Bansilal Ramnath Agarwal Charitable Trust's

Vishwakarma Institute of Technology

(An Autonomous Institute affiliated to Savitribai Phule Pune University)

Structure & Syllabus of

B. Tech. (Chemical Engineering)

Pattern 'B19/C19/D19'

Effective from Academic Year 2019-20

Prepared by: - Board of Studies, Chemical Engineering

Approved by: - Academic Board, Vishwakarma Institute of Technology, Pune

Signed by

Chairman -BOS   Dean-Academics   Chairman – Academic Board

Vision of the Institute

To be globally acclaimed Institute in Technical Education and Research for

holistic Socio-economic development

Mission of the Institute

1. To endure that 100% students are employable in Industry, Higher studies, Become Entrepreneurs, Civil/Defense Services / Government Jobs and other areas like Sports and Theatre.

2. To strengthen Academic Practices in terms of Curriculum, Pedagogy, Assessment and Faculty Competence.

3. Promote Research Culture amongst Students and Faculty through Projects and Consultancy.

4 To make students Socially Responsible Citizen.

Vision of the Department

To achieve excellence in chemical engineering education and research"

Mission of the Department

1. To impart quality education preparing students for careers in conventional chemical engineering as well as niche areas such as advanced materials, environmental, biochemical and energy systems engineering.

2. To create a vibrant research environment for carrying out multidisciplinary research in collaboration with organizations of national and international repute.

3. To inculcate entrepreneurship and managerial skills with effective industry – institute interaction.

4. To foster holistic development of students and contribute to the society by addressing social, economic and environmental aspects

Program Educational Objectives (PEOs)

Graduates of the B. Tech. chemical engineering program should be able to utilize the expertise gained from the program to:

1. Pursue industrial and research careers in a global environment.

2. Successfully undergo a postgraduate program.

3. Contribute to multidisciplinary fields such as food and biotechnology, nanotechnology and advanced materials, energy and environmental engineering, product design etc.

4. Demonstrate a zeal for life-long learning.

5. Function effectively in teams, displaying ethical conduct.

Program Outcomes

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
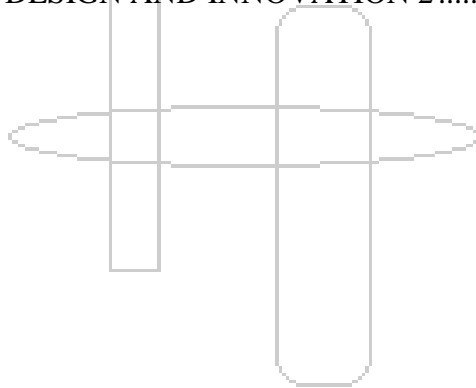
PROGRAM SPECIFIC OUTCOMES (PSOs)

Engineering Graduates will be able to:

1. Work in chemical engineering organizations demonstrating expertise in conventional chemical engineering design and operations.

2. Work in diverse, multidisciplinary fields such as biotechnology, nanotechnology, food, energy, environmental, product designs etc.

Pattern 'B19'
SY BTech Chemical Engineering
Academic Year 2019-20

Contents

Module III Second Year B. Tech Chemical Engineering FF: 653

Title: Course Structure   **Branch: Chemical Engineering**
Year: Third Year B. Tech.   Academic Year: 2019-20 Semester: I
Module: III   **Pattern: B-19**

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme						Total	Credits
			Theory	Lab	ISA				ESA		Total	
					HA	LAB	MSE	GD/PPT	ESE	VIVA		
1	CH2001	Fluid Flow Operations	3	2	10	30	15	10	15	20	100	4
2	CH2003	Process Calculations	3	2	10	30	15	10	15	20	100	4
3	CH2002	Mechanical Operations	3	2	10	30	15	10	15	20	100	4
4	CH2007	Heat Transfer	3	2	10	30	15	10	15	20	100	4
5	CH2009	Differential Equations	2	-	20	-	30	-	30	20		
6	CH2075	Engineering Design & Innovation1	1	6							100	4
Total												20

Abbreviations Used			
ISA	In Semester Assessment	MSE	Mid Semester Examination
HA	Home Assignment	ESE	End Semester Examination
ESA	End Semester Assessment	Lab	Laboratory

CH2001::FLUID FLOW OPERATIONS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1   **(20 Hours)**
Fluids and properties of fluids, Newton's law of viscosity, rheological classification of fluids, types of flow, lines to describe the flow. The basic equation of fluid statics, pressure-depth relationship, pressure forces on surfaces, pressure measurements, pressure measuring devices. Mass, momentum and energy balance equations, venturi meter, orifice meter, pitot tube for velocity measurement, variable area meter. Fundamental dimension of quantities, dimensional homogeneity, Reyleigh's method and Buckingham's π method.

Section 2   **(20 Hours)**
Concept of hydrodynamic boundary layer, growth over a flat plate, change in nature of boundary layer, and different thicknesses of boundary layer, drag on flat plate, coefficient of drag and its variation, hydrodynamic, thermal and concentration boundary layers. Shell balance based solutions for laminar flow through circular tube (Hagen Poiseuelle equation), on inclined plane, Darcy-Weisbach equation, friction factor chart. Minor losses and major losses in pipes, concept of equivalent pipe, series and parallel pipe systems, different pipe fittings and valves, transportation of fluids, pumps, blowers and compressors.

List of Practical:
Minimum 6 experiments from the following list to be performed:
1. Determination of viscosity of liquids
2. Pressure measurements by manometers
3. Reynolds experiment
4. Verification of Bernoulli principle
5. Calibration of venturimeter
6. Calibration of orificemeter
7. Calibration of rotameter
8. Friction in flow through pipes
9. Operating characteristics of centrifugal pump
10. Minor losses in pipes
11. Completion of any two of the above experiments on virtual lab
12. Review of various types of valves used in process industry

List of Project Areas:
Minimum 1 Project from list to be completed:
1. Flow measurement using variable head meters
2. Flow measurement using variable area meters
3. Design of pressure measurement system
4. Laminar flow systems
5. Turbulent systems
6. Applications of Governing Equations of Fluid Flow
7. Transportation of Fluids
8. Centrifugal pump

9. Positive displacement pumps
10. Design of hydrodynamic cavitation device using orificemeter
11. Design of hydrodynamic cavitation device using venturimeter
12. Review on modern sensors for flow measurement

Text Books:
1. Warren Lee McCabe, Julian Smith, Peter Harriott ; Unit Operations in Chemical Engineering., 7th edition, McGraw Hill Publications
2. Bansal R.K.; A Textbook of Fluid Mechanics and Hydraulic Machines., 9th edition, Laxmi Publications (P) Ltd
3. Coulson J.M. and Richardson J.F.; Chemical Engineering Vol. 2, Pergamon Press, 5th ed.

Reference Books:
1. Den M.M.; Process Fluid Mechanics; 1980., Prentice Hall
2.Yunus A.Cengel and John M. Cimbala.; Fluid Mechanics-Fundamentals and Applications; 3rd edition, Tata McGraw Hill

Course Outcomes:
The student will be able to –
1. Determine various properties and flow behaviors.
2. Select and use manometers for pressure measurement.
3. Solve fluid flow problems by using conservation equations of mass, momentum, and energy.
4.   Develop correlations using dimensional analysis.
5. Design the pipe size and flow meters requirements under laminar and turbulent flow conditions.
6. Determine the power requirements of pumping and transportation of fluids.

CH2003::PROCESS CALCULATIONS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1   **(20 Hours)**
Dimensions and Units, Significance Unit conversions of mass, energy and pressure chemical calculations including mole, equivalent weight, solids, liquids, solutions and their properties, properties of gases. Non ideal calculations, for gas and liquid mixtures, Process flow sheet, Concept, Material balance calculations, Material balance of unit operations such as distillation, crystallization. Recycling, bypass and purge operations, material balance of unsteady state processes, Mass balance with chemical reactions, single, multiple reactions, excess and limiting reactants, conversion, yield and selectivity. Material balance with recycle, bypass and purge operation. Material balance of unsteady state processes with chemical reaction.

Section 2:   **(20 Hours)**
Sensible heat changes in gases, liquids and solids, latent heat of phase change, Enthalpy changes in pure substances and their mixtures, Heat of solutions, Heat of crystallisation, energy balance of unit operations, Standard heat of formation and combustion, effect of temperature on heat of formation and Heat of reaction. Energy balance unit processes, Psychometric calculations, calculations for n number of reactions, simultaneous material and energy balance, adiabatic flame temperature calculations. combustion of fuels and combustion calculations. Application of spreadsheet software in process calculations.

List of Lab experiments:
Minimum 6 experiments from the following list to be performed:
1. Conversion of units
2. Material balance on unit process at steady state
3. Material balance on unit process at unsteady state
4. Material balance on unit operation
5. Energy balance on unit operation
6. Energy balance on unit process
7. Recycle without chemical reaction on unit operation
8. Recycle with chemical reaction on unit operation
9. Finding standard heat of formation from data
10. Finding adiabatic flame temperature from data
11. Fuel and combustion calculations with data
12. Various Gas laws calculations

List of Project areas
Minimum 1 Project from list to be completed:
1. Preparation of conversion charts.
2. Preparation of block diagram
3. Preparation of process flow sheet.
4. Material balances of process; steady state.

5. Material balances of process with recycle; steady state.
6. Energy balances of process; steady state.
7. Combine material and energy balance.
8. Unsteady state material balance.
9. Psychometric calculations.
10. Calculation based on gas laws
11. Fuel and combustion calculations
12. Determination of standard heat of formation

Text Books:

1. Bhatt B. I. and Thakore S. M.; Stoichiometry, Tata McGraw-Hill Publication, Fifth Edition, 2010 .
2. Himmelblau D. M.; Basic Principles and Calculations in Chemical Engineering , Tata McGraw-Hill Publication, 7th Edition, 1997.
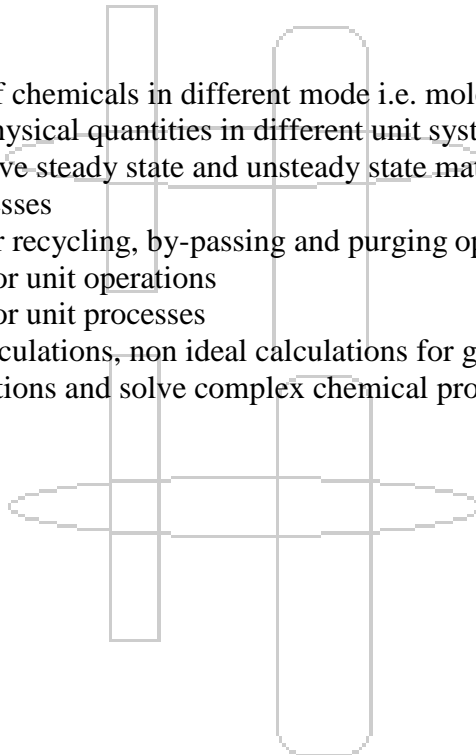
Reference Books:

1. Hougen O. A. and Watson K. M.; Chemical Process Principles (Part I), CBS Publishers New Delhi, 2nd Edition, 2001.

Course Outcomes:
The student will be able to –
1. Determine the quantities of chemicals in different mode i.e. moles and equivalent mass and able to convert various physical quantities in different unit systems
2. Formulate, analyse and solve steady state and unsteady state material balances for unit operations and unit processes
3. Make material balances for recycling, by-passing and purging operations
4. Perform energy balances for unit operations
5. Perform energy balances for unit processes
6. Perform Psychrometric calculations, non ideal calculations for gaseous and liquid mixtures, combustion calculations and solve complex chemical problems

CH2002::MECHANICAL OPERATIONS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section I: **(20 Hours)**

Relevance of fluid and particle mechanics, Particle size and shape, Mixtures of particles, Characterization of solid particles, Relationship among shape factors and particle dimensions; Specific surface area; Measurement of surface area, mixing of solids, size reduction, industrial screening equipment, crushing efficiency, open circuit and closed circuit grinding, size reduction equipments, Nucleation and growth of particles, solid storage, characteristics of Bulk solids, different operations for solid separation from gases and liquid- Froth flotation, magnetic separator, fiber and fabric filter, electrostatic precipitators, cyclone separator, hydrocyclone, Mineral jig, scrubbers, centrifuges, centrifugal clarifier, necessity of mixing and agitation in chemical industries, calculation of power requirement of mixing equipment, solid – Solid Mixing, agitator selection, Conveyors: design, calculation of Screw conveyors, Belt Conveyors, Chain and Flight conveyors, bucket elevators, pneumatic conveyors**,** mixing equipment of pastes and viscous material, mixing equipment of free flowing solids.

Section 2:   **(20 Hours)**

Filter media and filter aids, classification of filtration, pressure drop through filter cake, filter medium resistance, specific cake resistance, continuous filtration, washing and dewatering of filter cakes, centrifugal filtration, filtration equipments, motion of particles in liquid, drag force, drag coefficients, gravity settling method, terminal velocity, stoke's law, free settling, sink and float method, differential settling, Sedimentation and thickening: Batch sedimentation, equipments for sedimentation, kynch theory of sedimentation, calculation of area and depth of continuous thickeners, Flow around immersed bodies: Concept of drag, boundary layer separation, skin and form drag, drag correlations, flow through packed beds, Void fraction, superficial velocity, channeling, Ergun equation and its derivation, Kozeny Carman equation, Darcy's law and permeability, characteristics of fluidized systems, minimum fluidization velocity, types of fluidization, applications of fluidization technique, spouted beds and fixed bed

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. Properties of solids: To determine Avg. Particle size, Specific surface of mixture and No. of particles in the mixture.
2. Screening: To determine the effectiveness of screen.
3. Sedimentation: To determine area of thickener by conducting batch sedimentation test.
4. Centrifugal sedimentation of fine particles slurry.
5. Ball mill: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
6. Jaw Crusher: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
7. Vacuum Leaf Filter: To determine filter medium resistance and cake resistance by using vacuum leaf filter.
8. Cyclone Separator: To determine efficiency of cyclone separator.

