Rashtrasant Tukadoji Maharaj Nagpur University

Faculty of Science & Technology

Structure & Syllabus

5th and 6th Semester B. Tech

(Chemical Engineering)

SCHEME OF EXAMINATION
RASHTRASANT TUKADOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
FIFTH SEMESTER B. TECH (CHEMICAL ENGINEERING)

Sr. No.	Code	Subject	Board	Work Load Hrs				Credit				Marks				Total Marks	Min. % of Marks Required for Passing
	Theory (T)			L	P	T	Total	L	P	T	Total	Theory		Practical			
	Practical (P)											College Assessment	University	College Assessment	University		
1	CE-PCC-501T	Heat Transfer	BCE	3	0	1	4	3	0	1	4	30	70	-	-	100	45%
2	CE-PCC-502T	Chemical Reaction Engineering I	BCE	3	0	1	4	3	0	1	4	30	70	-	-	100	45%
3	CE-PCC-503T	Mass Transfer II	BCE	4	0	1	5	4	0	1	5	30	70	-	-	100	45%
4	CE-CEL-504T	Core Elective I	BCE	3	0	0	3	3	0	0	3	30	70	-	-	100	45%
5	CE-OEL-505T	Open Elective I	BCE	3	0	0	3	3	0	0	3	30	70	-	-	100	45%
6	CE-HSMC-HS-506T	HASS III: Industrial Economics & Project Management	BCE	2	0	0	2	2	0	0	2	15	35	-	-	50	45%
7	CE-PCC-507P	Chemical Reaction Engineering I Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
8	CE-PCC-508P	Mass Transfer Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
9	CE-PCC-509P	Heat Transfer Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
10	MC	Constitution of India/ Essence of Indian Traditional Knowledge		2	0	0	2	0	0	0	0	-	-	-	-	-	Audit Course S/SF**
		Total		20	9	3	32	18	4.5	3	25.5	165	385	75	75	700	-

** **S/SF Grade for Audit Course S – Satisfactory or SF – Not Satisfactory**

Elective	Subject Name		
	BOARD		
	BCE		
Core Elective I	Statistical Design of Experiments	Non-Newtonian Flow and Rheology	Chemical Process Synthesis and Design
Open Elective I	Environmental Pollution and Control	Renewable Energy	Energy Conservation and Recycling

SCHEME OF EXAMINATION
RASHTRASANT TUKADOJI MAHARAJ NAGPUR UNIVERSITY, NAGPUR
SIXTH SEMESTER B. TECH (CHEMICAL ENGINEERING)

Sr. No.	Code Theory (T) Practical (P)	Subject	Board	Work Load Hrs				Credit				Marks				Total Marks	Min. % of Marks Required for Passing
												Theory		Practical			
				L	P	T	Total	L	P	T	Total	College Assessment	University	College Assessment	University		
1	CE-PCC-601T	Chemical Reaction Engineering II	BCE	3	0	1	4	3	0	1	4	30	70	-	-	100	45%
2	CE-PCC-602T	Process Equipment Design	BCE	3	0	1	4	3	0	1	4	30	70	-	-	100	45%
3	CE-PCC-603T	Process Dynamics & Control	BCE	3	0	1	4	3	0	1	4	30	70	-	-	100	45%
4	CE-CEE-604T	Core Elective- II	BCE	3	0	0	3	3	0	0	3	30	70	-	-	100	45%
5	CE-OLE-605T	Open Elective- II	BCE	3	0	0	3	3	0	0	3	30	70	-	-	100	45%
6	CE- HSMC-HS -606T	HASS IV Industrial organization & Entrepreneurship Development	BCE	2	0	0	2	2	0	0	2	15	35	-	-	50	45%
7	CE-PCC-607P	Chemical Reaction Engineering II Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
8	CE-PCC-608P	Process Equipment Design & Drawing Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
9	CE-PCC-609P	Process Dynamics & Control Lab	BCE	0	3	0	3	0	1.5	0	1.5	-	-	25	25	50	50%
10	CE-PCC-610P	Summer Internship (3-4 weeks) (to be evaluated in seventh semester)	BCE	0	0	0	0	0	0	0	0	-	-	-	-	-	-
		Total		17	9	3	29	17	4.5	3	24.5	165	385	75	75	700	-

Elective	Subject Name		
	BOARD		
	BCE		
Core Elective II	Advanced Separation Processes	Computational Fluid Dynamics	Process Intensification
Open Elective II	Polymer Science and Engineering	Chemical Processing for Microelectronics	Membrane Technology

Rashtrasant Tukadoji Maharaj Nagpur University

Faculty of Science & Technology

Syllabus for

Fifth Semester B.Tech. Chemical Engineering

Subject: CE-PCC-501T (BCE) **Heat Transfer (Theory)**

Lecture	: 3 Hours	Tutorial: 1 Hour	No. of Credits	: 4
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand basic concepts and laws of heat transfer.
- To Formulate heat balance equations for heating, boiling & related operations.
- To Evaluate the coefficients for heat transfer operations based on concepts of resistances.
- To classify, analyse and design of double pipe heat exchanger, shell & tube heat exchanger and evaporators.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the basic laws governing modes of heat transfer & estimation of heat rate, load, transfer area & temperature distribution for various geometries of objects for steady & unsteady state heat transfer.

CO2: Understand heating, cooling operations & phenomena of natural & forced convection and evaluation of heat transfer coefficient.

CO3: Understand boiling & condensation operations and evaluation of heat transfer coefficient.

CO4: Estimation of design parameters of double pipe and shell & tube heat exchanger from first principle as per requirements of the situation/problem

CO5: Understand radiative heat transfer. Analysing given situation/problem for the estimation of heat transfer coefficient for different types of heat transfer equipment such as packed bed, fluidized bed.

Unit 1: Concept of Heat Transfer, Unsteady State Heat Transfer, Fins & Insulation: Introduction & mechanism of heat transfer. Development and use of general differential equation for heat transfer rate & temperature distribution for steady state heat conduction for various shapes & geometries of solids with various boundary conditions, with & without heat generation. Use of lumped capacitance, Heisler charts and error function methods for unsteady state heat transfer. Classification of fins. Fin efficiency and overall effectiveness. Classification and selection of various types of thermal insulations. The concept of critical and economical thickness of insulation and its evaluation for cylindrical and spherical heat transfer equipment.

Unit 2: Natural & Forced Convection: Heat Transfer without Phase Change: Introduction to natural and forced convection in laminar and turbulent flow over flat plate, over cylinder & sphere and through closed channels. Concept and use of thermal & hydrodynamic boundary layer and its significance. Prediction of heat transfer coefficient using theoretical, empirical and analogies concepts.

Unit 3: Condensation & Boiling: Convection Heat Transfer with Phase Change: Mechanism of condensation: Nusselt's approach and its extension. Heat transfer in saturated pool & forced convection boiling of liquids. Study of Boiling curve: Its significance and relevance in constant wall temperature & constant heat flux boiling with specific reference to critical (Maximum) heat flux and minimum heat flux (Ladenfrost point).

Unit 4: Heat Exchangers & Evaporators: Concept of fouling resistance & overall heat transfer coefficient in heat exchangers. Classification of heat exchangers. Design and rating of double pipe, shell and tube heat exchangers by LMTD and ε-NTU methods. Compact heat exchangers: Plate heat exchangers, helical coil heat exchangers, spiral heat exchangers, regenerators. Classification of evaporators. Steam economy and capacity of multiple effect evaporators. Design considerations of evaporators.

Unit 5: Radiation & Special Cases of Heat Transfer: Radiation fundamentals, properties of materials and heat exchange. Use of solar energy & thermic fluids. Heat transfer in furnaces, agitated vessels, fluidized beds, packed beds, jacketed vessels, immersed helical and spiral coil equipment.

Books Recommended:

1. B. K. Dutta, Heat transfer Principles and Applications, PHI Private Limited, 2001.
2. S. D. Dawande, Principles of Heat Transfer and Mass Transfer, Denett & Co, 2009.
3. R. K. Rajput, Heat and Mass Transfer, S. Chand & Company Ltd., 2007.
4. C. J. Geankoplis, Transport Processes and Separation Process Principles, 4 Edition, Prentice Hall, 2003
5. J. M. Coulson, J. F. Richardson with J. R. Backhurst, J. H. Harker, Chemical Engineering Vol. I: Fluid Flow, Heat Transfer and Mass Transfer, Sixth Edition, Butterworth-Heinemann an imprint of Elsevier

6. J. M. Coulson, J. F. Richardson with J. R. Backhurst, J. H. Harker, Chemical Engineering Vol. II: Particle Technology and Separation Processes, Fifth Edition, Butterworth-Heinemann an imprint of Elsevier
7. J. M. Coulson, J. F. Richardson, R. K. Sinnott, Chemical Engineering Vol. 6 - Design, Pergamon Press, 1983
8. W. L. McCabe, J. C. Smith, P. Harriott, Unit Operations of Chemical Engineering, Seventh Edition, McGraw Hill Publication, 2005.
9. D. S. Kumar, Basics of Heat & Mass Transfer, Eight Edition, S.K. Kataria & Sons, 2010.
10. W. L. Badger, J. T. Banchero, Introduction to Chemical Engineering, Tata McGraw Hill Education, 1997.

Subject: CE-PCC-502T (BCE) **Chemical Reaction Engineering I (Theory)**

Lecture	: 3 Hours	Tutorial: 1 Hour	No. of Credits	: 4
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- Basic Concepts of Kinetics and Rate Laws
- Design and Rating of Ideal Reactors including heat effects
- Interpretation of Rate data
- Design and Rating of Reactors involving multiple reactions including heat effects
- Analysis of Non-ideal flow Behavior in Reactors

Course Outcomes:

After completion of the course, students will be able to:

CO1: Determine the rate laws for reactions using concentration time data obtained from batch reactor

CO2: Determine volume of ideal reactors (batch, mixed flow and plug flow) for given conversion using model equations

CO3: Suggest the best arrangement of a set of combinations of ideal reactors (reactors in series / parallel) to maximize the conversion

CO4: Determine the volume of mixed flow reactor, adiabatic plug flow reactor, adiabatic recycle reactor, and plug flow reactor with optimum temperature progression

CO5: Plot C, E, and F curves and explain the concepts of residence time distribution and also define mechanism of catalysis and related concepts.

