation and petroleum distillation

Unit IV: Distillation curves and their interconversion at atmospheric, sub atmospheric and super atmospheric pressure, Collection and data for distillation column design and operation etc.

Unit V: Atmospheric distillation, principles and mode of excess heat removal, Flash zone calculation and estimation of side draw tray temperatures, Design aspects, Post treatment of straight run products.

Unit VI: Vacuum distillation column internals and operational aspects for lubes, asphalt, cracking feedstock, Pressure distillation and gas fractionation units, Difference between various types distillation regaining products of pressure distillation.

Texts / References:

- B. K. Bhaskara Rao, Modern Petroleum Refining Processes, Oxford & IBH (2006)
- W.L. Nelson, Petroleum Refinery Engineering, McGraw –Hill, 1964
- 3 M. Van winkle, Distillation, McGraw –Hill, 1961

BTCHC 605 Plant Utilities and Plant Safety

Course Outcomes: At the end of the course, the student will be able to:

CO1	List utilities in a plant.
CO2	Understand properties of steam and operation of boilers for steam generation
CO3	Understand refrigeration methods used in industry
CO4	Compare power generation methods
CO5	Classify and describe the types of water, water treatment methods, storage and distribution techniques

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO4	✓	-	✓	✓	-	✓	-	-	-	-	-	-
CO5	✓	-	✓	✓	-	✓	✓	-	-	-	-	-

Detailed Syllabus:

UNIT I: Identification of common plant utilities: water, compressed air, steam, vacuum, refrigeration, venting, flaring and pollution abating. Water and its quality, storage and distribution for cooling and fire fighting.

UNIT II: Steam generation by boilers: Types of boilers and their operation, Steam generation by utilizing process waste heat using thermic fluids, Distribution of steam in a plant.

UNIT III: Principles of refrigeration: Creation of low temperature using various refrigerants.Creation of low pressure/vacuum by pumps and ejectors.

Unit IV: Safety in Chemical Processes: Introduction, Chemical Process classification, Process design and safety parameters. Safety parameters in the process design of phenol from cumene, safety in polyvinyl chloride plant. Chemicals and their Hazards: Introduction, Acetonitrile, acetyl chloride, butyl amine, acrylamide, acrylonitrile, allyl alcohol, benzene, bromine, isopropyl alcohol, acetaldehyde, ethylene oxide, butane, n-hexane, anhydrous ammonia, acetone, toluene, p-xylene, acetic acid, monochloro benzene, oleum, carbon mon

Unit V: Hazards in Chemical Process plants: Introduction, Hazards, Hazard code and explosive limit, electrical safety in chemical process plants, static electricity hazards, pressure vessel hazards, LEL and UEL of various compounds, explosive hazard, flammable liquid hazards, protection to storage tanks, fire zone location, fireball, fireball hazard. Safety in handling gases, liquids and solids: Introduction, safety in handling of gases, chlorine hazards, chlorine leakage management, safety in handling of fluorine, important safety considerations in ammonia storage, flammable solids storage, flammable liquid storage, handling of LNG, requirements to be fulfilled for storing hydrocarbons or chemicals, fail safe concept, transportation of hazardous chemicals, Hazardous in plastics processing.

Unit VI: Combating Chemical Fires: Classification of fires, control of high vapour pressure fire, firefighting foams, foam for fire protection, Foam characteristics, gaseous agent extinguishing system, automatic sprinkler system, chemical extinguishing powders, natural gas fire control. Portable fire extinguishers: Soda-acid extinguishers, carbon dioxide extinguisher, dry chemical fire extinguisher, general safety precautions for maintenance of fire extinguishers. Safety Checklist: safety studies for chemical plants, safety checklist during startup, safety checklist during shutdown mode, safety checklist for installation, safety needs during construction. Protective devices.

Texts / References:

- D. A. Wangham, Theory and practice of Heat engines, ELBS cambridge University press, 1970.
- J. L. Threlkeld, Thermal Environmental Engineering, Prentic Hall 1970.
- S.D.Dawande, Chemical Hazards and safety, Dennet& Co publishers, 2007

BTCHE 606 Elective III
A. Catalyst Science and Technology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand details of catalytic processes
CO2	Understand characterization of catalyst
CO3	Apply knowledge for catalyst selectivity
CO4	Know in newer development in the field of catalysis

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO2	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO3	✓	✓	✓	✓	-	✓	-	-	-	-	-	-
CO4	✓	-	✓	✓	-	✓	-	-	-	-	-	-

Detailed Syllabus:

UNIT I: Heterogeneous catalytic processes, types of heterogeneous reactions. Absorption, absorption isotherms, rates of absorption, Physisorption and chemisorptions. Solid catalysis, types of catalysts, catalyst formulations and Preparation methods.