9. Froth Flotation: To determine separation efficiency using froth flotation.
10. Fluidization: To determine minimum fluidization velocity and verify with Ergun Equation.
11. Drag Coefficient: To determine terminal settling velocity and compare with theoretical settling velocity.
12. Determination and comparison of solid separation efficiency using gravity and centrifugal sedimentation

List of Project areas:
Minimum 1 Project from list to be completed:

1. Design of filtration process
2. Design of gravity sedimentation process.
3. Design of fluidization process.
4. Design of conveyor belt.
5. Review on recent trends in filtration.
6. Plant design of STP.
7. Plant design of ETP plant.
8. Review on recent trends in gas-solid separation
9. Design of cyclone separator
10. Design of hydro-cyclone separator
11. Design of centrifugal sedimentation process
12. Review on recent trends in solid-solid mixer

Text Books:

1. McCabe W. L. and Smith J. C.; Unit Operations of Chemical Engineering; McGraw Publications, 5th Edition.
2. Coulson J.M. and Richardson J.F.; Chemical Engineering Vol. 2, Pergamon Press, 5th ed., 2002.

Reference Books:

1. Badger W. L. and Banchero J. T.; Introduction to Chemical Engineering; McGraw Hill Publications, 1997.
2. Foust A.S.; Principles of Unit Operations; John Wiley and Sons, 1965.
3. Stanley Walas, Butterworth-Heinemann; Chemical Process Equipment Selection and Design; 1990.

Course Outcomes:
The student will be able to –
1. Recognize basic principle of particle size measurement and select suitable size reduction equipment.
2. Select suitable solid-solid, solid-fluid separation technique and storage tank
3. Select suitable solid conveying system and solid-solid mixing process
4. Describe concept of filtration and design filtration unit
5. Describe concept of sedimentation and design sedimentation unit
6. Describe concept of flow through packed bed and design fluidized bed

CH2007::HEAT TRANSFER

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (PROJ/LAB) Hours / Week**

Section 1:   **(20 Hours)**
Introduction to heat transfer, heat transfer mechanisms: conduction, convection and radiation heat transfer. Specific heat. Fourier's law of heat conduction, thermal conductivity, general differential equation for conduction heat transfer. Thermal resistance concept. Thermal resistance network. Steady state heat conduction through a plane slab, composite slab, hollow cylinder, composite cylinder, hollow sphere and composite sphere, thermal contact resistance. Thermal insulation and critical thickness of insulation.
Physical mechanism of convection, velocity boundary layer, thermal boundary layer. Dimensionless numbers. Application of dimensional analysis to forced and natural convection problems by Rayleigh's and Buckingham's method. Newton's law of cooling, heat transfer correlations in natural and forced convection systems. Heat transfer from extended surfaces/fins with uniform cross section.
Boiling Heat Transfer: pool boiling and flow boiling, boiling regimes and the boiling curve, heat transfer correlations in pool boiling, enhancement of heat transfer in pool boiling. Flow boiling correlations.
Condensation Heat Transfer: film and dropwise condensation, Nusselt's theory. Condensation on vertical/horizontal plate and cylinder. Condensation on bank of horizontal tubes.

Section2:   **(20 Hours)**
Fundamental facts and definition of terms in radiation heat transfer. Emission from the surface. Concept of black, real and gray surface. Laws of black body radiation. Radiation incident on a surface. Directional nature of thermal radiation, concept of solid angle and intensity. Lambert's law – concept of diffuse surface. Kirchhoff's law. Heat transfer by radiation between two black surface elements. Concept of shape factor.
Classification of heat exchangers, flow arrangements. Concept of overall heat transfer coefficient, fouling factor. Derivation of LMTD equation for various flow arrangements. LMTD correction factor for cross flow and multipass shell and tube heat exchanger. Effectiveness-NTU method for heat exchanger design. Selection of heat exchangers.
Concept of evaporation, performance evaluation of tubular evaporators: capacity and economy, boiling point elevation, type of evaporators, single and multiple effect evaporation, material and energy balance calculations, preliminary evaporator design.

List of Lab experiments:
Minimum 6 experiments from the following list to be performed:
1. Determination of thermal conductivity of insulating powder
2. Determination of thermal conductivity of composite wall
3. Determination of thermal conductivity of a metal rod and to study effect of temperature on its thermal conductivity.
4. Determination of heat transfer coefficient for convection heat transfer
5. Determination of efficiency temperature distribution along the fin in natural convection
6. Determination of efficiency temperature distribution along the fin in forced convection
7. Verification of Stefan-Boltzmann constant
8. Determination of emissivity of a nonblack surface
9. Determination critical heat flux in pool boiling
10. Analysis of heat exchangers performance in double pipe heat exchanger
11. Determination of heat transfer coefficient for convection heat transfer by NTU Method.
12. Determination of heat transfer coefficient for evaporation.

List of Project areas:
Minimum 1 Project from list to be completed:
1. Design of heat exchangers.
2. Design of evaporators.
3. Design of boiler.
4. Review on recent trends in heat exchangers.
5. Review on recent trends in evaporators.
6. Furnace design
7. Review on Effect of LMTD in different heat exchangers
8. Review of thermal and hydrodynamic boundary layer
9. Understanding filmwise and dropwise condensation.
10. Review of radiation and application of radiation
11. Design of nuclear reactor using radiation heat transfer
12. Review of boiling point elevation during evaporator design

Text Books:

1. Cengel Y. A.; Heat Transfer: A Practical Approach; 4th Edition; McGraw Hill Education(India) Private Limited
2. Sukhatme S.P.; A Textbook on Heat Transfer; 4th Edition; Universities Press.

Reference Books:

1. Incropera F. P., DeWitt D. P., Bergman T. L., Lavine A. S.; Fundamentals of Heat and Mass Transfer; 7th Edition; John Wiley and Sons
2. Kern D.Q.; Process Heat Transfer; 1st Edition; Tata McGraw Hill
3. McCabe W.L., Smith J.C., Harriott P.; Unit Operations of Chemical Engineering; 7th edition; McGraw Hill

Course Outcomes:
The student will be able to
1. Distinguish between mechanisms of heat transfer and derive basic heat transfer equations from first principles.
2. Solve convection heat transfer problems using empirical correlations.
3. Solve boiling and condensation problems using empirical correlations.
4. Solve radioactive heat transfer problems.
5. Design simple heat exchangers and condensers.
6. Design evaporators, furnaces and reboilers.

CH2009::DIFFERENTIAL EQUATIONS

Credits: 02   **Teaching Scheme: 02 Hours / Week**

Section 1   (15 Hours)
Introduction to Mathematical Modeling of Chemical Engineering Systems:
Balances, allied relations such as constitutive equations. Mathematical modeling of simple systems such as storage tank, steam-heated tank etc.

Ordinary Differential Equations:
First Order ODEs, Second Order Linear ODEs, Homogeneous ODEs with constant coefficients, Nonhomogeneous ODEs etc
Numerical methods for solving ODEs

Laplace Transforms:
Laplace Transform and inverse Laplace Transform definition and transforms of common functions.
Solution of ODEs using Laplace Transforms.

Section 2   (15 Hours)
Fourier Analysis:
Fourier series, complex Fourier series. Fourier Transform.

Partial Differential Equations:
First order PDEs. Dynamic PFR with first order reaction.
Types of Second Order linear PDEs. Heat equation.

Text Books:
1. Advanced Engineering Mathematics, Erwin Kreyszig, 10th ed, J. Wiley, 2015.
2. Higher Engineering Mathematics, B.S. Grewal, Khanna Publishers, 2014.

Reference Books:
1. Advanced Engineering Mathematics, Michael D. Greenberg, Prentice Hall International
2. publishers, 2008
3. Advanced Engineering Mathematics, Alan Jeffrey, Academic Press, 2000.
4. Advanced Engineering Mathematics, Dennis G. Zill and Michael R. Cullen, Narosa
5. Publishing House, 2010.

Course Outcomes:
The student will be able to
1. Write and analyze mathematical models of simple chemical engineering systems
2. Solve ODEs using analytical tools wherever possible
3. Solve ODEs using numerical methods
4. Solve ODEs for dynamical systems using Laplace Transform technique
5. Carry out Fourier analysis of signalS
6. Solve second order linear PDEs

CH2075 :: ENGINEERING DESIGN AND INNOVATION 1

Credits: 4   **Teaching Scheme: 01 (TH) + 06 (LAB) Hours / Week**

Contents:
This stage will include a complete report consisting of synopsis, the summary of the literature survey carried out, Details of experimental/theoretical work and results and discussion and conclusion.

Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.

A technical report of 15 pages is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

The external from Industry/research organization is invited to evaluate the projects done by students.

Course Outcomes:
The student will be able to –
1. Apply chemical engineering knowledge.
2. Learn how to work in team.
3. Define a task (problem) and execute it.
4. Carry out literature search related to topic.
5. Write synopsis and complete literature search related to topic and complete report.
6. Identify the idea and execute it in team.

Module IV Second Year B. Tech Chemical Engineering FF: 653

Title: Course Structure   **Branch: Chemical Engineering**
Year: Third Year B. Tech.   **Academic Year: 2019-20 Semester: II**
Module: IV   **Pattern: B-19**

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme						Total	Credits
			Theory	Lab	ISA				ESA			
					HA	LAB	MSE	GD/PPT	ESE	VIVA		
1	CH2005	Chemical Engineering Thermodynamics	3	2	10	30	15	10	15	20	100	4
2	CH2004	Mass Transfer Operations	3	2	10	30	15	10	15	20	100	4
3	CH2006	Chemical Reaction Kinetics	3	2	10	30	15	10	15	20	100	4
4	CH2008	Chemical Technology	3	2	10	30	15	10	15	20	100	4
5	CH2010	Numerical Methods for Chemical Engineering	2	-	20	-	30	-	30	20		
6	CH2076	Engineering Design & Innovation 2	1	6							100	4
7	CH2074	**General Proficiency 2										
		Total										20

**Audit course

Abbreviations Used			
ISA	**In Semester Assessment**	**MSE**	**Mid Semester Examination**
HA	**Home Assignment**	**ESE**	**End Semester Examination**
ESA	**End Semester Assessment**	**Lab**	**Laboratory**

CH2005::CHEMICAL ENGINEERING THERMODYNAMICS

Credits: 4   **Teaching Scheme: 03(TH) + 02(LAB) Hours / Week**

Section 1:   **(20 Hours)**
Properties of Fluids and Solution Thermodynamics: The fundamental property relations for homogeneous phases, Maxwell relationships, relations between thermodynamic properties, residual properties, residual properties by equations of state, thermodynamic diagrams. Single phase mixtures and solutions; ideal solutions; partial molar properties; chemical potential, effect of temperature and pressure on chemical potential, fugacity and fugacity Coefficient – pure species and species in solution, activity and activity coefficient, ideal solution model. Non-ideal solutions; excess properties; generalized correlation for fugacity coefficient, activity coefficient models, Gibbs-Duhem equation; criteria for thermodynamic equilibrium; models for the excess Gibbs energy, property changes of mixing

Section 2:   **(20 Hours)**
Phase Equilibria and Chemical Reaction Equilibria: The nature of equilibrium, criteria of phase equilibrium, Phase rule, Duhem's Theorem, Introduction to VLE, Raoult's law, VLE by modified Raoult's law, dew point and bubble point calculations, flash calculations, determine whether azeotrope exist. Equilibrium and stability, Introduction to liquid -liquid equilibrium (LLE). The reaction coordinates criteria for equilibrium to chemical reactions, the standard Gibbs free energy change and the equilibrium constant, effect of temperature on equilibrium constant, evaluation of the equilibrium constant, relation of equilibrium constant to composition, calculation of equilibrium conversion for single reaction. Phase rule and Duhem's theorem for reacting systems.

List of Practical:
Minimum 6 experiments from the following list to be performed:
1. To determine thermodynamic properties like internal energy, enthalpy for pure fluids
2. To determine residual properties of gases
3. To determine fugacity and activity
4. To determine activity coefficient
5. To determine thermodynamic properties of solution
6. To determine excess property of solution
7. To determine property changes of mixing of solution
8. To carry out flash calculation for binary system
9. To generate VLE data
10. To generate LLE data
11. To determine equilibrium constant for chemical reactions
12. Case Study of chemical plant

List of Project areas:
Minimum 1 Project from list to be completed:
1. Analysis of system containing pure fluids/solution.
2. Verification of experimental data
3. Bubble point and dew point calculation for binary system

4. Property changes of mixing
5. Flash calculations
6. Prediction of azeotrope formation
7. Analysis of phase equilibria
8. Analysis of chemical reaction equilibria
9. Determination of equilibrium conversion
10. Study of non-ideal solutions
11. Solid liquid equilibrium (SLE)
12. Solid vapor equilibrium (SVE).

Text Books:
1. Smith J. M., Van Ness H. C., Abbott M. M.; Introduction to Chemical Engineering Thermodynamics, Seventh Edition, McGraw-Hill
2. Narayanan K. V.; A Textbook of Chemical Engineering Thermodynamics, Third Edition, Prentice-Hall of India Pvt. Ltd.

Reference Books:
1. Kyle B. G.; Chemical and Process Thermodynamics, Third Edition, Prentice Hall, New Jersey
2. Sandler S. I.; Chemical and Engineering Thermodynamics, Third edition, John Wiley, New York
3. Hougen O. A., Watson K. M., Ragatz R. A.; Chemical Process Principles Part II, Thermodynamics, John Wiley 1970
4. Reid R., Praunitz J., Sherwood T.; The Properties of Gases and Liquids, Third edition, McGraw-Hill, New York

Course Outcomes:
The student will be able to –
1. Estimate thermodynamic properties of pure substances in gas or liquid state
2. Estimate important thermodynamic properties of ideal and real mixtures of gases and liquids
3. Solve simple and complex chemical engineering problems using thermodynamic concepts, data and models
4. Apply criteria of phase equilibria for vapour liquid system and generate VLE data
5. Analyze phase equilibria involving vapor and/or liquid and/or solid
6. Analyze chemical reaction equilibria and use standard heats and free energies of formation to evaluate equilibrium constants and determine equilibrium

CH2004::MASS TRANSFER OPERATION

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hours)**
Introduction to Mass Transfer and Molecular Diffusion: Introduction to Mass Transfer Operations. Molecular Diffusion in gases and liquids, diffusivities of gases and liquids, types of diffusion, Fick's and Maxwell law of diffusion, Measurement of liquid-phase diffusion coefficient, Concept of diffusivity, diffusivity of liquids, Eddy diffusion, film theory, penetration theory, surface renewal theory, Steady state diffusion. mass transfer coefficients, Mass, heat and momentum transfer analogies. ; Interphase mass transfer, local two phase mass transfer, overall mass-transfer coefficient, average overall coefficient, steady state co-current and countercurrent processes, Continuous co-current and counter current processes, cascades, batch processes, Stages and mass transfer rates. Gas-liquid operations and Equipment for Mass Transfer, Overall mass transfer coefficient, Gas dispersal equipments – bubble columns, Liquid dispersal equipments – Venturi scrubbers, wetted wall columns. Gas dispersed Sparged vessels – flow of gas velocity problems based on aeration tank as a time for sparging Gas hold up. Liquid hold up – determination of interfacial area based on hold up and MTC. Tray tower versus packed tower.