Unit 1: Kinetics of homogeneous reactions: Irreversible and reversible reactions, Equilibrium; Order and molecularity of reaction. Elementary and non-elementary reactions; Fractional conversion and equilibrium conversion. Rate of reaction based on all components of the reaction and their interrelation. Law of mass action, Rate Constant-Based on thermodynamic activity, Temperature dependency of rate Constant -Arrhenius law, Transition state theory and collision theory. Temperature and conversion profiles for exothermic and endothermic reactions

Unit 2: Batch Reactor Data: Batch reactor concept, Constant volume Batch reactor system; Design equation for zero, first, second order irreversible and reversible reactions, graphical interpretation of these equations and their limitations, Variable volume Batch reactors. Design equation for first and second order irreversible and reversible reactions, Graphical interpretation of their limitations, Multiple reactions-stoichiometry and rate equations for series and parallel reactions, Non elementary single reactions Development of rate expression; Chain reactions development of rate expressions, Batch recycle reactors, Semi-batch reactor, related examples etc.

Unit 3: Flow Reactors: Types of flow reactors and their differences, space-time and space velocity, Design equation for plug flow reactor and CSTR; Size comparison of single reactors; Different reactor arrangements, optimum size determination; Performance of Recycle reactors, Auto-catalytic (recycle) reactors, Yield and selectivity, Best operating condition for mixed and plug flow reactors, Multiple reactions in CSTR and PFR reactors. Maximization of desired product rate in a plug flow reactor and back mixed reactor, product distribution in multiple reactions, related examples etc.

Unit 4: Temperature and Pressure Effects: Equilibrium Conversion, Optimum temperature progression, Adiabatic and non-adiabatic operations, Temperature and conversion profiles for exothermic and endothermic reactions and related examples etc.

Unit 5: Residence Time Distribution: Residence time distribution in reactors: E, F and C curve, and their relationship, conversion in reactors having nonideal flow; models for non-ideal flow: Dispersion model, dispersion number, Tank in Series model, Multi parameter model, mixing of fluids: Self-mixing of single fluid. Two parameter models.

Books Recommended:

1. O. Levenspeil, Chemical Reaction Engineering, 3rd Edition, John Wiley & Sons, 2001.
2. H. S. Fogler, Elements of Chemical Reaction Engineering, 3rd Edition, PHI, 2002.
3. S. D. Dawande, Chemical Reaction Engineering, 3rd Edition, Denett & Co, 2009.
4. S. M. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.
5. J. M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1987.

Subject: CE-PCC-503T (BCE) **Mass Transfer II (Theory)**

Lecture	: 4 Hours	Tutorial: 1 Hour	No. of Credits	: 5
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand basic concepts of separation operations such as extraction, leaching, drying, adsorption, crystallization, humidification and membrane separation
- To understand, interpret and evaluate mass transfer coefficients in liquid-liquid extraction operations.
- To classify & analyse working principles of cooling towers, crystallizers, dryers and adsorbers.
- To design dryers, cooling towers and crystallizers.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Estimation of mass transfer coefficient and process design parameters for liquid-liquid extraction and leaching.

CO2: Understanding the concept of drying, humidification and estimation design parameters of dryers and cooling towers from first principle.

CO3: Understanding the concept of adsorption and ion exchange and estimation of design parameters of adsorbers.

CO4: Understanding the concept of crystallization and estimation of design parameters of crystallizers.

CO5: Understanding fundamentals and types of membrane separation processes and other novel separation techniques.

Unit 1: Liquid – Liquid Extraction: Liquid-liquid equilibria, single stage extraction, multistage crosscurrent, countercurrent and cocurrent extraction, calculations based on triangular diagrams, stage efficiency, Continuous contact extraction in packed towers, HTU and NTU concept, Equipments for extraction

Solid – Liquid Extraction: General principles, continuous leaching, ideal stage equilibrium, Calculation for number of stages, constant and variable underflow, stage efficiencies, right angle triangle diagram, Leaching equipments

Unit 2: Humidification, Dehumidification, and Drying: General principles, vapour-liquid equilibria, enthalpy of pure substances, wet bulb temperature relation, psychrometric chart, Lewis relation, methods of humidification and dehumidification, cooling towers & calculation of height of cooling tower – HTU, NTU concept. Introduction and Principles of drying, equilibrium in drying, type of moisture binding, mechanism of drying, continuous drying, time required for drying, mechanism of moisture movement in solid, heat & mass balance in drying, drying equipments and their design principles.

Unit 3: Adsorption and Ion Exchange: Basic principle and equilibria in adsorption. Types of adsorption – Physical and chemical, adsorption isotherms- Langmuir and Freundlich, Single gases and vapors, Introduction to pressure Swing Adsorption (PSA), and Temperature Swing Adsorption (TSA), Equipments: Continuous Contact: steady state–moving bed Adsorbers. Ion Exchange- Principles of Ion Exchange, Techniques and applications, Equilibria and rate of ion exchange, equipments

Unit 4: Crystallisation: Crystallization fundamentals, solubility and saturation, Miers theory of crystallization, crystal nucleation, crystal growth, population balance and size distribution, material and energy balances, crystallization equipments, fractional crystallization, freeze crystallization, calculations of yield.

Unit 5: Novel Techniques: Introduction and types of membrane separation processes, Membrane separation techniques- microfiltration, ultrafiltration. Nanofiltration, reverse osmosis, dialysis, pervaporation, gas permeation membrane process, molecular sieves. Other advanced separation processes, selection of separation processes for downstream processing.

Books Recommended:

1. J.M. Coulson, J.F. Richardson with J.R. Backhurst, J.H. Harker, Chemical Engineering Vol. I: Fluid Flow, Heat Transfer and Mass Transfer, Sixth Edition, Butterworth-Heinemann an imprint of Elsevier
2. J. M. Coulson, J.F. Richardson with J.R. Backhurst, J.H. Harker, Chemical Engineering Vol. II: Particle Technology and Separation Processes, Fifth Edition, Butterworth-Heinemann an imprint of Elsevier
3. R. E. Treybal, Mass Transfer Operations, 3rd edition, McGraw Hill, 1980.
4. C. J. Geankoplis, Transport Processes and Separation Process Principles, 4 Edition, Prentice Hall, 2003
5. W. L. McCabe, J.C. Smith, P. Harriott, Unit Operations of Chemical Engineering, Seventh Edition, McGraw Hill Publication, 2005.
6. B. K. Dutta, Principles of Mass transfer and separation processes, PHI Learning, 2007.
7. J. D. Seader, E. J. Henley, Separation Process Principles, Wiley, 1998.

Subject: CE-CEE-504T (BCE)

Core Elective- I: Statistical Design of Experiments (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To learn how to plan, design and conduct experiments efficiently and effectively, and analyze the resulting data to obtain objective conclusions.
- To understand the statistical analysis methods and standard statistical software packages for computational purposes for effective analysis of the experimental data.

Course Outcomes:

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

CO1: Plan experiments for a critical comparison of outputs.

CO2: analyse the various models and interpret the practical results.

CO3: understand the basic principles of design of industrial experiments and select the quality characteristics for industrial experiments.

CO4: Understand the response surface methods for the analysis of experimental data.

CO5: design & analyse the experiments and screen the experiments. Estimate parameters by multi-dimensional optimization.

Unit 1: Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments. Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Unit 2: Experiments with Single Factor; An example, the analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Nonparameteric methods in the analysis of variance, Problems.

Unit 3: Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments.

Unit 4: Response Surface Methods: Introduction, the methods of steepest ascent, Analysis of a second-order response surface, Experimental designs for fitting response surfaces: Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.

Unit 5: Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment-method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youdens Squares, Basic experiment-mathematical modeling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Nongradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Books Recommended:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, Wiley, 5th Edition, 2010.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

Subject: CE-CEE-604T (BCE)

Core Elective- I: Non-Newtonian Flow and Rheology (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the non-Newtonian flow behaviour through the use of standard flows and analyse the rheological properties of fluids
- To understand and analyse the flow behaviour in various particulate systems.
- To understand and analyse heat transfer characteristics of non-Newtonian fluids in pipes and the mixing behaviour of liquids and selection of mixing equipments.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the concept of Newtonian and Non-Newtonian fluids and analyse the rheological properties of fluids.

CO2: Understand and Analyse the flow behaviour in pipes.

CO3: Understand the various particulate systems and analyse the flow behaviour in various particulate systems.

CO4: Understand and analyse heat transfer characteristics of non-Newtonian fluids in pipes.

CO5: Understand and analyse the mixing behaviour of liquids and selection of mixing equipments.

Unit 1: Non-Newtonian fluids: Introduction, Classification of fluid: Time-independent, Time-dependent, Visco-elastic. Dimensional considerations for visco-elastic fluids. **Rheometry for non-Newtonian fluids:** Introduction, Various viscometers, Yield stress measurements, Normal stress measurements, Oscillatory shear measurements, High frequency techniques, The relaxation time spectrum etc.

Unit 2: Flow in pipes: 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. Gas-non-Newtonian liquid two phase flow.

Unit 3: Particulate systems: Introduction, Drag force on a sphere, Motion of bubbles and drops, Flow of a liquid through beds of particles, Flow through porous media of particles, Liquid-solid fluidization.

Unit 4: 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, etc.

Unit 5: Mixing of Liquids: Introduction, Liquid mixing, Gas-liquid mixing, heat transfer. Selection of mixing equipments. Mixing in continuous system.

Books Recommended:

1. R. P. Chhabra, J. F. Richardson, Non-Newtonian Flow and Applied Rheology: Engineering Applications, 2nd Edition, Butterworth-Heinemann, 2008.
2. Christopher W. Macosko, RHEOLOGY: Principles, Measurements and Applications, WILEY-VCH, 1994.
3. R. B. Bird, W.E. Stewart, E.W. Lighfoot, Transport Phenomena, 2nd Edition, John Wiley,
4. Alexander Ya. Malkin, Rheology Fundamentals, ChemTech Publishing, 1994.

Subject: CE-CEE-504T (BCE)

Core Elective- I: Chemical Process Synthesis and Design (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To impart the knowledge of design decisions regarding the routes for products.
- To use hand calculations, spreadsheets, mathematical computer packages and process simulators in selection of reactors & separators and design of the heat exchange network, distillation sequencing.
- To create awareness of many kinds of environmental and ethical issues and safety considerations that are prevalent in the design of chemical products and processes.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Comparison of reaction paths and selection of reactors for various processes.