UNIT II: Catalysts Characterization methods: Surface area and pore volume determinations, XRD, various Spectroscopic techniques, Temperature programmed reduction & oxidation, Electron microscopy.

UNIT III: Testing of catalysts, various types of reactors, activity and selectivity studies. Effect of external transport processes on observed rate of reactions. Effect of internal transport processes: reactions and diffusion in porous catalysts.

UNIT IV: Mechanism of catalytic reactions, Rates of adsorption, desorption, surface reactions, rate determining steps. Kinetic modelling and Parameter estimations, Model discriminations.

UNIT V: Catalysts promoters, Inhibitors, catalyst deactivations, kinetics of catalyst deactivations. Industrial processes involving heterogeneous solid catalysts.

UNIT VI: New development in solid catalysis, monolith catalysts, Nano catalysts, Fuel cell catalysts, Environmental catalysts, Insitu characterization.Design of catalysts; simulation techniques.

Texts / References:

- J. M. Thomas and W.J. Thmos , “Introduction of the principles of Heterogeneous catalysis” Academic Press ,1967

- P.H. Emmett, “Catalysis”, Reinhold ,1954
- C.N. Satterfield and T.K. Sherwood, ”The role of diffusion in cat lysis” Addison Wesley, 1963

B. Polymer Science and Engineering

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand thermodynamics of polymer structures
CO2	Select polymerization reactor for a polymer product.
CO3	Characterize polymers.
CO4	State polymer additives, blends and composites.
CO5	Understand polymer rheology

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	-	✓	✓	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-
CO3	✓	✓	✓	✓	-	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	✓	-	-	-	-	-

Detailed Syllabus:

Unit I: Introduction- Basic concepts of Polymer Science, Various molecular forces in polymer, Various Molecular weights and their distribution.

Unit II: Polymerization- Step growth: Mechanism, Kinetics, Polyfunctional Step growth polymerization. (ii) Radical polymerization: Mechanism, Kinetics, Effects of temperature, pressure. (iii) Ionic and Coordination Polymerization: Kinetics of Cationic and Anionic polymerization.

Unit III: Polymerization Conditions- Bulk, Solution, Suspension and Emulsion polymerization.

Unit IV: Measurement of Molecular Weight- End group analysis, Colligative property measurement, Gel Permeation Chromatography.

Unit V: Polymer Processing- Plastic technology: Molding, Extrusion, Additives and Compounding;

Unit VI: Fiber Technology- Textile and Fabric properties, Spinning, Elastomer technology: Vulcanization, Reinforcement.

Texts/References:

- Text book of Polymer Science: Fred W. Billmeyer, Jr., Second Edition, 1994, John Wiley and Sons, Inc., Singapore.
- Principals of Polymerization, George Odian, Third Edition, 2002, John Wiley and Sons, Inc., Singapore.
- Fundamentals of Polymers, Anil Kumar and Gupta, R. K., McGraw Hill, 1998.

C Non-Newtonian Flow and Rheology

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the types of non-Newtonian fluids
CO2	Understand the macroscopic behavior of the complex fluids
CO3	Analyze the flow of non-Newtonian fluids through circular and non-circular cross sectional conduits
CO4	Develop heat and mass transfer characteristics of non-Newtonian fluids
CO5	Develop models of non-Newtonian fluid flow

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO2	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO3	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO4	✓	✓	✓	✓	✓	-	-	-	-	-	-	-
CO5	✓	✓	✓	✓	✓	-	-	-	-	-	-	-

Detailed Syllabus:

Unit I: Non-Newtonian fluid behaviour - Introduction, Classification of fluid behaviour, Time-independent fluid behaviour, Time-dependent fluid behaviour, Visco-elastic fluid behaviour, Dimensional considerations for visco-elastic fluids.

Unit II: Rheometry for non-Newtonian fluids - Introduction, Capillary viscometers, Rotational viscometers, The controlled stress Rheometer, Yield stress measurements, Normal stress measurements, Oscillatory shear measurements, High frequency techniques, The relaxation time spectrum, Extensional flow measurements.