Section 2:   **(20 Hours)**
Gas Absorption: Mechanism of gas absorption, equilibrium in gas absorption, choice of solvent, Countercurrent multistage operation, Non-isothermal operation, absorption in wetted wall columns, values of transfer coefficient, absorption in packed tower and spray tower, calculation of HETP, HTU, NTU, calculation of height of packed and spray tower. Absorption in tray towers, absorption and stripping factors, calculation of number of trays for absorption Tray efficiencies, absorption with chemical reaction. ; Humidification, Dehumidification Principles, vapour-liquid equilibria, enthalpy of pure substances, wet bulb temperature relation, Lewis relation, Psychrometric chart, methods of humidification and dehumidification, cooling tower design – HTU, NTU concept, calculation of height of cooling tower.; Drying and *Liquid-liquid extraction*: Principles, equilibrium in drying, type of moisture binding, mechanism of batch drying, continuous drying, time required for drying, mechanism of moisture movement in solid, Design principles of tray dryer, rotary dryer, spray dryer. Spray dryer, fluidized bed and spouted bed dryer, pneumatic dryer and vacuum dryer. Crystallisation- Theory and design.

List of lab Practical:
Minimum 6 experiments from the following list to be performed:

1. Study diffusion of liquid into a gas in a vertical pipe and calculate mass transfer coefficient.
2. Study steady state diffusion of acetone in air and calculate diffusivity.
3. To study characteristics of tray dryer and calculate rate of drying.
4. To study steady state molecular diffusion of acetic acid through water and determine diffusivity.
5. To determine efficiency of rotary dryer.
6. To study characteristics of cooling tower for efficiency and relative cooling.
7. To calculate mass transfer coefficient for absorption of CO_2 into NaOH solution.

8. To calculate mass transfer coefficient for absorption of CO_2 into water.
9. To determine mass transfer coefficient for air-water system during humidification and de-humidification process.
10. To study crystallization to find yield.
11. Study diffusion of solid into a liquid and calculate mass transfer coefficient
12. Any two experiments from above syllabus using virtual lab.

List of Project areas
Minimum 1 Project from list to be completed:

1. Design of tray dryer
2. Design of rotary dryer
3. Design of plate column stripper
4. Design of packed column stripper
5. Design of tray tower absorber
6. Design of packed tower absorber
7. Design of cooling tower
8. Design of batch crystallizer
9. Design of forced circulation crystallizer
10. Data analysis of diffusion of solid into liquid
11. Data analysis of diffusion of liquid into gas
12. Data analysis of diffusion of liquid into liquid

Text Books:
1. Treybal, R.E;Mass Transfer Operations, 4th Edition, McGraw Hill.
2. McCabe, W. L.; Smith, J. C.; Harriett, .;Unit Operations of Chemical Engineering, 4th Edition, McGraw-Hill.

Reference Books:
1. Datta B. K., Principles of Mass Transfer and Separation Processes, 1st Edition, Prantice Hall.
 2. Perry, Robert H.; Green, Don W.; Perry's Chemical Engineer's Handbook; 6th Edition, McGrawHill, 1984.
3. Coulson J. M.; Richardson, J. F.; Chemical Engineering – Vol. I & II; 6 th Edition, Butterworth-Heinemann.

Course Outcomes:
The student will be able to
1. Apply principles of diffusion to separation and purification processes and calculate mass transfer flux and estimate mass transfer coefficient and diffusivity for gas-liquid and liquid-liquid system
2. Select and design appropriate gas-liquid contacting devices
3. Select and design gas absorption and stripping column
4. Calculate mass transfer coefficient for humidification and dehumidification and design cooling tower
5. Calculate rate of drying and Select proper dryer, and find batch time for batch drier and design rotary drier for given requirement
6. Comprehend crystallization system and fundamental of design

CH2006::CHEMICAL REACTION KINETICS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hours)**
Homogeneous reaction kinetics and design of Ideal reactors
Elementary and non elementary reactions, Stoichiometry, Fractional conversion. Rate of reaction based on all components of the reaction and their interrelation. Law of mass action, Rate Constant-Based on thermodynamic activity, partial pressure, mole fraction and concentration of the reaction components and their interrelation, Temperature dependency of rate Constant - Arrhenius law, Transition state theory and collision theory.
Batch reactor concept- Constant volume Batch reactor system; Design equation for zero, first, Second 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. Ideal reactors-Concept of ideality, Types of flow reactors and their differences, Design equation for plug flow reactor and CSTR.

Section 2:   **(20Hours)**
Multiple reactor systems and Temperature and Pressure Effects
Multiple reactor systems- Size comparison of reactors, Optimum size determination, Staging of reactors, Reactors in series and parallel, Performance of infinite number of back mix reactors in series, Back mix and plug flow reactors of different sizes in series and their optimum way of staging;
 Recycle reactors- Optimum recycle ratio for auto-catalytic (recycle) reactors ,Yield and selectivity, Parallel reactions, best operating conditions for mixed and plug flow reactors, irreversible Series reactions,
Effect of temperature and pressure- Equilibrium Conversion, Optimum temperature progression, Adiabatic and non adiabatic operations, Temperature and conversion profiles for exothermic and endothermic reactions

List of lab Experiments:
Minimum 6 experiments from the following list to be performed:

1. To calculate value of rate constant 'k' for the saponification of ethyl acetate with NaOH in batch reactor – I (Where M=1)
2. To determine rate constant 'k for the saponification of ethyl acetate with NaOH in batch reactor – I (Where M>1)
3. To calculate value of rate constant 'k' for the saponification of ethyl acetate with NaOH in straight tube, coli Bent Tube reactor and PFR
4. To calculate value of rate constant 'k' for the saponification of ethyl acetate with NaOH in mixed flow reactor.
5. To calculate value of rate constant 'k' for the saponification of ethyl acetate with NaOH in mixed flow reactors in series.
6. Verification of Arrhenius law

7. Semi batch Reactor Addition of NaOH in Ethyl acetate, Utilization of POLYMATHS for finding Behavior of products with respective of time.
8. Study the effect of various combination of reactors on conversion
9. To determine optimum residence time for multiple parallel reactions
10. Study of a chemical process based on multiple reactions
11. To generate the temperature-conversion profile for a CSTR
12. To generate the temperature-conversion profile for a PFR

Project areas:
Minimum 1 Project from list to be completed:
1. Utilization of POLYMATHS for finding behavior of products with respective of time in reactors
2. Effect of reactor types on product distribution for multiple reactions.
3. To generate temperature conversion profiles for exothermic and endothermic reactions
4. Design of ideal plug flow reactor
5. Design of ideal mixed flow reactor
6. Design of recycle reactor
7. Performance of adiabatic plug flow reactor
8. Study of product distribution for series reactions in plug flow reactor
9. Study of product distribution for parallel reactions in plug flow reactor
10. Study of product distribution for parallel reactions in mixed flow reactor
11. Study of product distribution for series reactions in mixed flow reactor
12. Determination of the reaction kinetics for multiple reactions

Text Books:
3. Levenspiel, O., 'Chemical Reaction Engineering', 3rd. edition, John Wiley& Sons, 2001.
4. Fogler, H. S., 'Elements of Chemical Reaction Engineering', 3rd Ed., PHI, 2002.

Reference Books:
1. Walas, S. M., 'Reaction Kinetics for Chemical Engineers', McGraw Hill, 1959.
2. Smith, J.M., 'Chemical Engineering Kinetics', 3rd ed., McGraw Hill, 1987.

Course Outcomes:

The student will be able to –
1. Develop rate expressions from elementary and non elementary step mechanisms using steady-state and quasi-equilibrium approximations.
2. Determine rate expressions by analyzing reactor data including integral and differential analysis on constant and variable volume systems
3. Design ideal reactors i.e. plug flow and CSTR for first and second order reversible and irreversible, constant and variable volume systems.
4. Select and size isothermal reactors for series and/or parallel systems of reactions and product distribution for multiple reactions
5. Quantitatively predict the performance of common chemical reactors in various combinations
6. Generate temperature and conversion profiles for exothermic and endothermic reactions

CH2008::CHEMICAL TECHNOLOGY

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (PROJ/LAB) Hours / Week**

Section 1:   **(20 Hours)**
Basic Concepts: Theory of Unit operations and industrial equipment and systems used in large scale plants; Unit processes, Development of flow diagram, schematic representation and application for unit operations and unit processes. Study the selection and process specific applications knowing available industrial equipment and plant accessories. Chlor-Alkali Industry : Chlor-alkali chart and importance of chlor-alkali industry, manufacturing processes process economics, and plants in India and a few examples of latest technology used in other nations; Manufacturing of soda ash, caustic soda, chlorine and engineering problems. Membrane cell, mercury cell diaphragm cell processes and electrolytic cell processes and flowsheets. Nitrogen industry : Role of nitrogen in fertilizers, manufacturing of ammonia, nitric acid, urea, the above study must involves different routes adopted, limitations, advantages and disadvantages of the process; steam-reforming process technology. Coal gasification technologies (Fixed bed (Lurgi Process), Fluidised bed (Winkler Process)

Section2:   **(20 Hours)**
Sulfur and Sugar Industry: Importance, manufacturing of sulfur by Frasch process, technology for the manufacturing of sulfuric acid. Sugar Industry: Manufacture of sugar and engineering problems associated, Dextrin and starch derivatives. detailed study and comparison between chamber and DCDA processes; process economics. Phosphorus and Paper Pulp Industry: Importance, manufacturing of super phosphate, triple super phosphate, phosphoric acid, electro thermal processes and NPK fertilizers, production of pulp, engineering problems involved, paper manufacturing from pulp, and comparison of methods of manufacturing. Petroleum and polymer industry : Overview of refinery process, Crude multicomponent distillation, Cracking, Reforming, polymerization industries (polyethylene, polypropylene, PVC and polyester synthetic fibers).

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. Drawing process flow diagram for reactor and distillation column with different combination of gas, liquid, solid reactants, endothermic, exothermic reactions, high low pressure system.
2. Literature review on synthesis of Chemical Products.
3. Market review for given chemical product.
4. Report writing on the chemical plant in Latex including literature, market survey, raw material handling, packing etc.
5. Industrial visit to Chemical Plant.
6. Preparing material safety data sheet for Chemical Product
7. Preparing OSHA sheets
8. Waste treatment methods in Chemical Industry
9. Heating arrangements/cooling arrangements in Chemical Industry
10. Systems for obtaining vacuums in Chemical industry
11. Details of sulfuric acid plant with all details of temperature, pressure, catalyst etc.
12. Details of sugar industry with additives, temperature, pressure, economics etc.

List of Project areas:
Minimum 1 Project from list to be completed:

1. Draw process flow diagram, process utility diagram, P & ID diagram, complete floorwise digram, (individual process to individual student) for the processes of Chemical Technology.
2. Basic material and Energy Balance of Chemical Plant
3. Find breakeven point for the New Chemical Plant.
4. Pinch Analysis for Chemical Plant
5. Complete Hazop study of Chemical Plant Plant design of ETP plant.
6. Review Recent trends in Chemical Reactor used in industry.
7. Review on Energy studies in Chemical Industry
8. Review on Raw materials and products in Chemical industry.
9. Detail study of Converter in Sulfuric acid plant
10. Details of Sulfur Burner in Sulfuric acid plant
11. Detail study of absorber in Sulfuric acid plant
12. Review of petroleum industry products, equipments, cost.

Text Books:

1. 'Dryden Outline of Chemical. Technology', Rao, M. Gopala, , 3rd Edition, East West Publishers, 1997.
2. 'Shreve's Chemical Process Industries', Austin, George T., 5th Edition, McGraw-Hill, 1984.

Reference Books:

1. 'Chemical Process Design and Integration', Smith, R., 3rd Edition, Wiley, 2005.
2. 'Unit Processes in Organic Synthesis', Groggins, P.H., 3rd Edition, McGraw-Hill Book Co., 1958.

Course Outcomes:
The student will be able to –
1. Understand process fundamentals of chemical technology in process industries.

2. Apply knowledge of chemical technology in unit operations and unit processes happening in chemical industry.

3. Draw process flow sheets for production of specific chemical product.

4. Comprehend reaction temperature, pressure condition and heat network in process flowsheet. 5. Analyze different process for same product based on economics, effluent treatment, social aspects.

6. Appreciate Petroleum refinery operation and supplementary processes.

CH2010::NUMERICAL METHODS FOR CHEMICAL ENGINEERING

Credits: 02   **Teaching Scheme: 02 Hours / Week**

Section 1:   **(15 Hours)**
System of Linear Equation: Introduction to modeling, Matrix algebra**,** Systems of linear equation using Eigen values and Eigen vector, multiple ODE, steady state analysis, *Statistical Data Analysis:* Least square method, curve fitting and Regression (linear, multiple linear, polynomial and nonlinear), Numerical Analysis I*:* Root finding methods for algebraic equations:- False position method, Newton-Raphson method), Bisection method, Trapezoidal rule, Simpson's 1/3 rule, integration with unequal segments, Simpson's 3/8 rule

Section 2:   **(15 Hours)**
Numerical Analysis II: Properties of finite methods (stability, convergence etc.) Finite difference method, elliptical and parabolic equations, Laplace equation, solution techniques, boundary conditions ,explicit and implicit method. Optimization: Basic concept of optimization and formulation, Nature of optimization problem (constraints and unconstraint), Liner programming by simplex method. Unconstraint Optimization problem: Global and local optimization.