CO2: Selection of appropriate method of separation and evaluation based on economic potential

CO3: To apply pinch technology in Heat integration and heat exchanger networks analysis

CO4: Apply knowledge base to evaluate an optimal distillation sequence with and without heat integration for simple and complex systems.

CO5: To understand basics of safety and evaluate hazard related chemical process industries

Unit 1: Introduction of Chemical Process and Product Design: Introduction, Approach to Process Development, Different Considerations, development of Particular Process, Overall Process design, Onion Model, Case studies of product design.

Unit 2: Choice of Reactor: Reaction Path, Types of Reaction Systems, Performance of Reactor, Idealized Reactor Models, Effect of various process variables.

Unit 3: Choice of Separator: Separation of Homogeneous and Heterogeneous Mixtures, Distillation, Azeotropic Distillation, Absorption, Evaporation, Drying etc.

Unit 4: Heat Exchanger Networks: Energy Targets, Composite Curves, Heat Recovery Pinch, Threshold Problems, Problem Table Algorithm, Process Constraints, Utility Selection, Furnaces, Combined Heat and Power, Integration of Heat Pump, Integration of Refrigeration Cycles, Overall Heat Exchanger Network and Utilities

Unit 5: Distillation Sequencing: Distillation Sequencing using simple columns, Heat Integration of Sequences of Simple Distillation Columns, Distillation Sequencing using thermal coupling, Optimization of Reducible Structure reactions

Books Recommended:

1. Robin Smith, Chemical Process design and Integration, Wiley-Blackwell, 2 Sub edition, 2005.
2. J. Douglas, Conceptual Design of Chemical Processes, New York, NY: McGraw-Hill, 1988.
3. L. Biegler, I. E. Grossmann, A. W. Westerberg, Systematic Methods of Chemical Process Design, Upper Saddle River, NJ: Prentice Hall PTR, 1997.
4. W. D. Seider, J. D. Seader, D. R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, 2nd ed. New York, NY: Wiley, 2003.
5. D. F. Rudd, G. J. Powers, J. J. Siirola, Process Synthesis, Englewood Cliffs, NJ: Prentice Hall, Inc., 1973.
6. R. Turton, R. C. Bailie, W. B. Whiting, J. A. Shaeiwitz, Analysis, Synthesis, and Design of Chemical Processes, Upper Saddle River, NJ: Prentice Hall PTR, 1997
7. P. H. Grogins, Unit process in organic synthesis, McGraw-Hill, Second Edition, 1938.

Subject: CE-OLE-505T (BCE)

Open Elective- I: Environmental Pollution and Control (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the various physico-chemical unit processes and operations as applied to water and wastewater systems and designing of water supply and treatment system.
- To apply engineering concepts to Air Pollution Control and Environmental Management.
- To understand environmental policies and apply environmental management methods for case studies.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the concept of water quality. Classify the sources, types of environmental pollutant and fundamentals of pollution parameters.

CO2: Analyse the natural process of water purification and understand the importance of air pollution and estimation of design parameters of the equipment for industrial air pollution control.

CO3: Identify the sources of water pollution and estimation of design parameters of water treatment process.

CO4: Understand, classify and select the techniques for the processing of solid waste.

CO5: Assess the global and national environmental policies along with pollution control in selected process industries.

Unit 1: Environmental Pollutants: Sources & characterization of various pollutants. Concepts of biodegradability, biosorption, biomagnifications. Measurement: COD, BOD, TOD, ThOD, soluble, suspended, volatile solids, ammoniacal nitrogen. Mathematical model for BOD. Re-oxygenation and de-oxygenation in natural purification process.

Unit 2: Natural Process of Water & Air Pollution Control: Mathematical analysis by Streeter-Phelps of oxygen sag curve in natural purification of waste water. Determination of stack height and plume rise. Meteorological parameters and their effects on dilution/dispersion of pollutants present in flue/exhaust gases coming out from stationery and moving sources. Prediction of pollutant concentration downstream of discharge point. Plume behavior. Air Pollution Management: Basic design and operating principles of wet & dry equipments for removal of particulate and gaseous pollutants. Control of air pollution by process changes.

Unit 3: Water Pollution Management: Principles of primary secondary, tertiary and advanced treatment of waste water. Aerobic and anaerobic processes in ponds and lagoons. Basic process design and operating principles of various activated sludge (suspended growth) processes. trickling filter & rotating biological contactor (Attached growth). Special reactors.

Unit 4: Solid Waste Pollution Management: Solid waste management by dumping, landfill, incineration, composting, vermiculture; using bioremediation for specific pollutants like chromium. Mercury, ammonia / urea, phenolic sludge. E-waste. Hazardous waste management.

Unit 5: Pollution Control in Selected Process Industries & Major Issues: Pollution in fertilizer industries, petroleum refineries and petrochemical units, pulp and paper industries, Sugar industries, Dairy, Alcohol industries. Radioactive wastes. Case studies. Environmental impact assessment (EIA), Environmental audit, Major disasters, global environmental policies and national strategies.

Books Recommended:

1. Metcalf and Eddy, Wastewater Engineering: Treatment, Disposal and Reuse, Tata McGraw-Hill Pub.Co.Ltd., New Delhi, 1979.
2. S.P. Mahajan, Pollution Control in Process Industry, Tata McGraw Hill Publishers, 1987.
3. G.N. Pandey, G.C. Camey, Environmental Engineering, Tata McGraw-Hill Pub.Co.Ltd., 1992.
4. H.S. Peavy, D.R. Rowe, G. Tchobanoglous, Environmental Engineering, McGraw-Hill, 1986.
5. C.N. Sawyer, P.L. McCarty, G.F. Parkin, Chemistry for Environmental Engineering, Tata-McGraw-Hill Edition, 2003.
6. B.C. Punmia, A.K. Jain, A. K. Jain, Wastewater Engineering, Laxmi Publications, 2005.
7. S.K. Garg, Sewage Disposal and Air Pollution Engineering, Khanna Publishers, 2010.
8. M.N. Rao, H.V. Rao, Air Pollution, McGraw-Hill Europe, 1989.

Subject: CE-OLE-505T (BCE)

Open Elective- I: Renewable Energy (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the various forms of conventional energy resources and present energy scenario.
- To understand the need of energy conservation and various forms of renewable energy.
- To understand utilization of renewable energy sources for both domestics and industrial application and environmental aspects.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the use of solar energy and the various components used in the energy production.

CO2: Understand the use of wind energy and the various components used in the energy production.

CO3: Understand the concept of Bioenergy resources and their classification, types of biogas plants and applications.

CO4: Understand concept of hydrogen generation and storage and its application in fuel cells.

CO5: Understand geothermal, tidal and ocean as nonconventional energy generation sources; concept of energy audit and cost-effective analysis.

Unit 1: Solar-Energy: Solar radiation its measurements and prediction, solar flat plate thermal collectors concentrating collectors-applications-heating, cooling, desalination, power generation, drying, cooking etc. Principle of photovoltaic conversion of solar energy, types of solar cells and fabrication. Photovoltaic applications: battery charger, domestic lighting, street lighting, and water pumping, power generation schemes.

Unit 2: Wind Energy: Atmospheric circulation- classification, factors influencing-wind shear-turbulence-wind speed monitoring-Aerodynamics of wind turbine rotor-site selection-wind resource assessment-wind energy conversion devices-classification, characteristics and applications. Hybrid systems-safety and environmental aspects.

Unit 3: Bio-Energy: Biomass resources and their classification, chemical constituents and physicochemical characteristics of biomass- Biomass conversion processes- Thermo chemical conversion: direct combustion, gasification, hydrolysis and liquefaction- biochemical conversion: anaerobic digestion, alcohol production from biomass- chemical conversion process: hydrolysis and hydrogenation. Biogas- generation-types of biogas Plants applications.

Unit 4: Hydrogen and Fuel Cells: Thermodynamics and electrochemical principles-basic design, types and applications, production methods, Biophotolysis: hydrogen generation from algae biological pathways, storage gaseous, cryogenic and metal hydride a transportation. Fuel cell: principle of working, various types, construction and applications.

Unit 5: Other Types of Energy and Energy Audit: Ocean energy resources, principles of ocean thermal energy conversion systems, ocean thermal power plants, principles of ocean wave energy conversion and tidal energy conversion, hydropower, site selection, construction, environmental issues, geothermal energy, types of geothermal energy sites, site selection and geothermal power plants. Concept of energy of audit, analysis of the cost effectiveness of renewable energy sources, present status, comparison, forecast.

Books Recommended:

1. D. P. Kothari, K.C. Singal, R. Rajan, Renewable Energy Sources and Emerging Technologies, PHI Learning Pvt. Ltd, 2009.
2. G. D. Rai, Non-conventional Energy Sources, Khanna Publishers, 2007
3. J. Twidel, T. Wier, Renewable Energy Sources, Taylor & Francis Publishers, 2005
4. S. P. Sukhatme, Solar Energy, Tata McGraw Hill Publishing Company Limited, 2006
5. K. C. Khandelwal, S.S. Mahdi, Biogas Technology- A Practical Handbook, Tata McGraw Hill, 1986.
6. Y. P. Abbi, S. Jain, Handbook on Energy Audit and Environment Management, TERI, 2006.

Subject: CE-OLE-505T (BCE)

Open Elective- I: Energy Conservation and Recycling (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the energy scenario in various sectors and need of energy conservation.
- To understand the planning of the energy conservation and management programs for effective utilization of energy in various sectors.
- To understand and analyse the energy conservation measures in both domestics and industrial sector.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the energy sources and its consumption pattern for the growth of nation.

CO2: Understand the use of energy in industrial sector and understand the effective energy conservation techniques.

CO3: Understand the planning of the energy conservation and management programs for learning the various elements of energy conservation and management.

CO4: Understand the various processes and guidelines for improving the process operation for effective utilization.

CO5: Understand and study the various case studies related to chemical engineering for energy conservation and waste minimization.