Unit III: Flow in pipes and in conduits of non-circular cross-sections - Introduction, Laminar flow in circular tubes, Criteria for transition from laminar to turbulent flow, Friction factors for transitional and turbulent conditions, Laminar flow between two infinite parallel plates, Laminar flow in a concentric annulus, Laminar flow of inelastic fluids in non-circular ducts. Flow of multi-phase mixtures in pipes - Introduction, Two-phase gas-non-Newtonian liquid flow, Two-phase liquid-solid flow (hydraulic transport).

Unit IV: Particulate systems - Introduction, Drag force on a sphere, Effect of particle shape on terminal falling velocity and drag force, Motion of bubbles and drops, Flow of a liquid through beds of particles, Flow through packed beds of particles (porous media), Liquid-solid fluidization.

Unit V: Heat transfer characteristics of non-Newtonian fluids in pipes - Introduction, Thermo-physical properties, Laminar flow in circular tubes, Fully-developed heat transfer to power-law fluids in laminar flow, Isothermal tube wall, Constant heat flux at tube wall, Effect of temperature-dependent physical properties on heat transfer.

Unit VI: Momentum transfer in boundary layers - Introduction, Integral momentum equation, Laminar boundary layer flow of power-law liquids over a plate, Laminar boundary layer flow of Bingham plastic fluids over a plate, Transition criterion and turbulent boundary layer flow, Heat transfer in boundary layers, Mass transfer in laminar boundary layer flow of power-law fluids, Boundary layers for visco-elastic fluids. Liquid mixing - Introduction, Liquid mixing, Gas-liquid mixing, Heat transfer, Mixing equipment and its selection, Mixing in continuous systems.

Texts / References:

- Chhabra R.P., J.F. Richardson, Non-Newtonian Flow and Applied Rheology: Engineering Applications, 2nd Edition, Butterworth-Heinemann, 2008.
- Christopher W. Macosko, RHEOLOGY: Principles, Measurements and Applications, WILEY-VCH, 1994.
- Alexander Ya. Malkin, Rheology Fundamentals, Chem Tech Publishing, 1994.

D. Optimization Techniques

Course Outcomes: At the end of the course, the student will be able to:

CO1	Formulate and solve linear Programming Problems
CO2	Determine the optimum solution to constrained and unconstrained problems
CO3	Apply dynamic programming principle to Linear programming problems
CO4	Determine the integer solutions to Linear Programming Problems

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO2	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO3	-	-	-	-	✓	✓	-	-	✓	-	-	-
CO4	-	-	-	-	✓	✓	-	-	✓	-	-	-

Detailed Syllabus:

UNIT I: Single-variable optimization algorithms: Optimal problem formulation, Optimization algorithms, Optimality criteria, Bracketing methods, Region-elimination methods, Point-estimation method, Gradient based methods, Root finding using optimization techniques.

UNIT II: Multi-variable optimization algorithms: Unidirectional search, Direct search methods, Gradient based methods.

UNIT III: Constrained optimization algorithms: Kuhn-Tucker conditions, Transformation methods,

UNIT IV: Sensitivity analysis, Direct search for constrained minimization, Linearized search techniques, Feasible direction method, Generalized reduced gradient method, Gradient projection method

UNIT V: Specialized algorithms: Integer programming, Geometric programming.

UNIT VI: Nontraditional optimization algorithms: Genetic algorithms, Simulated annealing, Global optimization.

Texts / References:

- Deb K., Optimization for Engineering Design, Algorithms and Examples, Prentice Hall of India, New Delhi 1996
- Himmelblau. Optimization of Chemical Processes

E. Heat Transfer Equipment Design

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand different type of heat transfer equipment
CO2	Design of heat transfer equipment
CO3	Compare and evaluate design of equipment
CO4	Apply knowledge of selection of equipment

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓					✓					
CO2	✓	✓			✓		✓					
CO3	✓	✓					✓					
CO4	✓	✓			✓		✓					

Detailed Syllabus:

Unit I: Detailed Process Design of Double Pipe Heat Exchangers

Unit II: Detailed Process Design of Shell and Tube heat exchanger

Unit III: Detailed Process design of condenser

Unit IV: Detailed Process Design of Evaporator

Unit V: Detailed process design of Agitator

Unit VI: Detailed process design of Reboiler

Texts / References:

- J. M. Coulson and J. F. Richardson, “Chemical Engineering” Vol. 2 ELBS, Pergamon Press, 1970
- D. Q. Kern, “Process Heat Transfer”, McGraw Hill, 1950.