Text Books:
1. Chapra, S.C.; Canale, R.P., "Numerical Methods for Engineers", 4th Edition, Tata-McGraw Hill Publications, 2002.
2. Edger, T. F.; Himmelblau, D. M., "Optimization of chemical processes", McGraw-Hill, 2nd Edition, 2001.
3. R.B. Bird, W.E. Stewart and E.W. Lightfoot, "Transport Phenomena", John Wiley,

Reference Books:
1. Rice, R.G.; Do, D.D., "Applied Mathematics and Modeling for Chemical Engineers", John Wiley and Sons, 1995.
2. Jenson, V.G.; Jeffreys, G. V., "Mathematical Methods in Chemical Engineering", 2nd Edition, Academic Press, 1997.
3. Mickley, H. S.; Shewrwood, T. S.; Reed, C. E., "Applied Mathematics in Chemical Engineering", McGraw-Hill, 1957.
4. Riggs, James B., "An Introduction to Numerical Methods for Chemical Engineers", 2nd Edition, Texas Tech University Press, 1994.
5. Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley and sons, inc.

Course Outcomes:
The student will be able to –
1. Solve different Chemical engineering problems by using matrix
2. Do statically data analysis
3. Solve different Chemical engineering problems using numerical methods
4. Solve different elliptical and parabolic equations
5. Solve industrial problems by using linear optimization techniques

CH2076::ENGINEERING DESIGN AND INNOVATION 2

Credits: 4   **Teaching Scheme: 01 (TH) + 06 (LAB) Hours / Week**

Contents:
This stage will include a complete report consisting of synopsis, the summary of the literature survey carried out, Details of experimental/theoretical work and results and discussion and conclusion.
Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.
A technical report of 15 pages is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.
The external from Industry/research organization is invited to evaluate the projects done by students.
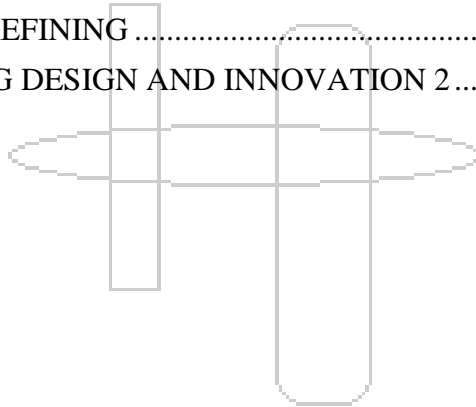
Course Outcomes:
The student will be able to –
1. Apply chemical engineering knowledge.
2. Learn how to work in team.
3. Define a task (problem) and execute it.
4. Carry out literature search related to topic.
5. Write synopsis and complete literature search related to topic and complete report.
6. Identify the idea and execute it in team.

Pattern 'C19'
TY BTech Chemical Engineering
Academic Year 2019-20

Contents

Module V Third Year B. Tech Chemical Engineering   **FF: 653**
Title: Course Structure   **Branch: Chemical Engineering**
Year: Third Year B. Tech.   Academic Year: 2019-20   Semester: V
Module: V   Pattern: C-19

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme							Credits
			Theory	Lab	ISA				ESA		Total	
					HA	LAB	MSE	GD/PPT	ESE	VIVA		
1	CH3001	Chemical Reaction Engineering	3	2	10	30	15	10	15	20	100	4
2	CH3003	Separation Techniques	3	2	10	30	15	10	15	20	100	4
3	CH3061	Mechanical Operations	3	2	10	30	15	10	15	20	100	4
4	CH3047	Optimization Techniques	3	2	10	30	15	10	15	20	100	4
5	CH3075	Engineering Design & Innovation1	1	6							100	4
		Total										20

Abbreviations Used			
ISA	**In Semester Assessment**	**MSE**	**Mid Semester Examination**
HA	**Home Assignment**	**ESE**	**End Semester Examination**
ESA	**End Semester Assessment**	**Lab**	**Laboratory**

CH3001:: CHEMICAL REACTION ENGINEERING

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hours)**

Non-Ideal flow and Heterogeneous processes, catalysis and adsorption
Residence time distribution in vessels: E, F and C curve, and their relationship for closed vessels, conversion in reactors having non-ideal flow; models for non-ideal flow: Dispersion model, Tank in Series, model, Multi parameter model. Mixing of fluids, Self-mixing of single fluid. Dead Zone and Bypass model Two parameter models. Early and late mixing of fluid, mixing of two miscible fluids. Global rate of reaction, Types of Heterogeneous reactions Catalysis, The nature of catalytic reactions, Adsorption: Surface Chemistry and adsorption, adsorption isotherm, Rates of adsorption. Solid catalysts: Determination of Surface area, Void volume and solid density, Pore volume distribution, Theories of heterogeneous catalysis, Classification of catalysts, Catalyst preparation, Promoters and inhibitors, Catalyst deactivation (Poisoning). Mechanism of deactivation, Rate equation for deactivation, Regeneration of catalyst.

Section 2:   **(20 Hours)**

Fluid-particle noncatalytic, catalytic and fluid-fluid non-catalytic reactions
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, Application of models to design problems. Various contacting patterns and their performance equations. 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. Introduction of fluid particle catalytic reactions, Rate equation, Pore diffusion controlling, Heat effects during reaction, Various types of catalytic reactors : Fixed bed reactor- construction, operation and design, Isothermal operation, Adiabatic operation, Fluidized bed reactor, Slurry reactor, Trickle bed reactor. Experimental methods for finding rates.

List of labs:
Minimum 6 experiments from the following list to be performed:

1. To calculate the mass-transfer coefficient (KSL) for physical and chemical dissolution and to calculate the enhancement factor for 'solid-liquid' systems
2. To calculate the mass-transfer coefficient for physical and chemical dissolution and to calculate the enhancement factor for 'liquid-liquid' systems
3. To study residence time distribution (RTD) in a CSTR and to find out peclet No.
4. To determine RTD of a packed bed reactor and to find out Peclet No.
5. To study residence time distribution (RTD) in a plug flow reactor
6. Finding optimum residence time using polymaths for parallel Reactions
7. Finding conversion and rate of heterogeneous reactions.
8. Study reaction in heterogeneous and homogeneous manner

9. Study of a packed bed reactor it's performance
10. Study of a fluidized bed reactor and its performance
11. Case study of the solid catalyzed reaction mechanisms
12. Case study of three phase reactors

Project areas:
Minimum 1 Project from list to be completed:

1. Synthesizing a rate law, mechanism and rate limiting step for heterogeneous reactions.
2. Design of fluid- fluid reactors
3. Design of fluid- particle reactors
4. Catalyst preparation, adsorption isotherms
5. Conversion prediction by segregation model
6. Conversion prediction by maximum mixedness model
7. Conversion prediction by dispersion model
8. Evaluate different moments of Non ideality
9. Design of a slurry reactor
10. Design of a trickle bed reactor
11. Conversion prediction by tank in series model
12. Conversion prediction by two parameter model

Text Books:

1. Levenspiel, O., 'Chemical Reaction Engineering', 3rd. edition, John Wiley& Sons, 2001.
2. Fogler, H. S., 'Elements of Chemical Reaction Engineering', 3rd Ed., PHI, 2002.

Reference Books:

1. Walas, S. M., 'Reaction Kinetics for Chemical Engineers', McGraw Hill, 1959.
2. Smith, J.M., 'Chemical Engineering Kinetics', 3rd ed., McGraw Hill, 1987.

Course Outcomes:
The student will be able to –

1. Distinguish between various RTD curves and predict the conversion from a non-ideal reactor using tracer information
2. Calculate the global rate of heterogeneous catalytic reactions
3. Determine the characteristics of solid catalyst like porosity, pore volume, etc
4. Select model for fluid-particle reactions and calculate the rate of reactions
5. Select model for fluid-fluid reactions and calculate the rate of reactions
6. Design the various types of rectors depending on the different types of heterogeneous
   Catalytic and non-catalytic reactions

CH3003:: SEPARATION TECHNIQUES

Credits: 4   **Teaching Scheme: 03(TH) + 02(LAB) Hours / Week**

Section 1:   **(20Hours)**

Distillation and Liquid-Liquid Extraction. Distillation: Vapour – liquid equilibria for ideal and non-ideal systems, relative volatility, methods of distillation - differential, flash, low pressure, batch rectification. Continuous rectification for binary system, multistage (tray) towers, Lewis Sorrel method, McCabe Thiele method, concept of reflux, Fenske's equation, Fenske-Underwood equation, use of open steam. Partial and total Condensers, reboilers. Ponchon Savarit method for multistage operations, tray efficiencies, packed column design, complex distillation columns, concept of multi component distillation, extractive and azeotropic distillation, Fenske- Underwood-Gilliland shortcut method for multi-component distillation.
Liquid-Liquid Extraction: Ternary liquid-liquid equilibrium, triangular coordinates, single-stage extraction, Multi-stage crosscurrent extraction, continuous countercurrent multistage extraction. Types of extractors.

Section 2:   **(20Hours)**
Leaching, Adsorption and Ion Exchange. Solid-Liquid Extraction: Single stage leaching, continuous counter current leaching, ideal stage equilibrium, operating time, constant and variable underflow, number of ideal stages, stage efficiencies, Leaching equipments.
Adsorption: Physical and chemical adsorption, adsorbents, adsorption equilibrium and isotherms, Single-stage, multi-stage cross-current and multi-stage counter current operations, equilibrium and operating lines, Liquid-solid agitated vessel adsorber, packed continuous contactor, breakthrough curves, Rate equations for adsorbents, nonisothermal operation, pressure-swing adsorption, Ion Exchange- Principles of Ion Exchange Equilibria and rate of ion exchange

List of Practicals:

Minimum 6 experiments from the following list to be performed:

1. To generate VLE data for binary ideal/non-ideal systems
2. To study differential distillation and verify Rayleigh equation
3. To carry out steam distillation of substance and determine steam requirement
4. To conduct binary distillation in a packed column at total reflux and to estimate HETP and HTU for column
5. To obtain data for equilibrium distribution of solute in two insoluble solvents for example acetic acid in water and toluene phases and determine percentage extraction
6. To study the (cross current) liquid- liquid extraction for extracting acetic acid from benzene using water as solvent
7. To carry out leaching operation using groundnuts and n-Hexane and find out quantity of oil and to determine the efficiency of single stage leaching operation
8. To verify Freundlich/ Langmuir isotherm equation for batch adsorption
9. To obtain the breakthrough curve for continuous process in adsorption column

10. To study the operation of a batch rectification column under constant or total reflux condition
11. Case study on industrial separation equipments.
12. Case study on separation processes in chemical plant.

List of Project areas:

Minimum 1 Project from list to be completed:

1. Design of distillation column
2. Design and simulation of reactive distillation
3. To prepare the ternary diagram for a system of three liquid one pair partially soluble for example acetic acid, benzene and water system
4. Study liquid- liquid extraction in a packed column and determine HTU and HETP for the tower
5. Analysis of ion-exchange equilibria
6. Process Design of Solvent Extractors
7. Design of multi-component distillation system using ASPEN software
8. Design and analysis of Supercritical Extraction
9. Process design of leaching equipment
10. Analysis of Reactive Extraction
11. Process design of adsorbers.
12. Analysis and Design of hybrid separation processes

Text Books:
1. Treybal R. E.; Mass Transfer Operations, Third edition, McGraw Hill, 1980
2. Coulson J. M., Richardson J. F.; Chemical Engineering – Vol. I & II, Sixth edition, Butterworth Heinemann, 1999
3. King C.J.; Separation Processes; Tata McGraw - Hill Publishing Co. Ltd., 1982.
4. Dutta B. K.; Principles of Mass Transfer and Separation Processes; Prentice-Hall of India Private Ltd., 2007
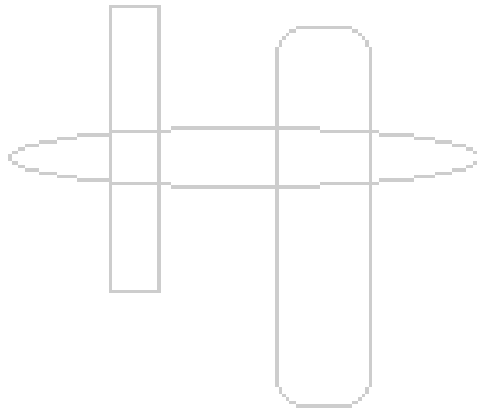
Reference Books:
1. McCabe W. L., Smith J. C., Harriett P.; Unit Operations of Chemical Engineering; Fourth edition, McGraw-Hill, 1985.
2. Wankat. P.C.; Separations in Chemical Engineering: Equilibrium Staged Separations; Prentice Hall, NJ, US, 1988
3. Perry R. H., Green D. W.; Perry's Chemical Engineer's Handbook; Sixth Edition, McGraw-Hill, 1984

Course Outcomes:
The student will be able to –
1. generate VLE data for ideal and non-ideal system
2. carry out process design of distillation column
3. analyze implications of factors affecting distillation column operation and design like the effect of reflux ratio, feed conditions etc. and also the implications of non-ideal phase behavior (e.g., azeotropes) and apply to multicomponent distillation

4. select suitable solvent for liquid-liquid extraction based on properties like selectivity, distribution coefficient etc. and design liquid-liquid extraction column and select equipment required for given separation
5. calculate the number of stages required for a leaching operation
6. draw analogy between adsorption and ion exchange, carry out process design of adsorption column

CH3061:: MECHANICAL OPERATIONS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section I: **(20 Hours)**

Relevance of fluid and particle mechanics, Particle size and shape, Mixtures of particles, Characterization of solid particles, Relationship among shape factors and particle dimensions; Specific surface area; Measurement of surface area, mixing of solids, size reduction, industrial screening equipment, crushing efficiency, open circuit and closed circuit grinding, size reduction equipments, Nucleation and growth of particles, solid storage, characteristics of Bulk solids, different operations for solid separation from gases and liquid- Froth flotation, magnetic separator, fiber and fabric filter, electrostatic precipitators, cyclone separator, hydrocyclone, Mineral jig, scrubbers, centrifuges, centrifugal clarifier, necessity of mixing and agitation in chemical industries, calculation of power requirement of mixing equipment, solid – Solid Mixing, agitator selection, Conveyors: design, calculation of Screw conveyors, Belt Conveyors, Chain and Flight conveyors, bucket elevators, pneumatic conveyors, mixing equipment of pastes and viscous material, mixing equipment of free flowing solids.