Unit 1: **Energy Scenario**: Classification of energy sources, commercial and non-commercial energy, energy resources, commercial energy production, final energy consumption, energy needs of growing economy, long term energy scenario. energy and environment, air pollution, climate change, energy security, energy conservation and its importance. **Energy Management and Audit:** Definition, energy audit – need, types of energy audit, energy management (audit) approach understanding energy costs, bench marking, energy performance, matching energy use requirement maximizing system efficiencies, optimizing the input requirements, fuel and energy substitution, energy audit instruments.

Unit 2: **Energy Available for Industrial Use:** Introduction, methodology for forecasting industrial energy supply and demand. New energy technologies and conservation, motivation of implementing conservation measures, evaluating costs and benefits of conservation measures.

Unit 3: **Management and Organization of Energy Conservation Programs**: Human aspect of energy conservation, involvement tree, elements of energy management program, promoting energy conservation, program planning, setting goals, setting priorities, allocation of resources, scheduling, measuring, monitoring and reporting, organization of energy conservation programs, plant level organization, division level organization, corporate level organization.

Unit 4: **Guidelines for Improving Process Operations for Energy Conservation**: Energy conservation checklist, potential energy conservation in boilers, chilled water plants and central air – conditioning system, compressors and fans, heat pumps and cooling systems, water heaters and coolers, lighting systems, motors and transformers, mixing vessels, heat exchangers, evaporators, distillations, housekeeping.

Unit 5: **Case Studies –Waste - Minimization and Resource Conservation**. Make detail study report for dairy industry, sugar industry, distilleries, fertilizer industry, food industry, cement, and petroleum. These must include-importance of waste minimization and its classification, housekeeping, process change, recycling, product modification, waste minimization methodology steps, benefits of waste minimization.

Books Recommended:

1. Industrial Energy Management and Utilization, Larry C. Witte, Philip S. Schmidt, Davis R. Brown. 1988
2. Handbook of Industrial Energy Conservation, S. David HU.
3. Energy Engineering and Management- Amlan Chakrabarti, PHI Learning-2011.
4. Guide book for National Certification Examination for Energy Managers and Energy Auditors-Book 1,2,3 and 4. Bureau of Energy Efficiency (BEE)
5. Energy Conservation in the Process Industries- W. F. Kenny, Academic Press Inc., 1984
6. Energy Conservation in the Chemical and Process Industries, Colin D. Grant, the Institution of Chemical Engineers. 1979
7. Solar Engineering of Thermal Processes, John A. Duffie and William A. Beckman, 3rd Edition-2006

Subject: CE -HSMC-HS -506T (BCE)

HASS III: Industrial Economics & Project Management (Theory)

Lecture	: 2 Hours	No. of Credits	: 2
University	: 35 Marks	College Assessment	: 15 Marks

Duration of Examination: 2 Hours

Course Objectives:

- To understand the fundamentals of industrial economics
- To understand standard market structure and evaluate profitability of projects
- To understand the complete project life cycle and role of project management in it

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the scope of industrial economics and application of industrial efficiency

CO2: Understand standard market structure and conceptual framework for industrial economics

CO3: Estimating profitability criteria and understanding various theories of profit and financial ratios

CO4: Understanding various facets of project management and key competences of project manager

CO5: Understanding of processes involved in initiating, planning, executing. Monitoring and controlling and closing of projects

Unit 1: Scope for industrial economics, Industrial efficiency- concept & measurement

Unit 2: Standard forms of Market structure such as perfect competition, monopoly, monopolistic competition, oligopoly, market conduct and Conceptual framework

Unit 3: Determining profitability, theories of profit, analysis of financial ratios and relationships

Unit 4: Introduction to project management The Importance of Project Management, Relationship of Project, Program, Portfolio and Operations Management, role of project manager and project manager competencies

Unit 5: Processes involved in initiating, planning, executing. Monitoring and controlling and closing process groups

Books Recommended:

1. Baharwal R. R., Industrial economics: An introduction, New age international Pvt Ltd Publishers (2004)
2. Tirole, Jean, The theory of industrial organizations, The MIT Press, Cambridge Massachusetts London

3. A guide to project management body of knowledge PMBOK® Guide 6th edition
4. M. S. Mahajan, Industrial organization and management, Nirali Publications
5. Harold R. Kerzner, Project Management A Systems Approach to Planning Scheduling and Controlling 12Th Edition by, John Wiley

Subject: CE-PCC-507P (BCE)

Chemical Reaction Engineering I Lab (Practical)

Practical	: 3 Hours	No. of Credits	: 1.5
University	: 25 Marks	College Assessment	: 25 Marks

Duration of Examination: 6 Hours

Course Objectives:

- To learn chemical reaction engineering principles and their practical applications in the areas of reaction engineering.
- To inculcate the ability to plan experiments, apply theoretical concepts for data analysis and interpretation
- Understand the experimental techniques related to chemical reaction engineering

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand and perform experiments related to ideal batch reactors

CO2: Understand and perform experiments related to CSTR

CO3: Understand and perform experiments related to Isothermal plug flow reactor

CO4: Understand, perform experiments and estimate parameters pertaining to various combinations of PFR and CSTR in series

LIST OF EXPERIMENTS:

Required to perform minimum 8 practicals from the list given below:

1. To study of a non-catalytic homogeneous second order liquid phase reaction (Equimolar) in an isothermal Batch Reactor at ambient conditions
2. To study of a non-catalytic homogeneous second order liquid phase reaction (non-equimolar) in an isothermal Batch Reactor
3. To determine the pseudo first order reaction rate constant for the selected reaction in a constant volume adiabatic batch reactor
4. To determine the Effect of Temperature on Reaction rate constant and to determine the Activation Energy for selected reaction in a Batch Reactor
5. To determine overall order of Reactions for bimolecular reactions in Semi-Batch Reactor
6. To Study the performance of isothermal continuous stirred tank reactor (CSTR) for selected reaction
7. To study the kinetics of selected reaction in isothermal Plug Flow Reactor (PFR)
8. To Study the performance of various combinations of PFR and CSTR in series for selected reaction

9. To study the performance of CSTRs in series for the selected reaction scheme

Books Recommended:

1. O. Levenspiel, Chemical Reaction Engineering, 3rd Edition, Wiley India, 2006.
2. H. S. Fogler, Elements of Chemical Reaction Engineering, 4th Edition, PHI, 2005.
3. J. M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981.
4. S. D. Dawande, Principles of Reaction Engineering, Denett & Co, 2007
5. S. M. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.

Subject: CE-PCC-508P (BCE) **Mass Transfer Lab (Practical)**

Practical	: 3 Hours	No. of Credits	: 1.5
University	: 25 Marks	College Assessment	: 25 Marks

Duration of Examination: 6 Hours

Course Objectives:

- To perform experiments related to estimation of diffusion coefficient and mass transfer coefficient for vapor-liquid, liquid-liquid and solid-liquid systems.
- To perform experiments related to evaporation from free surface, batch & forced draft drying, crystallization and adsorption.
- To introduce different experiments based on types of distillation, absorbers, extractors and membrane-based method of separation
- To relate theoretical knowledge with laboratory-based experiments for the analysis of input and output conditions.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand diffusion mechanism and estimation of mass transfer coefficient for vapor-liquid, liquid-liquid and solid-liquid systems

CO2: Understand and analyse equilibria in distillation, absorption, extraction and membrane-based processes

CO3: Study of evaporation from free surface, batch & forced draft drying, crystallization and adsorption for estimation of various process parameters

CO2: Apply various approaches and to estimate the desired degree of separation using distillation, absorption, extraction etc. and Apply separation principles in estimation of design parameters of contacting equipment for distillation, absorption, extraction.

LIST OF EXPERIMENTS:

Required to perform minimum 10 practicals from the list given below:

1. Winkelmann’s method – To find the diffusion Coefficient of vapour in still air
2. Liquid Diffusion – To find the Diffusion Coefficient for a liquid –liquid system
3. To calculate rate of Drying.
4. Studies of crystallization phenomena in Batch Crystallization
5. To evaluate the performance of Cooling Tower.
6. To find the mass transfer coefficient in a wetted wall Column
7. Determination of solid-liquid mass transfer coefficient.

8. Evaporation from free surface.
9. Determination of HTU in packed bed.
10. Study of Ion exchange process.
11. Removal of impurities by use of adsorption techniques.
12. To verify Rayleigh’s Equation for Simple Distillation
13. To construct the boiling point diagram for binary – miscible system
14. Distillation using Sieve Plate, Bubble Cap Column
15. To determine the thermal and vaporization efficiencies in Steam Distillation
16. Single/multiple stage extraction studies
17. To prepare the ternary phase diagram.
18. Soxhlet Extraction
19. Absorption studies in packed column
20. Absorption studies in bubble column
21. Batch/ Continuous Leaching
22. Membrane separation

Books Recommended:

1. J. M. Coulson, J. F. Richardson with J. R. Backhurst, J.H. Harker, Chemical Engineering Vol. I: Fluid Flow, Heat Transfer and Mass Transfer, Sixth Edition, Butterworth-Heinemann an imprint of Elsevier
2. J. M. Coulson, J. F. Richardson with J. R. Backhurst, J. H. Harker, Chemical Engineering Vol. II: Particle Technology and Separation Processes, Fifth Edition, Butterworth-Heinemann an imprint of Elsevier
3. R. E. Treybal, Mass Transfer Operations, 3rd edition, McGraw Hill, 1980.
4. C. J. Geankoplis, Transport Processes and Separation Process Principles, 4 Edition, Prentice Hall, 2003
5. S. L. Pandharipande, Principles of Distillation, Dennet and Co.
6. W. L. McCabe, J. C. Smith, P. Harriott, Unit Operations of Chemical Engineering, Seventh Edition, McGraw Hill Publication, 2005.
7. B. K. Dutta, Principles of Mass transfer and separation processes, PHI Learning, 2007.
8. J. D. Seader, E. J. Henley, Separation Process Principles, Wiley, 1998.