BTCHM 607 Mini Projects IV

The purpose behind the mini project is that the student should be exposed to more hands-on rather than merely theory. It is expected that the student (or a small group say, not more than two in a group, to be confirmed) will undertake to make a working model, a program, critics on technology evolution, experimental work, survey etc. which he will benefit from since he /she will be doing it first-hand. It should be related to chemical engineering field.

BTCHL 608 Mass Transfer Laboratory – II

Course Outcomes: At the end of the course, the student will be able to:

CO1	Perform experiment related to VLE and draw conclusion
CO2	Design equipment for separation purposes
CO3	Evaluate the performance of given technique and compare with other techniques.
CO4	Analyze performance of unit operation.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓			✓			✓					
CO2	✓			✓								
CO3	✓			✓			✓					
CO4	✓			✓								

List of Practicals:

1. T-x-y diagram for water-acetone system
2. To prove Rayleigh equation by carrying out simple distillation of methanol-water system
3. To carry out crystallization of given salt
4. To determine rate of drying of given sample and to plot (kg moisture content/ kg of dry solid) V/S time and rate of drying V/S time
5. To study Swenson Walker crystallizer
6. Determination of HETP (Height equivalent to theoretical plate)
7. Study of fluidized bed dying
8. Study of steam distillation

BTCHL 609 Chemical Reaction Engineering Laboratory - II

Course Outcomes: At the end of the course, students will be able to:

CO1	Determine the kinetics of chemical reaction in Batch reactor, CSTR, PFR
CO2	Determine the kinetics using Dilatometer
CO3	Determine the temperature dependency of reaction rate constant
CO4	Analyze the performance of reactors through RTD studies
CO5	Compare the performance of CSTR-PFR with PFR-CSTR reactor systems
CO6	Compare the performance of single CSTR with series of CSTRs

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO2	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO3	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO4	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO5	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
CO6	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-

List of Practicals:

1. Studies on gas-liquid-solid reaction using hydrodynamic cavitation- carbonization process.
2.
3. Polymerization of acrylic acid in a batch reactor.
4. Demonstration of nitration reaction in Micro reactors
5. Demonstration of Microwave Reactor
6. Demonstration of Ultrasound Probe Reactor
7. Kinetic studies using Dilatometer.

BTPCS 610 Seminar

Course Outcomes: At the end of the course, the student will be able to:

CO1	Acquire knowledge on topics outside the scope of curriculum.
CO2	Communicate with group of people on different topic
CO3	Collect and consolidate required information on a topic
CO4	Prepare a seminar report

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	-	✓	✓	-	-	✓	✓	✓	✓
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	✓	✓
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	✓	✓

Each student is expected to collect information on recent advances in Chemical Engineering by regularly referring to national and international journals and reference books. At the end of the semester he/she is required prepare a report as per the guide lines prescribed by the Department. Each student will be assigned a guide for this seminar course.

Every student shall give a power point presentation on his Seminar topic before a panel of examiners.

BTPCF 611 Field Training / Internship/Industrial Training

(Minimum 4 weeks which can be completed partially in first semester and second Semester or in at one time.)

Course Outcomes: At the end of the course, the student will be able to:

CO1	Acquire knowledge on topics outside the scope of curriculum on summer training.
CO2	Communicate with group of people on different topics of summer training.
CO3	Collect and consolidate required information on a topic of summer training.
CO4	Prepare a seminar report on summer training

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	-	✓	✓	-	-	✓	✓	✓	✓
CO3	✓	✓	✓	✓	✓	-	✓	-	-	-	✓	✓
CO4	✓	✓	-	✓	-	✓	✓	-	-	-	✓	✓

Each student is expected to spend FOUR weeks in any one factory/project/workshop at the end of sixth semester (during summer vacation). Here he/she shall observe layout, working and use of various machinery, plants, design, instruments, process etc. under the general supervision of the foreman/artisan/engineer of the factory etc.

The student shall submit the report in a systematic technical format about the major field of the factory, particularly about the section/department where he/she has received the training giving details of equipment, machinery, materials, process etc. with their detailed specifications, use etc. The report shall be checked and evaluated by the concerned teacher and appropriate grade shall be awarded.