Section 2:   **(20 Hours)**

Filter media and filter aids, classification of filtration, pressure drop through filter cake, filter medium resistance, specific cake resistance, continuous filtration, washing and dewatering of filter cakes, centrifugal filtration, filtration equipments, motion of particles in liquid, drag force, drag coefficients, gravity settling method, terminal velocity, stoke's law, free settling, sink and float method, differential settling, Sedimentation and thickening: Batch sedimentation, equipments for sedimentation, kynch theory of sedimentation, calculation of area and depth of continuous thickeners, Flow around immersed bodies: Concept of drag, boundary layer separation, skin and form drag, drag correlations, flow through packed beds, Void fraction, superficial velocity, channeling, Ergun equation and its derivation, Kozeny Carman equation, Darcy's law and permeability, characteristics of fluidized systems, minimum fluidization velocity, types of fluidization, applications of fluidization technique, spouted beds and fixed bed

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. Properties of solids: To determine Avg. Particle size, Specific surface of mixture and No. of particles in the mixture.
2. Screening: To determine the effectiveness of screen.
3. Sedimentation: To determine area of thickener by conducting batch sedimentation test.
4. Centrifugal sedimentation of fine particles slurry.
5. Ball mill: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
6. Jaw Crusher: To determine crushing law constant (by using Rittingers law, Bonds law and Kicks law).
7. Vacuum Leaf Filter: To determine filter medium resistance and cake resistance by using vacuum

leaf filter.
8. Cyclone Separator: To determine efficiency of cyclone separator.
9. Froth Flotation: To determine separation efficiency using froth flotation.
10. Fluidization: To determine minimum fluidization velocity and verify with Ergun Equation.
11. Drag Coefficient: To determine terminal settling velocity and compare with theoretical settling velocity.
12. Determination and comparison of solid separation efficiency using gravity and centrifugal sedimentation

List of Project areas:
Minimum 1 Project from list to be completed:

1. Design of filtration process
2. Design of gravity sedimentation process.
3. Design of fluidization process.
4. Design of conveyor belt.
5. Review on recent trends in filtration.
6. Plant design of STP.
7. Plant design of ETP plant.
8. Review on recent trends in gas-solid separation
9. Design of cyclone separator
10. Design of hydro-cyclone separator
11. Design of centrifugal sedimentation process
12. Review on recent trends in solid-solid mixer

Text Books:

1. McCabe W. L. and Smith J. C.; Unit Operations of Chemical Engineering; McGraw Publications, 5th Edition.
2. Coulson J.M. and Richardson J.F.; Chemical Engineering Vol. 2, Pergamon Press, 5th ed., 2002.

Reference Books:

1. Badger W. L. and Banchero J. T.; Introduction to Chemical Engineering; McGraw Hill Publications, 1997.
2. Foust A.S.; Principles of Unit Operations; John Wiley and Sons, 1965.
3. Stanley Walas, Butterworth-Heinemann; Chemical Process Equipment Selection and Design; 1990.

Course Outcomes:
The student will be able to –
1. Recognize basic principle of particle size measurement and select suitable size reduction equipment
2. Select suitable solid-solid, solid-fluid separation technique and storage tank
3. Select suitable solid conveying system and solid-solid mixing process
4. Describe concept of filtration and design filtration unit
5. Describe concept of sedimentation and design sedimentation unit
6. Describe concept of flow through packed bed and design fluidized bed

CH3047 :: OPTIMIZATION TECHNIQUES

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1   **(20 Hours)**

Continuity of functions, Unimodal Versus Multimodal functions, Convex and Concave Functions, Convex Region, Necessary and sufficient conditions for an Extremum of an Unconstrained function. Interpretation of the objective function in terms of its quadratic approximation. Scanning and Bracketing Procedure. Newton, Quasi-Newton and Secant methods of Uni-dimensional Search. Elimination method: Exhaustive Search, Dichotomous Search, Interval Halving Method, Golden Section Method.

Section 2   **(20 Hours)**

Direct Method: Random Search Method, Simplex Method: Reflection, Expansion and contraction. Indirect Method (1st Order): Gradient Method. Indirect Method (2nd Order): Newton Method, Basic Concepts of Linear programming, Natural occurrence of Linear Constraints, Simplex Method of solving LP problems. Duality in Linear Programming, Optimal Design and Operation of Distillation Column, Formulation of Chemical reactor optimization problems. Optimal pipe diameter.

List of Practical:
Minimum 6 experiments from the following list to be performed:
13. Single variable unconstrained optimization
14. Unconstrained optimization using Newton's Methods
15. Multivariable unconstrained optimization
16. Random Search Methods
17. Optimization using elimination methods
18. 2-D constrained optimization with Graphical Method
19. Constrained optimization with Simplex method
20. Non Linear Constrained Optimization
21. Software/ packages for optimization
22. Engineering optimization with Spreadsheet applications
23. Duality in Linear Programming
24. Chemical Engineering applications of Optimization

List of Project Areas:
Minimum 1 Project from list to be completed:
1. Least cost design of a Tank
2. Optimal design of a waste water treatment plant
3. Design of a reactor for optimal growth rate of yeast
4. Optimization of multi product facility
5. Design of Zero Effluent Discharge Plant
6. Optimal design of waste stabilization & digestion plant

7. Design of a small heat exchanger network
8. Real time optimization of a distillation column
9. Model predictive control using optimization
10. Maximizing yield or selectivity in a complex chemical reaction
11. Data validation and reconciliation using optimization
12. Synthesis of optimal process system with uncertainty

Text Books:
1. T.F. Edgar; "Optimization of Chemical Processes"; McGraw Hill, 1989.
2. S.S.Rao, "Engineering Optimization-Theory and Practice", New Age International. Publishers, 2010

Reference Books:
1. K. Urbaniec and C. McDermott; "Optimal Design of Process Equipment", John Wiley, 1986

Course Outcomes:

The student will be able to –
1. Optimize the process objective function based on different types of constraints.
2. Calculate the search operation of optimization related problem based on different methods.
3. Problem solving using Linear Programming
4. Optimising design of chemical equipments.
5. Solving the problem of unimodal and multimodal function.

CH3075 :: ENGINEERING DESIGN AND INNOVATION 1

Credits: 4   **Teaching Scheme: 01 (TH) + 06 (LAB) Hours / Week**

Contents:
This stage will include a complete report consisting of synopsis, the summary of the literature survey carried out, Details of experimental/theoretical work and results and discussion and conclusion.
Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.
A technical report of 15 pages is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.
The external from Industry/research organization is invited to evaluate the projects done by students.

Course Outcomes:
The student will be able to –
1. Apply chemical engineering knowledge.
2. Learn how to work in team.
3. Define a task (problem) and execute it.
4. Carry out literature search related to topic.
5. Write synopsis and complete literature search related to topic and complete report.
6. Identify the idea and execute it in team.

Module VI Third Year B. Tech Chemical Engineering

Title: Course Structure   **Branch: Chemical Engineering**
Year: Third Year B. Tech.   **Academic Year: 2019-20** **Semester: VI**
Module: VI   **Pattern: C-19**

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme						Total	Credits
			Theory	Lab	ISA				ESA			
					HA	LAB	MSE	GD/PPT	ESE	VIVA		
1	CH3000	Process Equipment Design	3	2	10	30	15	10	15	20	100	4
2	CH3002	Instrumentation and Process Control	3	2	10	30	15	10	15	20	100	4
3	CH3014	Nanotechnology										
	CH3024	Environmental Engineering	3	2	10	30	15	10	15	20	100	4
4	CH3016	Fermentation Technology										
	CH3026	Petroleum Refining	3	2	10	30	15	10	15	20	100	4
5	CH3076	Engineering Design & Innovation 2	1	6							100	4
6	CH3174	General Proficiency 3*										
	Total											20

*Audit Course

Abbreviations Used			
ISA	In Semester Assessment	MSE	Mid Semester Examination
HA	Home Assignment	ESE	End Semester Examination
ESA	End Semester Assessment	Lab	Laboratory

CH3000::PROCESS EQUIPMENT DESIGN

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (PROJ/LAB) Hours / Week**

Section 1:   (20 Hours)
Heat Exchangers: Introduction, process heat transfer, types of heat exchangers, codes and standards for heat exchangers, materials of construction, API scale, LMTD, countercurrent & concurrent exchangers, temperature approach & cross, counter-flow: double pipe exchangers, baffles and tie rods, design of shell and tube heat exchangers as per IS: 4503 and TEMA standards i.e. shell, tube sheets, channel, channel cover, flanged joints. Design of Double pipe, plate type heat exchangers. Joints, bearings, drives, mechanical seals, fabrication methods. Evaporators & pressure vessels**:** Classification of vaporizing equipment, evaporators (including different types such as kettle, thermosiphon, vertical, horizontal etc. Chemical evaporators, natural circulation & forced circulation evaporators, the calculation of chemical evaporators. Types of pressure vessels, codes and standards for pressure vessels (ASME Sec VIII Div-1, 2), material of construction, selection of material, selection of corrosion allowance and weld joint efficiency, purging of vessels. selection and design of various heads such as flat, torispherical, elliptical, hemispherical and conical. Opening/ nozzles and manholes, nozzle sizing, calculations etc. Flanged joints: Gasket: types, selection, and design, bolt design and selection, flange dimensions flange rating calculation**.** Condenser Design and support design: Condenser design for condensation of single vapors, Design of total and partial condenser with pressure balance. Vertical condenser, horizontal condenser. Allowable pressure drop in condensers, condenser-subcooler, condensation of steam- surface condenser. jacket for vessels. Introduction and classification of supports, design of bracket or lug supports, saddle support.

Section2:   (20 Hours)
Mass transfer equipments with storage vessel and mixer consideration: Tray column design and storage vessels: Design of plate column- distillation columns, design variables in distillation, design methods for binary systems, plate efficiency, approximate column sizing, plate contactors, plate hydraulic design. Various types of storage vessels and applications, losses in storage vessels, storage of fluids- storage of volatile & non-volatile liquids- fixed roof and variable volume tanks, Various types of roofs used for storage vessels. Storage of gases- spherical vessels. Packed Column Design and mixers: Choices of packing, types of packing, packed bed height (distillation and absorption), HETP, HTU, NTU, Cornell's method, Onda's method, column diameter, column internals, column auxiliaries. Mixers- Various types of mechanical mixers- propeller, turbines & paddles their selection, flow patterns in agitated tanks, baffling, design practices, standard geometry tank, power dissipation and discharge flow correlation, mechanical agitator design. Reaction vessels. Filters, Dryers and auxillary process vessels **:** Study of various types of filters like vacuum filters, pressure filters, centrifuges and rotary drum filters, design of rotary drum filters including design of drum, shaft, bearing and drive system. Types of dryers, batch type dryers, continuous dryers. Study of auxiliary process vessels such as reflux drum, knockout drum, liquid-liquid and gas-liquid separators, entrainment separators, oil water separator, Decanter, gravity separator, safety devices.

List of Lab experiments:
Minimum 6 experiments from the following list to be performed:
1. Design of Shell and Tube heat exchanger.
2. Design of double pipe heat exchanger

3. Design of vaporiser
4. Design of condenser
5. Design of distillation column
6. Design of types of supports for vessels
7. Design of various types of heads for vessels
8. Design of agitators for chemical reactors
9. Literature survey on types of safety valves, safety devices for chemical equipments
10. Autocad drawing of tubes sheet for the Shell and tube heat exchanger.
11. Economic analysis for Shell and tube heat exchanger.
12. Mechanical design details for Shell and tube heat exchanger.

List of Project areas:
Minimum 1 Project from list to be completed:
1. Optimisation of Shell and Tube heat exchanger considering particular heating or cooling objective
2. Optimisation of Plate type heat exchanger considering particular heating or cooling objective
3. Optimisation of Double pipe heat exchanger considering particular heating or cooling objective
4. Optimisation of Helical tube type heat exchanger considering particular heating or cooling objective
5. Optimisation of evaporator to obtain thick liquor with particular concentration considering various industrial needs
6. Optimisation of tray/packed column for separation by using distillation, absorption, etc operations with an industrial example.
7. Condenser design for multicomponent vapor mixtures.
8. Design of multi-effect evaporator.
9. Design of extractive distillation system.
10. Design of rotary dryer.
11. Design of liquid-liquid separator.
12. Design of gas-liquid separator.
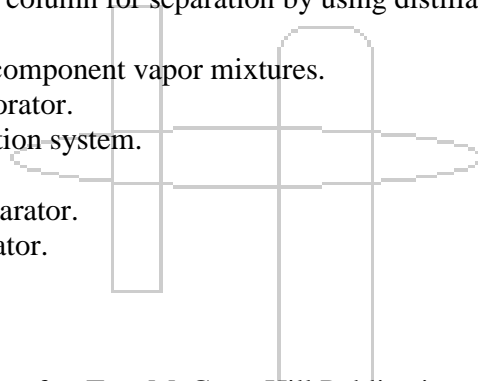
Text Books:

1. D. Q. Kern;Process Heat Transfer; Tata McGraw Hill Publications, 2009
2. R. K. Sinnott; Coulson & Richardson's Chemical Engineering, Volume-6; Elsevier Butterworth Heinemann, MA, 2005.
3. V.V. Mahajani, S. B. Umarji; Joshi's Process Equipment Design; 5th Edition; Trinity Press
4. Lloyd E. Brownell, Edwin H. Young; Process Equipment Design; 1st Edition; Wiley-Interscience

Reference Books:

1. Walas, S. M; Chemical process equipment: selection and design; Butterworth-Heinemann, 1990.
2. Ludwig, E.E.; Applied Process Design for Chemical and Petrochemical Plants, Vol. 1 and 2; 3rd Ed.; Gulf Publishing Co., 1997.
3. Eugene F. Megyesy; Pressure Vessel Handbook; 10th Edition; Pressure Vessel Publishing, INC.
4. R. K. Sinnott; Coulson and Richardson's Chemical Engineering Volume 6 - Chemical Engineering Design; 4th Edition; Pergamon Press.