Subject: CE-PCC-509P (BCE) Heat Transfer Lab (Practical)

Practical : 3 Hours

No. of Credits : 1.5

University : 25 Marks

College Assessment : 25 Marks

Duration of Examination: 6 Hours

Course Objectives:

- To perform experiments related to conduction as heat transfer mode and estimate various process parameters
- To perform experiments related to convection as heat transfer mode and estimate/ compare heat transfer coefficient using semi-empirical equations
- To perform experiments related to unsteady state heat transfer and estimate various process parameters
- To perform experiments related to radiation as heat transfer mode and application of Stefan – Boltzman law
- To perform experiments to study the effectiveness of fin

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand and perform experiments related to conduction and apply Fourier’s law of heat conduction for estimation of parameters

CO2: Understand and perform experiments related to convection and estimation/comparison of heat transfer coefficients

CO3: Understand and perform experiments related to radiation & fins

CO4: Understand, perform experiments and estimate parameters pertaining to industrially relevant heat transfer equipment

LIST OF EXPERIMENTS

Required to perform minimum 8 practicals from the list given below:

1. To determine total thermal resistance and thermal conductivity of composite wall
2. To determine thermal conductivity of lagging material
3. To study the heat transfer in a pin fin in natural convection
4. To study the heat transfer in a pin fin in forced convection
5. To determine Stefan – Boltzmann constant for radiation heat transfer
6. To determine overall heat transfer coefficient in shell and tube heat exchanger
7. To study plate type heat exchanger and determine overall heat transfer coefficient
8. To plot the temperature vs time response of three pipe (Heat Pipe Demonstrator)

9. To determine heat transfer coefficient for heating in jacketed agitated kettle
10. To evaluate the material and heat balance, capacity and economy at steady state condition for single effect evaporator
11. To study the heat transfer phenomena in vertical condenser and horizontal condenser
12. To study of radiation heat transfer by black plate and test plate (emissivity measurement apparatus)
13. To determine the experimental and theoretical heat transfer coefficient for drop wise and film wise condensation.
14. To study boiling phenomenon in a jacketed kettle with and without stirring.
15. To find heat transfer coefficient and heat transfer rate from vertical cylinder in natural convection

Books Recommended:

1. C. J. Geankoplis, Transport Processes and Separation Process Principles, 4 Edition, Prentice Hall, 2003
2. J. M. Coulson, J. F. Richardson with J. R. Backhurst, J. H. Harker, Chemical Engineering Vol. I: Fluid Flow, Heat Transfer and Mass Transfer, Sixth Edition
3. B. K. Dutta, Heat transfer Principles and Applications, PHI Private Limited, 2001
4. S. D. Dawande, Principles of Heat Transfer and Mass Transfer, Denett & Co, 2009
5. D. S. Kumar, Basics of Heat & Mass Transfer, Eight Edition, S. K. Kataria & Sons, 2010

Subject: MC

Constitution of India/Essence of Indian Traditional Knowledge (Audit Course)

The Constitution of India is the supreme law of India. Parliament of India cannot make any law which violates the Fundamental Rights enumerated under the Part III of the Constitution. The Parliament of India has been empowered to amend the Constitution under Article 368; however, it cannot use this power to change the “basic structure” of the constitution, which has been ruled and explained by the Supreme Court of India in its historical judgments. The Constitution of India reflects the idea of “Constitutionalism” – a modern and progressive concept historically developed by the thinkers of “liberalism” – an ideology which has been recognized as one of the most popular political ideology and result of historical struggles against arbitrary use of sovereign power by state. The historic revolutions in France, England, America and particularly European Renaissance and Reformation movement have resulted into progressive legal reforms in the form of “constitutionalism” in many countries. The Constitution of India was made by borrowing models and principles from many countries including United Kingdom and America.

The Constitution of India is not only a legal document but it also reflects social, political and economic perspectives of the Indian Society. It reflects India’s legacy of “diversity”. It has been said that Indian constitution reflects ideals of its freedom movement, however, few critics have argued that it does not truly incorporate our own ancient legal heritage and cultural values. No law can be “static” and therefore the Constitution of India has also been amended more than one hundred times. These amendments reflect political, social and economic developments since the year 1950. The Indian judiciary and particularly the Supreme Court of India has played an historic role as the guardian of people. It has been protecting not only basic ideals of the Constitution but also strengthened the same through progressive interpretations of the text of the Constitution. The judicial activism of the Supreme Court of India and its historic contributions has been recognized throughout the world and it gradually made it “as one of the strongest court in the world”.

Course contents:

Meaning of the constitution law and constitutionalism, Historical perspective of the Constitution of India, Salient features and characteristics of the Constitution of India, Scheme of the fundamental rights, The scheme of the Fundamental Duties and its legal status, The Directive Principles of State Policy – Its importance and implementation, Federal structure and distribution of legislative and financial powers between the Union and the States, Parliamentary Form of Government in India – The constitution powers and status of the President of India, Amendment of the Constitutional Powers and Procedure, The historical perspectives of the constitutional amendments in India, Emergency

Provisions: National Emergency, President Rule, Financial Emergency, Local Self Government – Constitutional Scheme in India, Scheme of the Fundamental Right to Equality, Scheme of the Fundamental Right to certain Freedom under Article 19, Scope of the Right to Life and Personal Liberty under Article 21.

Books Recommended:

Introduction to the Constitution of India, D. D. Basu, Lexis Nexis, 25th Edition

Rashtrasant Tukadoji Maharaj Nagpur University

Faculty of Science & Technology

Syllabus for

Sixth Semester B.Tech. Chemical Engineering

Subject: CE-PCC-601T (BCE)

Chemical Reaction Engineering II (Theory)

Lecture	: 3 Hours	Tutorial: 1 Hour	No. of Credits	: 4
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- Basic Concepts of Catalysis
- Kinetics and Mechanistic aspects of Catalysts
- Design and Rating of Catalytic Reactors
- Design Aspects of Gas-Liquid Reactors

Course Outcomes: After completion of the course, students will be able to:

CO1: Determine the rate laws for heterogeneous non-catalytic gas-solid and gas-liquid reactions using proper model equations

CO2: Solve the problems on tower design for gas-liquid reactions and fluidized bed reactor design for gas-solid reactions

CO3: Determine the rate laws for heterogeneous catalytic reactions and design the contactor (reactor) for given gas-solid-liquid catalytic reactions

CO4: Develop the kinetic models for step growth polymerization and free-radical polymerization reactions

CO5: Solve the problems on non-isothermal continuous flow reactor and non-adiabatic reactor operations.

Unit 1: Fluid-Particle and Fluid-Fluid Reactions (Non-Catalytic Systems): Selection of a model for gas-solid non catalytic reaction, Un-reacted core model, Shrinking core model, Rate controlling resistances, Determination of the rate controlling steps, Various contacting patterns and their performance equations, Application of models to design problems. Introduction to heterogeneous fluid - fluid reactions, Rate equation for instantaneous, Fast and slow reaction, Equipment used in fluid- fluid contacting with reaction, Application of fluid -

fluid reaction rate equation to equipment design, Towers for fast reaction, Towers for slow reactions

Unit 2: Solid Catalyzed Reactions: Catalysis in homogeneous and heterogeneous reactions, catalyst classification, preparation, poisoning and regeneration, Promoters and inhibitors, Catalyst deactivation, Mechanism of deactivation, catalyst effectiveness, related examples etc. The Rate Equation for Surface Kinetics, Pore Diffusion Resistance Combined with Surface Kinetics, Porous Catalyst Particles, Heat Effects During Reaction, Performance Equations for Reactors Containing Porous Catalyst Particles, Experimental Methods for Finding Rates, Product Distribution in Multiple Reactions, The Packed Bed Catalytic Reactor

Unit 3: Gas-Liquid Reactions on Solid Catalyst: Trickle Beds, Slurry Reactors, Three Phase Fluidized Beds, The General Rate Equation, Performance Equations under various conditions, selection of various types of Contactors, Applications

Unit 4: Polymerization Reaction Systems: Pseudo-Steady-State Hypothesis (PSSH), Searching for a Mechanism, Step Polymerization, Free-Radical Polymerization, Development of Rate Laws for the Net Rate of Reaction, Modeling a Batch Polymerization Reactor, Molecular Weight Distribution and Properties of Distribution, Design Aspects

Unit 5: Steady State Non-Isothermal Reactor Design: The Energy Balance, Non-isothermal continuous flow reactors, equilibrium conversion, non-adiabatic reactor operations, multiple steady states, non-isothermal multiple chemical reactions

Books Recommended:

1. O. Levenspiel, Chemical Reaction Engineering, 3rd Edition, Wiley India, 2006.
2. H. S. Fogler, Elements of Chemical Reaction Engineering, 4th Edition, PHI, 2005.
3. J.M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981.
4. S.D. Dawande, Principles of Reaction Engineering, Denett & Co, 2007
5. S. M. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.

Subject: CE-PCC-602T (BCE) **Process Equipment Design (Theory)**

Lecture	: 3 Hours	Tutorial: 1 Hour	No. of Credits	: 4
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the design procedure and material of construction for equipment in chemical process industries.
- To understand and apply the design procedure for low and high pressure vessels.
- To understand, analyse and estimate the design parameters for agitators, storage tanks and reaction vessels
- To understand various codes and standard applicable to process equipment

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the basic design consideration and selection of material for pressure vessel

CO2: Estimate the different stresses and thickness of pressure vessel subjected to internal and external pressure and understand design of thick-walled pressure vessel

CO3: Understand, analyse and estimate the design parameters for various types of support, nozzles. flanges and gaskets of a pressure vessel

CO4: Understanding the design considerations for cylindrical and spherical storage tanks

CO5: Understand the codes and standard for shell and tube heat exchanger and discuss various types of agitators along with estimation of power consumption of agitator

Unit 1: Basic considerations in design, design pressure, design temperature, design stress, Code and standards for pressure vessels (IS:2825:1969), and their significance, review of fabrication techniques. Principal stresses, theories of failure, Materials of construction for process equipment, linings and coatings for equipment.

Unit 2: Design procedure for pressure vessels subjected to internal pressure, and combined loading, closures for pressure vessels, Pressure vessels subjected to external pressure, Design of thick cylinder, pre-stressing, Analysis and design of high-pressure vessels: mono-block and compound (multilayer)

Unit 3: Introduction and classification and design of skirt, bracket & saddle supports. Design of jackets, coils for pressure vessels. Opening/ nozzles, manholes, Nozzle reinforcement design, etc. Flanged joints, classification of flanges, design of non-standard flanges, types of Gaskets their selection, and design. Bolt design and selection

Unit 4: Losses in storage vessels, Various types of roofs used for storage vessels, manholes, nozzles and mountings. storage tanks for solids and its design procedure,

Unit 5: Types of agitators, their selection, use of baffles & power consumption, Codes and standards for heat exchangers, Design of shell and tube heat exchangers as per IS: 4503 and TEMA standards

Books Recommended:

1. Introduction to Chemical Equipment Design – Mechanical Aspects by B.C. Bhattacharyya, CBS Publications.
2. Chemical Project Economics, Mahajani V. V. and Mokashi S. M., MacMillan India Ltd. 2005
3. Process Equipment Design-Vessel Design by Lloyd E. Brownell and Edwin Young, John Wiley, NewYork 1963
4. Plant Design and Economics for Chemical Engineers, Max Peters, Klaus Timmerhaus, Ronald West, McGraw Hill International Edition, 2013
5. Process Equipment Design Vol 1 & 2, S. D. Dawande, Denett Publication Seventh Edition, 2015

Subject: CE-PCC-603T (BCE)

Process Dynamics & Control (Theory)

Lecture	: 3 Hours	Tutorial: 1 Hour	No. of Credits	: 4
University	: 70 Marks		College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand the concept of control system block diagram and its elements
- To be able to apply the concept for obtaining the transfer function for Multi capacity control system.
- To be able to interpret the working of various types of controllers.
- To analyze and evaluate the direct digital feedback control for various unit operation and unit processes and to understand the working principles of various measuring instruments

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand & apply the concept of control system block diagram and its elements.

CO2: Apply the knowledge base to solve the problems of First order control systems and servo and regulatory control.

CO3: Apply the knowledge base to solve the problem of dynamics of second order control systems and estimation of various parameters

CO4: Understand, Analyse & apply the knowledge base in selection of various modes of controller for Chemical Process Industries

CO5: Evaluating the performance of Direct digital feedback control system. Understand the working mechanism of various instruments

Unit 1: Response of First and Second Order Systems: Process Dynamics—A Chemical Mixing Scenario, Mathematical Tools for Modeling. Solution of Ordinary Differential Equations (ODEs). Partial Fractions, Qualitative Nature of Solutions, Transfer Function, Transient Response, Forcing Functions, Step Response, Impulse Response, Ramp Response, Sinusoidal Response, Examples of First-Order Systems, Linearization, Noninteracting System, Interacting System, Second-Order System, Transportation Lag

Unit 2: Linear Closed Loop Systems: Components of a Control System, Development of Block Diagram, Mechanisms, Ideal Transfer Functions, Block Diagram of a Chemical-Reactor Control System, Standard Block-Diagram Symbols, Overall Transfer Function for Single-Loop Systems, Overall Transfer Function for Multiloop Control Systems, Transient Response of SimpleControl Systems, Proportional Control for Set Point Change, (Servo Problem—Set Point Tracking), Proportional Control for Load Change (Regulator Problem—Disturbance Rejection), Proportional-Integral Control for Load Change, Proportional-Integral Control for Set Point Change, Proportional Control of System with Measurement Lag,

Unit 3: Stability, Frequency Response: Definition of Stability (Linear Systems), Stability Criterion, Routh Test for Stability, Concept of Root Locus, Substitution Rule, Bode Diagrams, Tank Temperature Control System, The Bode Stability Criterion, Gain and Phase Margins, Ziegler-Nichols Controller Settings.

Unit 4: Process Applications and Microprocessor-Based Controllers: Cascade Control, Feedforward Control, Ratio Control, Dead-Time Compensation (Smith Predictor), Internal Model Control, Controller Tuning and Process Identification, Control Valve Construction, Valve Sizing, Valve Characteristics, Valve Positioner, Control of a Steam-Jacketed Kettle, Dynamic Response of a Gas Absorber, Distributed-Parameter Systems, Historical Background, Hardware Components, Tasks of a Microprocessor-Based Controller, Special Features of Microprocessor-Based Controllers, Distributed Control.

Unit 5: Instrumentation: Classification of Measurement, Classification of Instruments, Characteristics of Instruments, Classification of Transducers, primary and secondary, analog, digital, active and passive transducers Temperature measurement instruments, glass thermometer, pressure thermometer, liquid in metal thermometer, platinum resistance thermometer, thermistors, Thermocouples, Radiation and Optical pyrometer, Pressure measurement instruments, Ionization gauge, Pirani gauge, Bell differential pressure gauge, Pneumatic pressure meter, Level measurement instruments, float and shaft, float and tape, linear and rotary potentiometer, radiation and laser level unit.

Books Recommended:

1. D. R. Coughanour, Process system analysis and control, 2nd Edition, McGraw Hill publication, 1991.
2. G. Stephanopoulos, Chemical process control: An introduction to theory and practice, Prentice Hall of India private limited, 2008.
3. F.G. Shinskey, Process control systems, 2nd Edition, McGraw Hill book Company publication, 1979.
4. R.P. Vyas, Process control and Instrumentation, Seventh Edition, Denett & Co. publication, 2015.
5. R.P. Vyas, Measurement and Control, Denett & Co. Publication 2010.

Subject: CE-CEE-604T (BCE)

Core Elective- II: Advanced Separation Processes (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To develop VLE and estimate process parameters for separation of multicomponent mixtures.
- To obtain the process parameters for azeotropic and extractive distillation.
- To understand fundamentals and applications of membrane separation processes.
- To understand adsorption isotherms to design packed bed adsorber.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Development of VLE and estimation process parameters for separation of multicomponent mixtures.

CO2: Understand the bubble point and dew point calculations for the estimation of design parameters of multicomponent distillation.

CO3: Estimation of process parameters for azeotropic and extractive distillation.

CO4: Understand the fundamentals and applications of membrane separation processes.

CO5: Understand adsorption isotherms to estimate design parameters of packed bed adsorber.

Unit 1: Flux Definition, Differential Equations of Mass transfer, Molecular diffusivities, Molecular diffusion, Mass Transfer coefficients

Unit 2: Multicomponent distillation: Bubble point and dew point calculations, Lewis and Matheson calculation, Method of Thiele and Geddes; Azeotropic distillation; Extractive distillation; Molecular distillation; Reactive distillation

Unit 3: Azeotropic and extractive fractional distillation: Separation of homogeneous azeotropes, separation of heterogeneous azeotropes, choice of entrainer or solvent, design of an azeotropic distillation process, design of an extractive distillation process, methods of solvent recovery

Unit 4: Membrane separation processes: Fundamentals, mechanism and equilibrium relationships, types and structure of membranes, membrane permeation of liquids and gases, effects of concentration, pressure and temperature, dialysis: mechanism, basic idea on dialyser design, industrial application, reverse osmosis, definitions and theory, design considerations, applications, ultra-filtration.

Unit 5: Adsorption and Ion Exchange Processes: Adsorption and ion exchange equilibria. Various isotherms. Contact filtration, design of fixed bed adsorber including breakthrough curve.

Recommended Books:

1. R. E. Lacey, S. Loaeb, Industrial Processing with Membranes, Wiley –Inter Science, New York, 1972.
2. C. J. King, Separation Processes, Tata McGraw - Hill Publishing Co., Ltd., 1982.
3. C. J. Geankoplis, Transport Processes and Unit Operations, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
4. R. E. Treybal, Mass-Transfer Operations, McGraw-Hill, New York, 1980.
5. J. D. Seader, E. J. Henley, Separation Process Principles, Wiley, 2011.
6. B. K. Dutta, Principles of Mass Transfer and Separation Processes, PHI, 2006
7. T. K. Sherwood, R. L. Pigford, C.R. Wilke, Mass Transfer, McGraw-Hill, New York, 1975.
8. H. M. Schoew, New Chemical Engineering Separation Techniques, Interscience Publishers, 1972.
9. Osadar, Varid Nakagawa, Membrance Science and Technology, Marcel Dekkar, 1992.

Subject: CE-CEE-504T (BCE)

Core Elective- II: Computational Fluid Dynamics (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To provide brief introduction of Computational Fluid Dynamics and related discretization methods.
- To provide the understanding of calculations of the flow fields and turbulence modeling.
- To solve the PDE and simulate CFD model for various case studies related to fluid mechanics, heat transfer and reactor engineering.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand the concept of computational fluid dynamics and discretization methods used in CFD.

CO2: Understand and obtain various fundamental equations used for various calculations of the flow fields.

CO3: Understand and apply various models for turbulent systems.

CO4: Understand, analyse and simulate reactor engineering and flow processes using CFD.

CO5: apply CFD for the simulation of various chemical engineering problems.

Unit 1: Introduction and basic concepts, overview of CFD, basic transport equations, Application of CFD. **Discretization methods:** Nature of numerical methods, Methods of deriving the discretization equations, Control volume formulation. Discretization 1-D, 2-D and 3-D equations for steady state and unsteady state conduction. Various methods, Over-relaxation, Under-relaxation, Discretization of convection and diffusion terms, Upwind Scheme, Exact solution, Exponential scheme, Hybrid scheme, Power law scheme, other schemes etc. False diffusion.

Unit 2: Calculation of the Flow Field: Difficulties related pressure gradient term and continuity equation, Staggered grid, Momentum equation, Pressure and velocity correction, Pressure correction equations, SIMPLE, SIMPLER algorithms.

Unit 3: Turbulence Modeling: Introduction to turbulence, Mean flow equations, Nature of turbulence, Classification, Zero order equation models, One equation models, Two-equation models, Turbulent stress models, other models, Problems.

Unit 4: Reactor Engineering and Flow Modelling: Introduction to reactor engineering and flow modelling, Reactive flow processes, Multiphase flow processes, Reactor Engineering Methodology, Introduction to various CFD softwares.

Unit 6: CFD Case Studies: Design of stirred tank reactor, jet mixed tanks, bubble column, fluidized bed, submerged jets, flow in curved pipe, turbulent flow and heat transfer in finned tubes, melting around a vertical pipe, transient combined mixed convection and radiation from vertical aluminium fin, heat transfer in rotary kiln reactors, heat transfer in metal and alloy solidification, membrane reactors etc.