Course Outcomes:
The student will be able to –

1. Carry out the detailed thermal design of double pipe and shell and tube heat exchanger for given requirement
2. Design a multiple effect evaporation system for specific requirement of concentration
3. Do hydraulic plate design and tray column design for desired separation needs
4. Select type and size of packing and packed column design with internals for required separation
5. Select and design support for vessels
6. Choose and design auxiliary process equipment required for various simple separation & storage requirements
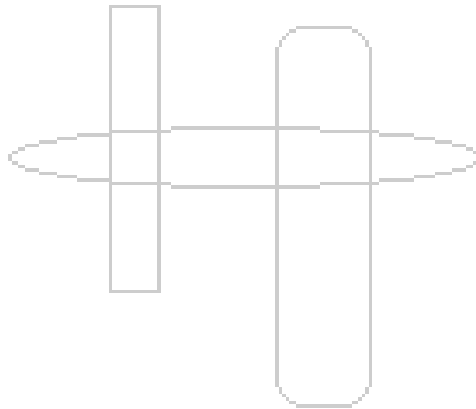
CH3002:: INSTRUMENTATION AND PROCESS CONTROL

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (PROJ/LAB) Hours / Week**

Section 1:   **(20 Hours)**

Instrumentation: Measurement fundamentals. Temperature, flow, pressure, level and composition measuring instruments. Static and dynamic characteristics. Control valves: sizing and valve characteristics Process Dynamics: Introduction to process control. Review of Laplace transforms. Development of mathematical and dynamic modeling of chemical engineering systems. First order, second order systems. Systems with time delays. Interacting & noninteracting processes Single loop feedback control: Feedback control. Block diagram. Feedback controllers: PID control etc. Typical time-domain responses of feedback control systems. Servo and regulatory problems.

Section 2:   **(20 Hours)**

Stability Analysis: Stability analysis of closed-loop control systems. Routh stability criterion. Root locus technique. Bode stability analysis. Design of Feeback Control Systems:Design of feedback control systems using time-domain and frequency-domain techniques. Controller tuning methods such as Ziegler-Nichols. Advanced Process Control: Feedforward control, cascade control, ratio control, selective control etc. Introduction to digital control. Multiloop and multivariable control. Plantwide control.

List of Practicals:
Minimum 6 experiments from the following list to be performed:
1. Measurements for temperature,
2. Measurements for pressure
3. Measurements for flow
4. Measurements for level
5. Process dynamics
6. PID Controlled system: P, I, D modes and controller tuning
7. Feedback control system design using Matlab
8. Dynamic simulation on a chemical engineering simulator such as Aspen
9. Dynamics of distillation column
10. Dynamics of reactor
11. Stability analysis
12. Dynamic behaviour of liquid level in two consecutive tanks.

List of Project areas:
Minimum 1 Project from list to be completed:
1. Controller tuning
2. P&ID diagrams for flow sheets
3. design a control system using time-domain techniques such as root-locus
4. design a control system using frequency-domain techniques such as Bode design
5. Dynamic behaviour of pure capacity process
6. Feedback control system design using Matlab
7. Dynamics of Chemical Engineering Systems
8. Feedforward control system

9. Control valves sizing
10. Cascade control
11. Selective control
12. Multiloop and multivariable control

Text Books:
1. Coughanowr D.R., "Process Systems Analysis and Control", 2nd ed, McGraw-Hill.
2. Nakra, B.C., Chaudhry, "Instrumentation, Measurement and Analysis", K.K., 2nd ed, Tata McGraw-Hill.

Reference Books:
1. Ekmann, D. P.; Industrial Instrumentation, Fifteenth Wiley Eastern Reprint, 1st Edition, Wiley Eastern Ltd.
2. Luyben, W.L. 'Process Modeling, Simulation and Control for Chemical Engineers', 2nd ed., McGraw-Hill.
3. Seborg, D. E.; Edgar, T. F.; MellichampD.A. 'Process Dynamics and Control', 2nd ed, John Wiley & Sons.
4. Considine, D. M., "Process/Industrial Instruments and Controls Handbook",4th Edition, McGraw-Hill.
5. George Stephanopolous, "Chemical Process Control", Eastern Economy edition, Prentice-Hall, 2005.
6. Liptak, B.G, "Instrument Engineer's Handbook, Volume I: Process Measurement and Analysis", 4th ed, CRC Press.
7. Liptak, B.G. 'Instrument Engineer's Handbook, Volume II: Process Control and Optimization', 4th ed, CRC Press, 2005.
8. Harriot, P., "Process Control" Tata McGraw Hill Publishing Co., 1991.
9. Doebelin, E.O., Manik, D.N., "Doebelin's Measurement Systems", 6th ed, McGraw-Hill.

Course Outcomes:
At the end of the course the student will be able to
1. carry out selection and performance analysis of measuring instruments
2. write dynamic models of chemical engineering systems
3. carry out process identification and tune a PID controlled system
4. design a control system using time-domain techniques such as root-locus
5. design a control system using frequency-domain techniques such as Bode design
6. carry out preliminary analysis of Advanced Process Control systems

CH3014:: NANOTECHNOLOGY

Credits: 04   **Teaching Scheme: 03(TH) + 02(LAB) Hours / Week**

Section 1:   **(20 Hours)**

Introduction
Histroical development of nanotechnology.
Overview of nanotechnology. Global trends.
Overview of typical products in market utilizing nanotechnology.

Physics of Nanomaterials
Coverage of physics of materials appropriate for applications to nanotechnology

Characterisation of Nanomaterials
Microscopy techniques, spectroscopy techniques, XRD etc

Section 2:   **(20 Hours)**
Synthesis / Fabrication of nanomaterials
Top-down and bottom-up approaches for synthesis of nanomaterials. Industrial scale production of nanomaterials.

Applications of Nanotechnology
Current and potential applications of nanotechnology. Biological nanomaterials. Nanoelectronics. Nanomachines& nanodevices etc.
Research directions. Economic, environmental and societal aspects of nanotechnology.

List of Practicals:
Minimum 6 experiments from the following list to be performed:
1. Copper nanoparticles synthesis
2. Silver nanoparticles synthesis
3. Gold nanoparticles synthesis
4. ZnO nanowires synthesis
5. MEMS/NEMS design and simulation
6. MEMS/NEMS fabrication
7. MEMS/NEMS testing and characterization
8. Nanolithography
9. Biosensing
10. Synthesis of $Cu(OH)_2$ nanowires
11. Synthesis of CuO nanowires
12. Sol-gel nanosynthesis

List of Project areas:
Minimum 1 Project from list to be completed:
1. Nanoparticle synthesis

2. Nanowire synthesis
3. Synthesis of quantum dots
4. Thin film synthesis
5. Characterisation of nanomaterials using SEM
6. Characterisation using AFM
7. Characterisation using STM
8. Characterisation using XRD
9. Product design involving some nanotechnology component
10. Analysis of research paper on nanoelectronics
11. Analysis of research paper on nanofabrication
12. MBE

Text Books:
1. "Nanoscale Science and Technology", R.W. Kelsall, I.W. Hamley, M. Geoghegan, John Wiley and Sons, 2005.
2. "Introduction to Nanotechnology", C.P. Poole Jr, F.J. Owens, Wiley India, 2006.

Reference Books :
1. "Springer Handbook of Nanotechnology", B. Bhushan, ed., Springer, 2004.

Course Outcomes:
The students will be able to
1. describe history of nanotechnology
2. understand basics of physics and chemistry involved in nanotechnology
3. explain the major characterization techniques used in nanotechnology
4. classify and describe various nanosynthesis methods
5. analyze any given nanotechnology product / process in terms of characterization techniques, synthesis methods and applications
6. analyse current and future trends

CH3024:: ENVIRONMENTAL ENGINEERING

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1   **(20 Hours)**
Pollution Prevention:
Environment and environmental pollution from chemical process industries, characterization of emission and effluents, environmental Laws and rules
Process modification, alternative raw material, recovery of by co-product from industrial emission effluents, recycle and reuse of waste, energy recovery and waste utilization
Material and energy balance for pollution minimization. Water use minimization, Fugitive emission/effluents and leakages and their control-housekeeping and maintenance
Solids waste disposal - composting, landfill, briquetting / gasification and incineration

Section 2   **(20 Hours)**
Air Pollution Control: Particulate emission control by mechanical separation and electrostatic precipitation, wet gas scrubbing, gaseous emission control by absorption and adsorption, Design of cyclones, ESP, fabric filters and absorbers
Water Pollution Control: Physical treatment, pre-treatment, solids removal by setting and sedimentation, filtration centrifugation, coagulation and flocculation.
Anaerobic and aerobic treatment biochemical kinetics, trickling filter, activated sludge and lagoons, aeration systems, sludge separation and drying.

List of Practicals:
Minimum 6 experiments from the following list to be performed:
1. Determination of acidity of various water samples.
2. Determination of the alkalinity of various water samples.
3. Determination of the chloride content in the given water samples.
4. Determination of the optimum coagulant dose for the removal of maximum turbidity
5. Determination of the hardness of the given water sample
6. Determination of the iron content of water samples
7. Literature survey on municipal waste management
8. Literature survey on domestic sewage treatment
9. Literature survey on air pollution
10. Literature survey on nuclear waste management
11. Literature survey on hazardous waste management
12. Industry visit for study of ETP

List of Project Areas:
Minimum 1 Project from list to be completed:

1. Municipal Solid waste management
2. Waste to Energy
3. Electronic waste management

4. Air pollution control-Removal of particulate matter
5. Air pollution control-Removal of SOx
6. Air pollution control-Removal of NOx
7. Water pollution control in Petroleum Industries
8. Water pollution control-Domestic sewage treatment
9. Water pollution control - Petroleum Industries
10. Water pollution control -Fertilizer Industries
11. Water pollution control -Sugar Industries
12. Removal of heavy metal from waste water

Text Books:
1. "Pollution Control Acts, Rules, Notifications issued there under" CPCB, Ministry of Env. and Forest, G.O.I., 2010.
2. Vallero D; "Fundamentals of Air Pollution", 4 th Ed; Academic Press.
3. Eckenfelder W.W; "Industrial Water Pollution Control", 2 Ed; McGraw Hill.
4. Kreith F. and Tchobanoglous G., "Handbook of Solid Waste Management", 2 Ed; Mc Graw Hill

Reference Books:
1. Pichtel J; "Waste Management Practices: Municipal, Hazardous and Industrial", CRC.
2. Tchobanoglous G., Burton F. L. and Stensel H.D., "Waste Water Engineering: Treatment and Reuse", 4th Ed; Tata McGraw Hill

Course Outcomes:
The student will be able to –
1. Determine type of pollution.
2. Select and use suitable method of gaseous pollution control
3. Select and use suitable method of water pollution control
4. Select and use suitable method of particulate pollution control
5. Select and use suitable method of solid waste management
6. Design the biological water treatment equipment

CH3016:: FERMENTATION TECHNOLOGY

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1   **(20 Hours)**
Manufacturing process for major products produced by biochemical reactions such as vitamins B, alcohol, acetic acid and vinegar, acetone, lactic acid, citric acid, wine, proteins, penicillin. Major components in bioreactor, Types of bioreactor, modern bioreactors types, scale up and its difficulties, considerations on aeration, agitation, and heat transfer, Bioreactor instrumentation and control, Modification in the design and analysis of chemical reactor as biological reactors. Computerized simulation of bioreactor. Fed batch reactor, CSTR, plug flow reactors, Reactor dynamics, reactor with non-ideal mixing, immobilized biocatalyst, Multiphase bioreactors, fermentation technology

Section 2   **(20 Hours)**
Aerobic and anaerobic waste water treatment, Microorganisms used in waste water processes, dissolved oxygen balance, dissolved oxygen model, organic discharge and stream ecology, growth and food utilization, suspended culture system, activated sludge, ponds and lagoons. Attached culture system, refractory chemicals, Product recovery operations:- Dialysis, Reverse osmosis, ultra-filtration, and Micro-filtration, Chromatography, electrophoresis, electro dialysis. Crystallization and drying, Technical aspects:-Bioprocess economics. Genetic information: potential uses and abuses, Biosafety, ideas and research, typical sequence of events, risk and rewards, patents and the protection of ideas.

List of Practicals:
Minimum 6 experiments from the following list to be performed:
1. To prepare culture for fermentation.
2. To carry out cleaning and sterilization by different methods.
3. To evaluate parameter of fermentation process.
4. To determination of kinetics of bioprocess.
5. To determination of growth constant of bioprocess.
6. To study of different types of bioprocesses.
7. To design different components of bioreactor.
8. To design of different types of bioreactor.
9. To estimate economic of bioprocess.
10. To do plant design of bioprocess.
11. To do literature survey of different bioprocesses.
12. To do literature survey of different bioreactors.

List of Project areas:
Minimum 1 Project from list to be completed:
1. Fermentation Technology
2. Enzyme Technology
3. Design of Bioreactors
4. Design of components of bioreactors
5. Design of agitators for Bioreactors
6. Design of sterilization system for Bioreactors

7. Kinetics of bioprocess
8. Different types of bioprocesses
9. Plant Design of bioprocess
10. Biological waste water systems
11. Immobilization of enzymes
12. Bio-business.

Text Books:
1. Bailey, James E Ollis, Davis F, "Biochemical Engineering", McGraw Hill.
2. Shuler M. L. and F. Kaegi, 'Bioprocess Engineering – Basic Concepts', Prentice Hall Publication ,2nd Edition

Reference Books:
1. Aiba A-Humphery A.E., Mills N.F , "Biochemical Engineering",., Academic Press.
2. Atkinson B, "Biochemical Reactors", Pion Ltd. London.
3. Ghosh T.K., et. Al., "Advances in Biochemical Engineering", Vol.1/3, Springer Verlag 1971-74
4. Wingard L.B., "Enzyme Engineering", Fr. Interscience N.Y. 1972.
5. Peavy H. S., Rowe D. R., Tchobanoglous G., "Environmental Engineering", McGraw-Hill, 1985.
6. P. F. Stanbury, A. Whitekar, S. J. Hall, 'Principles of Fermentation Technology', Butterworth-Heinemann An Imprint of Elsevier, 2nd Edition.