Books Recommended:

1. R. E. Lacey, S. Loaeb, Industrial Processing with Membranes, Wiley –Inter Science, New York, 1972.
2. J. D. Anderson, Computational Fluid Dynamics: The Basics with Applications, McGraw Hill, 1995.
3. S. V. Patankar, Numerical heat transfer and fluid flow, Mc Graw-Hill Book Company, 1st Edition, 1980.
4. P. S. Ghoshdastidar, Computer simulation of flow and heat transfer, Tata McGraw-Hill Publishing, 1st edition, 1998.
5. V. V. Ranade, Computational Flow Modeling for Chemical Reactor Engineering, Academic Press, 2002.
6. H. K. Versteeg and W. Malalasekera, “An introduction to CFD”, Longman Scientific and Technical, 1st edition, 1995.
7. E. S. Oran and J. P. Boris, Numerical Simulation of Reactive Flow, Cambridge University Press, 2nd edition, 2001.
8. J. H. Ferriger, M. Peric, Computational methods for fluid dynamics, Springer, 1st edition, 1996.
9. K. Muralidhar and T. Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publications, 2nd Edition, 2003.

Subject: CE-CEE-604T (BCE)

Core Elective- II: Process Intensification (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To provide an understanding of the concept of Process Intensification.
- To provide knowledge and understanding of application of intensification techniques to a range of processes e.g. heat and mass transfer, separation processes.
- To provide an understanding of basic operating principles of a variety of intensified process equipment such as various mixers, chemical reactors, micro-reactors, compact heat exchangers and separators etc.
- To acquainted with various energy-based intensifications like ultrasound and hydrodynamic cavitation-based processes.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Identify the scope for process intensification in chemical processes.

CO2: Implement methodologies for process intensification

CO3: Understand scale up issues in the chemical process.

CO4: Solve process challenges using intensification technologies.

CO5: Understand the energy-based process intensifications.

Unit 1: Introduction: Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process-Intensifying Equipment, Process intensification toolbox, Techniques for PI application. Process Intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Implementation of Microreaction Technology, From basic Properties to Technical Design Rules, Inherent Process Restrictions in Miniaturized Devices and Their Potential Solutions, Microfabrication of Reaction and unit operation Devices - Wet and Dry Etching Processes.

Unit 2: Scales of mixing, Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer Ultrasound Atomization, Nebulizers, High intensity inline MIXERS reactors Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers, Design Principles of static Mixers Applications of static mixers, Higee reactors.

Unit 3: Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification.

Unit 4: Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes, Design of compact heat exchanger - example.

Unit 5: Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation Reactors, Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor design, Nusselt-flow model and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sonocrystallization, Reactive separations, Super critical fluids.

Books Recommended:

1. Stankiewicz, A. and Moulijn, (Eds.), Reengineering the Chemical Process Plants, Process Intensification, Marcel Dekker, 2003.
2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.
3. Kamelia Boodhoo (Editor), Adam Harvey (Editor), Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, Wiley, 2013.
4. Segovia-Hernández, Juan Gabriel, Bonilla-Petriciolet, Adrián (Eds.), Process Intensification in Chemical Engineering Design Optimization and Control, Springer, 2016.
5. Reay, Ramshaw, Harvey, Process Intensification, Engineering for Efficiency, Sustainability and Flexibility, Butterworth-Heinemann, 2013.

Subject: CE-OLE-605T (BCE)

Open Elective- II: Polymer Science and Engineering (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand principles of polymer manufacture, properties and applications.
- To acquire knowledge of polymer processing and testing.
- To know methods of modifying polymer for enhanced applications.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Apply appropriate polymerization reaction and technique for polymer synthesis.

CO2: Select using appropriate method for characterization and testing the polymer.

CO3: Suggest suitable polymer for the given application on the basis of properties.

CO4: Modify polymer by blending or forming composite for enhanced performance.

CO5: Optimize process parameters to manufacture finished plastics product.

Unit 1: Chemistry of high polymers: Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness, polymerization methods: addition and condensation; their kinetics, metallocene polymers and other newer techniques of polymerization, copolymerization, monomer reactivity ratios and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, techniques for polymerization-bulk, solution, suspension, emulsion.

Unit 2: Polymer Characterization: Solubility and swelling, concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques.

Unit 3: Synthesis and properties: Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers, Thermosetting polymers: PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex, SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE.

Unit 4: Polymer blends and composites: Difference between blends and composites, their significance, choice of polymers for blending, blend miscibility-miscible and immiscible blends, thermodynamics, phase morphology, polymer alloys, plastic-plastic, rubber-plastic and rubber-rubber blends, FRP, particulate, long and short fibre reinforced composites, Polymer compounding-need and significance, different compounding ingredients for rubber and plastics, crosslinking and vulcanization, vulcanization kinetics.

Unit 5: Polymer processing: Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer, Polymer testing: Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact. Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance.

Books Recommended:

1. Polymer Science by V. R. Gowarikar, New Age Int (P) Ltd.
2. Principles of Polymerization by George Odian, Wiley Interscience.
3. Text Book of Polymers by Billmeyer, Wiley Interscience.
4. A Textbook of Polymer (Chem. & Tech. of Polymer) vol. I &II by M. S. Bhatnagar, S. Chand.
5. Outlines of Polymer Technology by R. P. Sinha, S. Chand.
6. Polymer Structure, Property and Applications by Deanin, ACS.
7. Fundamentals of Plastics Testing by Nayak, Springer.
8. Fundamentals of Polymers by Karak.

Subject: CE-OLE-605T (BCE)

Open Elective- II: Chemical Processing for Microelectronics (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand principles of polymer manufacture, properties and applications.
- To acquire knowledge of polymer processing and testing.
- To know methods of modifying polymer for enhanced applications.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Demonstrate an understanding of the basic principles and operations governing each of the most important unit processes involved in the fabrication of microelectronic devices.

CO2: Demonstrate the ability to quantitatively predict the outcome of a given process using simplifiedengineering models.

CO3: Apply chemical engineering principles to solve problems in areas outside traditional chemical engineering

CO4: Appreciate that microelectronics fabrication is a rapidly developing field and, therefore, they need toupdate their knowledge continually if they want to stay on top of this field.

CO5: Demonstrate an understanding of the basic principles of electrochemical deposition, thin-film characterization, and process integration.

Unit 1: Overview of microelectronic materials, devices and processing, Crystal growth, Oxidation: growth mechanisms and kinetics, thin oxides, process modelling.

Unit 2: Diffusion: models of solid-state diffusion, non-linear effects, Ion implantation, Thin-film deposition: fundamentals of vacuum science and technology, chemical vapor deposition (CVD), physical vapor deposition (PVD).

Unit 3: Rapid thermal processing (RTP), epitaxy, process simulation, Lithography: photoresists, optical lithography, advanced lithographies.

Unit 4: Plasma Processing: fundamentals of plasmas, plasma reactor design, plasma etching and deposition, process simulation.

Unit 5: Electrochemical deposition and chemical mechanical planarization, Thin-film characterization, Process integration.

Books Recommended:

1. Richard C. Jeager, “Introduction to Microelectronic Fabrication,” Second Edition.
2. Modular Series on Solid State Devices, Vol. V, G. W. Neudeck and R. F. Pierret, series editors, Prentice Hall, 2002.

Subject: CE-OLE-605T (BCE)

Open Elective- II: Membrane Technology (Theory)

Lecture	: 3 Hours	No. of Credits	: 3
University	: 70 Marks	College Assessment	: 30 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To understand principles and applications of various membrane separation processes
- To acquire knowledge of transport mechanisms through membranes
- To know various membrane modules and configurations

Course Outcomes:

After completion of the course, students will be able to:

CO1: Apply appropriate membrane separation process in industrial practice

CO2: Apply various techniques for membrane preparation to select the membranes as per process requirements

CO3: Understand the transport mechanism through various membranes

CO4: Understand working of electrically driven membrane separation processes

CO5: Apply various membrane modules and configurations in industrial practice

Unit 1: Introduction: Membrane separation process, Definition of Membrane, Membrane types, Advantages and limitations of membrane technology compared to other separation processes, Membrane materials.

Unit 2: Preparation of synthetic membranes: Phase inversion membranes, Preparation techniques for immersion precipitation, Synthesis of asymmetric and composite membranes, and Synthesis of inorganic membranes.

Unit 3: Transport in membranes: Introduction, Driving forces, Transport through porous membranes, transport through non-porous membranes, Transport through ion-exchange membranes.

Unit 4: Membrane processes: Pressure driven membrane processes, Concentration as driving force, Electrically driven membrane separation processes

Unit 5: Polarisation phenomena and fouling: Concentration polarization, Membranefouling, Modules: Introduction, membrane modules, Comparison of the moduleconfiguration

Books Recommended:

1. Mulder M, Basic Principles of Membrane Technology, Kluwer Academic Publishers, London, 1996.
2. Richard W. Baker, Membrane Technology and Research, Inc. (MTR), Newark, California, USA, 2004.
3. Kaushik Nath, Membrane Separation Processes, Prentice-Hall Publications, New Delhi,2008.

Subject: CE -HSMC-HS -606T (BCE)

HASS IV Industrial organization & Entrepreneurship Development (Theory)

Lecture	: 2 Hours	No. of Credits	: 2
University	: 35 Marks	College Assessment	: 15 Marks

Duration of Examination: 3 Hours

Course Objectives:

- To motivate students and inculcate entrepreneurial skills in them
- To provide exposure to different aspects of industrial organization & entrepreneurship
- To understand roles and responsibilities of different organs of organization
- To understand the synergy between different department for a successful business setup

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand various facets of entrepreneurship

CO2: Understand the behavioural aspects of management and identify roles and responsibilities of various organs of company management

CO3: Identify and understand different organizational structure and it legal aspects along interpreting various financial statement and project reports

CO4: Identify & understand aspects of material management and apply methodologies such as ABC analysis, EOQ etc. for inventory control

CO5: Understand the different aspects of marketing, business management and dealing with business crises

Unit 1: Entrepreneur, Enterprise & Entrepreneurship. Charms of being an entrepreneur. Motivation. Entrepreneurial competencies. Goal setting. Different types of goals.

Unit 2: Behavioural aspects of Management, Functions of management, organs of company management and their functions (shareholders, board of directors, CEO, managing director, manager, secretary), Personal management, Business crises

Unit 3: Benefits and types of organizational structure Different types of business structure in India - advantages disadvantages and its legal aspects, Sources of finance, financial statement, Project report/ Business plan

Unit 4: Material, management: Classes of materials, Purchasing, objectives of purchasing. Functions of purchase department. Inventory management and control. Economic Order Quantity (EOQ), ABC analysis

Unit 5: Marketing for small business, marketing research, Advertising & sales promotion, Channels of distributions. Managing your business for successful growth. Seven business crisis and techniques to beat them

Books Recommended:

1. Basu, S. K., Sahu, K. C., Rajiv Industrial organization and management-, B PHI learning private limited, New Delhi
2. P. C. Jain, Handbook for new entrepreneur, Oxford University Press, 2012.
3. V. G. Patel, The Seven-Business Crisis. How to beat them? Tata McGraw-Hill Co. Ltd, 1995.
4. Gupta C. B. and Srinivasan P., Entrepreneurship Development, Sultan Chand and Sons, New Delhi
5. M. S. Mahajan, Industrial organization and management, Nirali Publications
6. Khanka S. S., Entrepreneurial Development, S. Chand & Co. Ltd New Delhi, 1999
7. Philip Kotler, Marketing Management, Prentice Hall of India, New Delhi
8. Rathore B. S. and Dr. Saini J. S., A Handbook of Entrepreneurship, Aapga Publications, Panchkula (Haryana).
9. EDII - Faculty & External experts - A Hand Book for new Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1986.

Subject: CE-PCC-607P (BCE)

Chemical Reaction Engineering II Lab (Practical)

Practical	: 3 Hours	No. of Credits	: 1.5
University	: 25 Marks	College Assessment	: 25 Marks

Duration of Examination: 6 Hours

Course Objectives:

- To learn chemical reaction engineering principles and their practical applications in the estimation of design parameters of reactors.
- Understand the experimental techniques related to chemical reactor design.
- To inculcate the ability to plan experiments, apply theoretical concepts for data analysis and interpretation

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand and perform experiments related to Non ideal reactors (CSTR and PFR)

CO2: Understand and perform experiments related to Industrial reactors like, trickle bed reactor, packed bed reactors, fluidized bed reactor etc.

CO3: Understand the significance of reaction rate constant & the role of catalyst in chemical reactions

CO4: Understand, perform experiments and estimate parameters pertaining to mas transfer with chemical reaction and the solid fluid reactions and arrive at the regime of operation.

LIST OF EXPERIMENTS:

Required to perform minimum 8 practicals from the list given below:

1. To study Residence Time Distribution (RTD) of CSTR and determine the dispersion number
2. To study residence time distribution (RTD) in a Plug Flow Reactor and to find out Peclet Number.
3. To study residence time distribution (RTD) in a Trickle Bed Reactor and to find out Peclet number.
4. To study residence time distribution (RTD) in a Packed Bed Reactor and to find out Peclet Number.
5. Finding conversion and rate of polymerization reactions using gravimetric method
6. Studies in recycle bed reactor.
7. To study the performance of a fluidized bed reactor.
8. To study the heterogeneous catalysis in the fixed bed reactor
9. RTD Studies in a Series of CSTRs
10. Investigation of the absorption process (mass transfer with chemical reaction) when separating gas mixtures in a packed column and to determine the effectiveness factor and regime of operation.

11. Advanced oxidation with hydrogen peroxide and UV light
12. Kinetics of Solid Fluid Reaction: To study the decomposition of calcium carbonate ($CaCO_3$) in a muffle furnace
13. To determine void volume, solid density and porosity of a catalyst particle
14. To investigate the Industrial Reactors

Books Recommended:

1. O. Levenspiel, Chemical Reaction Engineering, 3rd Edition, Wiley India, 2006.
2. H. S. Fogler, Elements of Chemical Reaction Engineering, 4th Edition, PHI, 2005.
3. J.M. Smith, Chemical Engineering Kinetics, 3rd Edition, McGraw Hill, 1981.
4. S.D. Dawande, Principles of Reaction Engineering, Denett & Co, 2007
5. S. M. Walas, Reaction Kinetics for Chemical Engineers, McGraw Hill, 1959.

Subject: CE-PCC-608P (BCE)

Process Equipment Design and Drawing Lab (Practical)

Practical	: 3 Hours	No. of Credits	: 1.5
University	: 25 Marks	College Assessment	: 25 Marks

Duration of Examination: 6 Hours

Course Objectives:

- To understand various design aspects of process equipment
- To understand designing and representation of vessel supports
- To impart skill in drawing and interpretation of various process equipments
- To understands various aspects such as analysers, control logic, safety logic of P&ID of any process

Course Outcomes:

After completion of the course, students will be able to:

CO1. To identify and apply various symbols used in equipment and process design

CO2. To identify and apply various vessel connections such as nozzles, flanges, jacket and various vessel supports

CO3. To understand and apply various control logics, safety logics, analysers, dimensions of pipe etc used in a P&ID

CO4. To be able to design basic equipment on softwares such as AutoCAD/ Solid works

LIST OF EXPERIMENTS: Minimum 8 sheets related to design and drawing mentioned below should be drawn. Out of 8, two drawing should be performed/demonstrated on AutoCAD.

1. Design of Pressure Vessels
2. Design of Vessel Supports
3. Design of Storage Tanks
4. Design of Heat Exchangers
5. Design of Tray Towers
6. Design of Packed Towers
7. Process Flow Symbols
8. Process Flow Diagram
9. Piping & Instrumentation Diagram
10. Equipment Layout
11. Use of AutoCAD

Subject: CE-PCC-609P (BCE)

Process Dynamics & Control Lab (Practical)

Practical : 3 Hours
No. of Credits : 1.5
University : 25 Marks
College Assessment : 25 Marks
Duration of Examination: 6 Hours

Course Objectives:

- To perform experiments related to dynamics of First order and second order systems.
- To perform the experiments on transient response of control systems using PID controllers under Servo and Regulator problem.
- To perform experiments related to computer operated linear and non-linear level control.

Course Outcomes:

After completion of the course, students will be able to:

CO1: Understand and analyse physical and chemical phenomena involved in various process response for first order system.

CO2: Understand and analyse the response of multi capacity systems

CO3: Apply various analogous/ digital controller to control the system.

CO4: Evaluate the transient response of control system using PID controllers under Servo and Regulator problem.

LIST OF EXPERIMENTS:

Required to perform minimum 8 practical from the list given below:

1. To determine the time constant of mercury in glass thermometer.
2. To determine damping coefficient, decay ratio, overshoot and characteristics time for step response of mercury manometer.
3. To study the dynamic response of liquid level in single tank system.
4. To study the dynamic response of liquid level in two tanks non-interacting liquid level system and to compare experimental and theoretical responses.
5. To study the dynamic response of liquid level in two tank interacting liquid level system and to compare experimental and theoretical responses.
6. To determine the characteristics pneumatic control valve.
7. Use of MATLAB/Scilab/DCS Trainer for performing experiments
8. To study the level control process by means of level transmitter.
9. To study the flow control process by means of flow sensor.
10. To study the cascade control with level.

11. To study the ratio control with flow.
12. To study the behavior of P, I and D on the process control.
13. To study the open loop or manual control.
14. To study the proportional control.
15. To study the Two mode (P+I) control for linear level control
16. To study the Two mode (P+D) control for linear level control
17. To study the Three mode (PID) control for linear level control.
18. To study the tuning of controller (Open loop method) using Zeigler-Nichols method for linear level control.
19. To study the stability of the system using the BODE PLOT for linear level control.
20. To study the autotuning of controller for linear level control
21. To study principles of nonlinear level control

Books Recommended:

1. D. R. Coughanour, Process system analysis and control, 2nd Edition, McGraw Hill publication, 1991.
2. G. Stephanopoulos, Chemical process control: An introduction to theory and practice, Prentice Hall of India private limited, 2008.
3. F.G. Shinskey, Process control systems, 2nd Edition, McGraw Hill book Company publication, 1979.
4. R.P. Vyas, Process control and Instrumentation, Seventh Edition, Denett & Co. publication, 2015.
5. R.P. Vyas, Measurement and Control, Denett & Co. Publication 2010.

Subject: CE-PCC-610P (BCE)

Summer Internship (3-4 weeks) (Practical)

College Assessment : Evaluation in 7th Semester No. of Credits : Nil

Course Objectives:

- To offer the opportunity for the young students to acquire on job the skills, knowledge, attitudes, and perceptions along with the experience needed to constitute a professional identity.
- To provide means to immerse students in actual supervised professional experiences which will provide an insight into the working of the Chemical Industries.
- To appreciate the linkages among different functions and departments of chemical industries to develop perspective about business organizations in their totality.
- To help the students in exploring career opportunities in their areas of interest.

Course Outcomes:

After completion of the course, students will be able to:

CO1: construct the company profile by compiling the brief history, management structure, products / services offered, key achievements and market performance for his / her organization of internship.

CO2: determine the challenges and future potential for his / her internship organization in particular and the sector in general by assessing the Strengths, Weaknesses, Opportunities and Threats (SWOT) of the organization.

CO3: apply the chemical engineering fundamentals in practical situations and analyze and recommend changes for improvement in processes during the internship period.

CO4: apply various soft skills such as time management, positive attitude and communication skills during performance of the tasks assigned in internship organization.

After the end of the sixth semester examination and before the start of the seventh semester, every student will have to undergo Summer Internship. The Summer Internship will be for an individual student to work in industry for 3 to 4 weeks under the guidance of departmental faculty of the institute and respective industrial expert. The Summer Internship (preferably Industrial Internship) would be assigned to the student by the Departmental Internship Coordinator, with the approval of Head of the Department and the Institute.

The Summer Internship will involve the application of the fundamentals learned in the curriculum at industrial/pilot level. The Summer Internship could be of the following forms: (i) industrial internship in a company involved in R&D / design / manufacturing/ marketing / finance / consultancy/Technical services/ Engineering / Projects, etc. (ii) research internship in reputed Institutes like, ICT, IITs, NITs, IISC, NCL, IICT etc.

At the end of the Summer Internship, each student will submit a written report (2 copies) based on the work carried out during the Summer Internship in the given format. The report will be countersigned by the Supervisor from Industry / Institute as the case may be.

Performance of the student will be assessed based on the written report and a presentation to a departmental committee consisting of two faculty members from the Chemical Engineering Department. Students will be assigned a grade based on the written report and a presentation; evaluated by a committee of faculty members.