Course Outcomes:
The student will be able to –
1. Describe various bioprocesses in chemical industry
2. Describe various components and type of bioreactors
3. Describe and design bioreactors
4. Describe and design biological waste water treatment processes in chemical industry
5. Describe the separation and recovery operations in biochemical plants
6. Describe bio business and protection of ideas

CH3026: PETROLEUM REFINING

Credits: 4   Teaching Scheme: 03 (TH) + 02 (PROJ/LAB) Hours / Week

Section 1:   **(20 Hours)**

Petroleum composition, specifications of petroleum and some petroleum products such as LPG, Gasoline, Kerosene, Diesel oil and Engine oil.
Pre- refining operations: Settling, Moisture removal, Storage, Heating through exchangers and pipe seal heaters, Atmospheric distillation, Vacuum distillation
Significant conversion units such as, Reforming, Catalytic-Cracking, Hydro-cracking.

Section2:   **(20 Hours)**

Coking and Thermal Processes: Delayed coking, Flexi coking, Fluid coking.
Additives Production such as Ether and Isobutylene production
Refining of petroleum products such as Acid refining, Chemical refining, Hydro-refining, HDS, HDM, HAD.
Blending, Additives, Storage of products, Transportation, Housekeeping, Marketing of petroleum and petroleum products, Safety norms for petroleum products.

List of Lab experiments:
Minimum 6 experiments from the following list to be performed:
  1. Study of world oil reservoirs.
  2. Study of Indian oil reservoirs.
  3. Study of Indian oil refineries.
  4. Study of pre-refinery crude oil operations.
  5. Study of properties of petroleum products.
  6. Study of different additives and blending chemicals.
  7. Study of post refinery crude oil operations.
  8. Study of recent trends in petrochemicals in terms of packaging materials.
  9. Study of recent trends in petrochemicals in terms of catalyst.
  10. Study of recent trends in petrochemicals in terms of distillation.
  11. Study of recent trends in marketing of petroleum products.
  12. Study of safety norms of petroleum product.

List of Project areas:
Minimum 1 Project from list to be completed:
1. A project on design of fire heaters
2. A project on design of multistage atmospheric distillation column
3. A project on design of vacuum distillation column
4. A project on properties of gasoline.
5. A project on properties of diesel.

6. A project on properties of kerosene.
7. A project on properties of lubricating oil.
8. A project on overview of refinery processes.
9. A project on design of pipe still heater.
10. A project on gas to liquid technology.
11. A project on purification of natural gas.
12. A project on liquefaction of natural gas.

Text Books:

5. 1. Gary James, Handwerk, Glenn, Kaiser, Mark; Petroleum Refining: Technology and Economics; 5th Edition, Taylor and Francis - CRC Press, 2005.
6. 2. Nelson W. L.; Petroleum refinery Engineering; 3rd Edition, John Wiley and Sons New York, 1985

Reference Books:

1. Meyers R. A.; Handbook of Petroleum refining processes, 3rd Edition, H Prentice-Hall, 2003.
2. Speight J. G.; Chemistry and Technology of Petroleum; 4th Edition, Taylor and Francis - CRC Press, 1999.

Course Outcomes:
The student will be able to –
1. Find out composition, main characteristics and new trends of petroleum products
2. Select pre-refining operation depending on feed composition
3. Describe cracking and reforming processes
4. Describe coking and additive production processes
5. Select product refining operations and additives to increase quality of petroleum products
6. Develop knowledge of safety during storage, transportation and marketing of petroleum product

CH3076 :: ENGINEERING DESIGN AND INNOVATION 2

Credits: 4   **Teaching Scheme: 01 (TH) + 06 (LAB) Hours / Week**

Contents:

This stage will include a complete report consisting of synopsis, the summary of the literature survey carried out, Details of experimental/theoretical work and results and discussion and conclusion.

Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.

A technical report of 15 pages is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

The external from Industry/research organization is invited to evaluate the projects done by students.

Course Outcomes:

The student will be able to –

1. Apply chemical engineering knowledge.
2. Learn how to work in team.
3. Define a task (problem) and execute it.
4. Carry out literature search related to topic.
5. Write synopsis and complete literature search related to topic and complete report.
6. Identify the idea and execute it in team.

Pattern 'D19'
Final Year BTech Chemical Engineering
Academic Year 2019-20

Table of Contents

Module VII Final Year B. Tech Chemical Engineering

FF: 653

Title : Course Structure   **Branch: Chemical Engineering**

Year: Final Year B. Tech. Academic Year: 2019-20 Semester: VII Module: VII   Pattern: D19

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme							Credits
			Theory	Lab	ISA				ESA		Total	
					HA	LAB	MSE	GD/PPT	ESE	VIVA		
1	CH4063	Plant Engineering and Project Economics	3	2	10	30	15	10	15	20	100	4
2	CH4067	Transport Phenomena	3	2	10	30	15	10	15	20	100	4
3	CH4065	Chemical Reaction Engineering	3	2	10	30	15	10	15	20	100	4
4	CH4093	Major Project I		8								4
		Total										16

OR   FF: 653

Module VIII Final Year B. Tech Chemical Engineering

Sr. No.	Subject Code	Subject Name	Teaching Scheme(Hrs/ Week)		Examination scheme						Total	Credits
			Theory	Lab	ISa		MSE	ESA				
					HA	Lab		ESE	VIVA			
1	CH4096	Industry Internship									100	16
2	CH4095	Research Internship										
3	CH4097	International Internship										
4	CH4071	Project Internship										

Abbreviations Used			
ISA	In Semester Assessment	MSE	Mid Semester Examination
HA	Home Assignment	ESE	End Semester Examination
ESA	End Semester Assessment	Lab	Laboratory

Module VIII Final Year B. Tech Chemical Engineering

FF: 653

Title : Course Structure   **Branch: Chemical Engineering**

Year: Final Year B. Tech. Academic Year: 2019-20 Semester: VII Module: VII   Pattern: D19

Sr. No.	Subject Code	Subject Name	Teaching Scheme (Hrs/Week)		Examination scheme							Credits
			Theory	Lab	ISA				ESA		Total	
					HA	LAB	MSE	GD/ PPT	ESE	VIVA		
1	CH4064	Environment al Pollution	3	2	10	30	15	10	15	20	100	4
2	CH4066	Food Technology	3	2	10	30	15	10	15	20	100	4
3	CH4068	Analytical Chemistry	3	2	10	30	15	10	15	20	100	4
4	CH4094	Major Project II		8								4
		Total										16

CH4063: PLANT ENGINEERING AND PROJECT ECONOMICS

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hr)**
Chemical Engineering Plant Design; General Overall Design Considerations, Practical Design Considerations, Basic engineering in process, thermodynamic and kinetic feasibility, process feasibility, capacity identification, and selection process specification equipment specification material selection, Engineering Flow Diagrams: BFD, PFD, and P & ID, Pilot Plant. Health and Safety Considerations; General Design Considerations: Health and Safety Hazards, Loss Prevention: Hazard Assessment Techniques: HAZOP, HAZAN, Fault Tree Analysis, etc. , Environmental Protection, Plant Location, Plant Layout, Plant Operation and Control, etc, Process Design Development: Development of design database, Process Creation, Process Design, Patent considerations Importance of laboratory development to pilot plant, scale up methods.
Chemical Plant Cost Estimation; Cash flow for industrial operations: Cumulative cash position, Factors Affecting Investment and Production Costs, Capital Investments: Fixed-Capital Investment, Working Capital, and Estimation of Capital Investment: Types of Capital Cost Estimates, Cost Factors in Capital Investment, Estimation of Total Product Cost: Manufacturing Costs, General Expenses. Estimation of various components of project cost as per recommended practice by India Financial Institutes, Plant & machinery estimate, Cost of Production. Cost Indexes

Section 2:   **(20 Hr)**
Project Financing and Profitability Analysis: Project Financing Greenfield projects, Add-on projects, ongoing business Interest & Investment Costs: Types of interest: simple interest, ordinary and exact simple interest, nominal and effective interest rates, compound interest, continuous interest. Loan repayment, Periodic payments, annualized cost, capitalized cost, Present worth and discount, annuities, costs due to interest on investment; Borrowed capital versus owned capital, source of capital, income-tax effects, design-engineering practice for interest and investment costs. Taxes and Insurance: Types of taxes: property taxes, excise taxes, income taxes. Insurance, types of insurance. Profitability, Project Evaluation: Break even analysis, incremental analysis, ratio analysis, discounted profit flow technique. Feasibility report, Annual report, alternative investments, and replacements. Depreciation: purpose of depreciation as a cost, types of depreciation, depletion, service value, salvage value, present value, depreciation in chemical project, methods for determining depreciation, appreciation of depreciation concept, depreciation rates, the depreciation schedule.

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. To do material balance of chemical plant.
2. To do energy balance of chemical plant.
3. To do plant layout of chemical plant.
4. To do HAZOP analysis of chemical plant.
5. To do fault tree analysis of chemical plant.
6. To determination costs of various equipments.
7. To estimate economic of chemical plant.
8. To estimate capitalized cost of chemical plant.
9. To determine profitability of chemical plant.
10. To determine depreciation of equipments.
11. To study MSDS of various chemical.
12. To do market survey of particular chemical.

List of Project areas:
Minimum 1 Project from list to be completed:

1. General Overall Design Considerations
2. Plant layout of a chemical plant
3. HAZOP analysis of a chemical plant
4. Fault tree analysis of a chemical plant
5. Fixed Capital investment of a chemical plant
6. Capital cost estimation of a chemical plant
7. Cost index of equipments
8. Types of interest, present worth
9. Annuity
10. Estimation of depreciation of equipments
11. Estimation of profitability
12. Market survey of a particular chemical.

Text Books:

1. Peters, M.S., Timmerhaus, K.D. "Plant design and economics for chemical engineers", 4th Edition, McGraw Hill, 1990.

Reference Books:

1. Mahajani V.V., Mokashi S. M. "Chemical Project Economics", Macmillan India Publication, 1st Edition, 2005
2. Bausbacher E. and Hunt R. "Process Plant Layout and Piping Design", 1st Edition, Prentice Hall Publication, 1993

Course Outcomes:

The student will be able to –
1. Describe & design a chemical plant
2. Do and describe health & safety analysis
3. Estimate & predict cost estimation of chemical plant
4. Estimate & describe different types of interest
5. Estimate & describe taxes, insurance, profit analysis
6. Describe and calculate depreciation

CH4067: TRANSPORT PHENOMENA

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:
Newton's law of viscosity, temperature and pressure dependence of viscosity for gasesand liquids.Basics of momentum transport, combined momentum flux. Equation of continuity, equation of motion. Shell momentum balances and boundary conditions. Shell momentum balances for flow of falling film, flow through circular tube, flow through annulus, flow of two adjacent immiscible fluids etc.Fourier law of energy transport. Dependence of thermal conductivity on temperature, pressure. Shell energy balances for heat conduction: Heat flux and temperature distribution for heat sources such as electrical, nuclear, viscous. Heat flux through composite walls.

Section2:
Fick's law of diffusion. Temperature and pressure dependence of diffusivity.
Shell mass balances for diffusion through stagnant film, diffusion with homogeneous and heterogeneous chemical reaction, diffusion and chemical reaction inside a porous catalyst etc.
Turbulent transport phenomena, Boundary layer theory. Macroscopic momentum, energy and mass balances. Use of macroscopic balances to solve steady state and unsteady state problems.

List of Lab experiments:
Minimum 6 experiments from the following list to be performed:

1. Shell momentum balances: Cartesian coordinate system
2. Shell momentum balances: Cylindrical coordinate system
3. Shell momentum balances: Spherical coordinate system
4. Shell energy balances: Cartesian coordinate system
5. Shell energy balances: Cylindrical coordinate system
6. Shell energy balances: Spherical coordinate system
7. Shell mass balances: Cartesian coordinate system
8. Shell mass balances: Cylindrical coordinate system
9. Shell mass balances: Spherical coordinate system
10. Dimensional analysis
11. Boundary layer theory.
12. Turbulent transport phenomena.

List of Project areas:
Minimum 1 Project from list to be completed:

1. Macroscopic momentum balances
2. Macroscopic energy balances
3. Macroscopic mass balances
4. Combined mass, energy, momentum macroscopic balances

5. Dimensional analysis ans scale up
6. Product design involving transport phenomena
7. Coordinate transformations – rectangular to cylindrical
8. Coordinate transformations – rectangular to spherical
9. Application of boundary layer theory.
10. Equations of motion – Cartesian coordinate – Application.
11. Equations of motion – Cylindrical coordinate – Application.
12. Equations of motion – Spherical coordinate – Application.

Text Books:

1. Bird R. B, Stewart W.E., Lightfoot E.W., 'Transport Phenomena', John Wiley, 2ndEd., 2000.
2. Brodkey R. S., Hershey H. C., 'Transport Phenomena', McGraw-Hill International Edition, 1988.

Reference Books:

1. Wilty J.R., Wilson R.W., Wicks C.W., 'Fundamentals of Momentum, Heat and Mass Trasport', 2nd Ed., John Wiley, New York, 1973.

Course Outcomes:
The student will be able to –
1. Solve shell momentum balance problems for simple systems
2. Solve shell energy balance problems for simple systems
3. Solve shell mass balance problems for simple system
4. Setup and solve macroscopic momentum balances for a given system
5. Setup general equations of continuity and motion
6. Carry out dimensional analysis and scale up exercise for complex systems

CH4065::CHEMICAL REACTION ENGINEERING

Credits: 4　　　　　　　**Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:　　　　　　　　　　　　　　　　　　**(20 Hr)**

Non-Ideal flow and Heterogeneous processes, catalysis and adsorption
Residence time distribution in vessels: E, F and C curve, and their relationship for closed vessels, conversion in reactors having non-ideal flow; models for non-ideal flow: Dispersion model, Tank in Series, model, Multi parameter model. Mixing of fluids, Self-mixing of single fluid. Dead Zone and Bypass model Two parameter models. Early and late mixing of fluid, mixing of two miscible fluids. Global rate of reaction, Types of Heterogeneous reactions Catalysis, The nature of catalytic reactions, Adsorption: Surface Chemistry and adsorption, adsorption isotherm, Rates of adsorption. Solid catalysts: Determination of Surface area, Void volume and solid density, Pore volume distribution, Theories of heterogeneous catalysis, Classification of catalysts, Catalyst preparation, Promoters and inhibitors, Catalyst deactivation (Poisoning). Mechanism of deactivation, Rate equation for deactivation, Regeneration of catalyst.

Section 2:　　　　　　　　　　　　　　　　　　**(20 Hr)**

Fluid-particle noncatalytic, catalytic and fluid-fluid non-catalytic reactions
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, Application of models to design problems. Various contacting patterns and their performance equations. 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. Introduction of fluid particle catalytic reactions, Rate equation, Pore diffusion controlling, Heat effects during reaction, Various types of catalytic reactors : Fixed bed reactor- construction, operation and design, Isothermal operation, Adiabatic operation, Fluidized bed reactor, Slurry reactor, Trickle bed reactor. Experimental methods for finding rates.

List of labs:
Minimum 6 experiments from the following list to be performed:

1. To calculate the mass-transfer coefficient (KSL) for physical and chemical dissolution and to calculate the enhancement factor for 'solid-liquid' systems
2. To calculate the mass-transfer coefficient for physical and chemical dissolution and to calculate the enhancement factor for 'liquid-liquid' systems
3. To study residence time distribution (RTD) in a CSTR and to find out peclet No.
4. To determine RTD of a packed bed reactor and to find out Peclet No.
5.   To study residence time distribution (RTD) in a plug flow reactor
6. Finding optimum residence time using polymaths for parallel Reactions
7. Finding conversion and rate of heterogeneous reactions.

8. Study reaction in heterogeneous and homogeneous manner
9. Study of a packed bed reactor it's performance
10. Study of a fluidized bed reactor and its performance
11. Case study of the solid catalyzed reaction mechanisms
12. Case study of three phase reactors

Project areas:
Minimum 1 Projects from list to be completed:

1. Synthesizing a rate law, mechanism and rate limiting step for heterogeneous reactions.
2. Design of fluid- fluid reactors
3. Design of fluid- particle reactors
4. Catalyst preparation, adsorption isotherms
5. Conversion prediction by segregation model
6. Conversion prediction by maximum mixedness model
7. Conversion prediction by dispersion model
8. Evaluate different moments of Non ideality
9. Design of a slurry reactor
10. Design of a trickle bed reactor
11. Conversion prediction by tank in series model
12. Conversion prediction by two parameter model

Text Books:

1. Levenspiel, O., 'Chemical Reaction Engineering', 3rd. edition, John Wiley& Sons, 2001.
2. Fogler, H. S., 'Elements of Chemical Reaction Engineering', 3rd Ed., PHI, 2002.

Reference Books:

1. Walas, S. M., 'Reaction Kinetics for Chemical Engineers', McGraw Hill, 1959.
2. Smith, J.M., 'Chemical Engineering Kinetics', 3rd ed., McGraw Hill, 1987.

Course Outcomes:
The student will be able to –

1. Distinguish between various RTD curves and predict the conversion from a non-ideal reactor using tracer information.
2. Calculate the global rate of heterogeneous catalytic reactions.
3. Determine the characteristics of solid catalyst like porosity, pore volume, etc.
4. Select model for fluid-particle reactions and calculate the rate of reactions.
5. Select model for fluid-fluid reactions and calculate the rate of reactions.
6. Design the various types of rectors depending on the different types of heterogeneous
   Catalytic and non-catalytic reactions.

CH4093: MAJOR PROJECT 1

Credits: 4   **Teaching Scheme: 0 (TH) + 08 (LAB) Hours / Week**

Contents:
This is the final stage in the project work. This stage will include comprehensive report on the work carried out at this stage, including experimental studies, analysis and/or verification of theoretical model, conclusions etc.

Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. A detailed literature survey is expected to be carried out as a part of this work. The group of students is required to choose the topic in consultation with the Guide.

A technical report is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

Text Books:
   1. B.A. Bhanvase, "Project Writing Manual" Chemical Engineering Department, VIT, Pune

Reference Books: Nil

Course Outcomes:
The student will be able to –
1. Apply Chemical Engineering knowledge.
2. Learn How to Work in Team.
3. Define a task (problem) and execute it.
4. Carry out research and development work.
5. Design equipments or process for chemical engineering plants.
6. Document findings or design in selected topic

CH4096: INDUSTRY INTERNSHIP

Credits: 16

Guidelines:

1. HOD to constitute a committee of four senior faculty members for Internship allocation.
2. Students need to maintain minimum attendance of 75% at the place of work and produce digital record duly signed by competent authority.
3. Total Internship period is minimum16 weeks or 4 months.
4. Internship undertaken is to be Industrial Internship.
5. Students need to submit monthly reports to Company and Institute.
6. Final presentation (CVV) would be conducted at the end of semester.
7. Distribution of credits and other guidelines are subject to change.

Course Outcomes:

The student will be able to –

1. Apply Chemical Engineering knowledge
2. Design equipments or process for chemical engineering plants or apply knowledge in core and multidisciplinary field though research and development.
3. Work effectively as member or leader in team.
4. Organize, comprehend and write technical report.
5. Follow ethics and professional standards of organization/industry.

CH4095: RESEARCH INTERNSHIP

Credits: 16

Guidelines:

1. HOD to constitute a committee of four senior faculty members for Internship allocation.
2. Students need to maintain minimum attendance of 75% at the place of work and produce digital record duly signed by competent authority.
3. Total Internship period is minimum 16 weeks or 4 months.
4. Internship undertaken is to be Research Internship.
5. Students need to submit monthly reports on Research Project.
6. Final presentation (CVV) would be conducted at the end of semester.
7. Distribution of credits and other guidelines are subject to change.

Course Outcomes:
The student will be able to –

1. Apply Chemical Engineering knowledge
2. Design equipments or process for chemical engineering plants or apply knowledge in core and multidisciplinary field though research and development.
3. Work effectively as member or leader in team.
4. Organize, comprehend and write technical report.
5. Follow ethics and professional standards of organization/industry.

CH4097: INTERNATIONAL INTERNSHIP

Credits: 16

Guidelines:

1. HOD to constitute a committee of four senior faculty members for Internship allocation.
2. Students need to maintain minimum attendance of 75% at the place of work and produce digital record duly signed by competent authority.
3. Total Internship period is approximately 16 weeks or 4 months.
4. Internship undertaken to be taken outside India as Industrial Internship or Research Internship.
5. Students need to submit monthly reports on Industry Project/Research Project.
6. Final presentation (CVV) would be conducted at the end of semester.
7. Distribution of credits and other guidelines are subject to change.

Course Outcomes:

The student will be able to –

1. Apply Chemical Engineering knowledge
2. Design equipments or process for chemical engineering plantsor apply knowledge in core and multidisciplinary fieldthough research and development.
3. Work effectively as member or leader in team.
4. Organize, comprehend and write technical report.
5. Follow ethics and professional standards of organization/industry.

CH4071: PROJECT INTERNSHIP

Credits: 16

Guidelines:

1. HOD to constitute a committee of four senior faculty members for Internship allocation.
2. Students need to maintain minimum attendance of 75% at the place of work and produce digital record duly signed by competent authority.
3. Total Internship period is minimum 16 weeks or 4 months.
4. Internship undertaken is to be Project Internship.
5. Students need to submit monthly project report.
6. Final presentation (CVV) would be conducted at the end of semester.
7. Distribution of credits and other guidelines are subject to change.

Course Outcomes:
The student will be able to –
1. Apply Chemical Engineering knowledge
2. Design equipments or process for chemical engineering plantsor apply knowledge in core and multidisciplinary fieldthough research and development.
3. Work effectively as member or leader in team.
4. Organize, comprehend and write technical report.
5. Follow ethics and professional standards of organization/industry.

CH4064: ENVIRONMENTAL POLLUTION

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:
Introduction
An overview of environmental engineering, pollution of air, water and soil, impact of population growth on environment, impact of development on the environment, chemical pollution, solid wastes, prevention and control of environmental pollution.
Air Pollution- Sources, Effects and Measurement
Sources scales of concentration and classification of air pollutants. Effects of air pollutants on human health, plants, animals, materials, measurement of air pollutants, particulate pollution: cleaning methods, collection efficiency, particulate collection systems.
Water Pollution
Domestic and industrial wastewater, types, sources and effects of water pollutants. Waste water characteristics–DO, BOD, COD, TOC, total suspended solids, colour and odour, bacteriological quality, oxygen deficit, determination of BOD constants.

Section 2:
Waste Water Treatment
Primary and secondary treatment, design and basic operating principles of activated sludge process, sludge treatment and disposal, trickling filter. Advanced methods of waste water treatment, UASB, photo catalytic reactors, wet-air oxidation. Tertiary treatment methods
Solid Waste Management
Sources and classification of solid wastes, disposal methods, incineration, composting, recovery and recycling.
Regulations and Standards
Laws and standards for water pollution, air pollution, land pollution.
.
List of Lab experiments:
Minimum 6 experiments from the following list to be performed:
1. Determination of acidity of various water samples.
2. Determination of the alkalinity of various water samples.
3. Determination of the chloride content in the given water samples.
4. Determination of the optimum coagulant dose for the removal of maximum turbidity
5. Determination of the hardness of the given water sample
6. Determination of the iron content of water samples
7. Determination of Dissolved oxygen of water
8. Determination of Biochemical oxygen demand (B.O.D.) of given Water / wastewater samples (BOD_5)
9. Determination of Chemical oxygen demand (COD) of given sample.
10. Determination of sulphate content of the given water sample
11. Industry visit
12. Literature survey on pollution control in process industries

List of Project areas:
Minimum 1 Project from list to be completed:

1. Municipal Solid waste management
2. Waste to Energy
3. Electronic waste management
4. Air pollution control-Removal of particulate matter
5. Air pollution control-Removal of SOx
6. Air pollution control-Removal of NOx
7. Water pollution control in Petroleum Industries
8. Water pollution control-Domestic sewage treatment
9. Water pollution control - Petroleum Industries
10. Water pollution control -Fertilizer Industries
11. Water pollution control -Sugar Industries
12. Removal of heavy metal from waste water

Text Books:
1. Kiely Gerard; Environmental Engineering; Special edition 2007., TataMcGraw-Hill International
2. Metcalf and Eddy; Wastewater Engineering,; 3rd edition., Tata McGraw Hill Publishers
3. Rao C.S; Environmental Pollution Control Engineerin;, 2nd edition., New Age International (P) Ltd
4 Sasikumar K.; Solid Waste Management; 1st edition2009, Prentice Hall India Learning Private Limited

Reference Books:
1. Flagan R.C. and Seinfield J.H; Fundamentals of Air Pollution Engineering; 1988., Prentice Hall
2. Crowford Martin; Air Pollution Control Theory; 1st edition. McGraw Hill Publishers

Course Outcomes:
The student will be able to –
1. Identify hazardous pollutants in the plant or area.
2. Design reduction method and pollution treatment technique.
3. Develop the analysis techniques for different pollutants.
4. To determine the pollution level with respect to the pollution standards.
5. Analyse the impact of various factors on the environment.

CH4066: FOOD TECHNOLOGY

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hr)**

Properties of liquid, solids and gases used in food processing, water activity, effect of processing on sensory, nutritional properties. Food safety, good manufacturing practices and quality assurance, Food processing scenario of India, Need of food processing in India, Raw material preparations, size reduction, mixing and forming, separation and concentration of food components, fermentation and enzyme technology, irradiation, processing using electric field, high hydrostatic pressure, light or ultrasound. Survey of fermented food, advantages and disadvantages of fermented food, Heat Processing using steam or water, pasteurization, heat sterilization, evaporation and distillation, extraction, dehydration, dielectric, ohmic and infrared heating , Baking, roasting and frying.

Section 2:   **(20 Hr)**

Chilling controlled or modified atmosphere storage and packaging, freezing, freeze drying and concentration. Ice cream manufacture flow-sheet and process, Coating or enrobing, packaging, filling and sealing of containers, material handling, storage and distribution, Advertising of food products, Coating or enrobing, packaging, filling and sealing of containers, material handling, storage and distribution, Advertising of food products.

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. Study of food testing
2. Study of effect on nutritional values of fruits and vegetables
3. Study of Indian industries in food processing
4. Study of food processing and sensory characteristics
5. Study of water activity
6. Study of food decay
7. Study of food preservation
8. Study of additives in food
9. Study of food storage methods
10. Study of physic-chemical property of food product
11. Study of raw material preparation methods
12. Study of packaging and sealing of food

List of Project areas:
Minimum 1 Projects from list to be completed:
  1. A project on food preservation techniques
  2. A project on food analysis
  3. A project on packaging of food product
  4. A project on marketing of food product
  5. A project on byproduct of food waste
  6. A project on evolution in food processing
  7. A project on advertising of food products
  8. A project on manufacturing process of Ice cream
  9. A project on use of enzyme technology
  10. A project on fermented food
  11. A project on heat processing of food
  12. A project on food storage

Text Books:

  1. Fellows P.; Food Processing Technology; 2nd Edition ; CRC Press New York.

Reference Books:

  1. Considine D.M.; Food and Food Production Encyclopedia; 2nd Edition; VNR New York.
  2. Singh N. P.; Fruit and Vegetable Preservation; 1st Edition, Oxford Book Company India.
  3. Simpson S. P., Straus M. C.; Post Harvesting Technology of Horticultural Crops; Oxford Book Company India.

Course Outcomes:

The student will be able to –

  1. Understand need of food preservation and processing and food properties.
  2. Understand and select ambient temperature operations for food preservation and processing.
  3. Understand and select high temperature operations for food preservation and processing.
  4. Understand and select low temperature operations for food preservation and processing.
  5. Know the post processing operations, principles and equipment involved and its importance.

CH4068: ANALYTICAL CHEMISTRY

Credits: 4   **Teaching Scheme: 03 (TH) + 02 (LAB) Hours / Week**

Section 1:   **(20 Hr)**

Introduction to Analytical Chemistry, Conductometric titrations – General concept and basis of conductometric titrations, apparatus and measurement of conductivity, Applications of direct conductometric measurements.Standard and formal potentials, types of electrodes. Direct potentiometry and potentiometric titrations, Amperometry & Polarography - Theory, apparatus, qualitative and quantitative applications of polarography to organic and inorganic systems. Amperometric titrations – Theory, apparatus, types of titration curves, Electrogravimetry & Coulometry - Theory. coulometers coulometric titrations, Electrogravimetry – Theory of electrogravimetry

Section 2:   **(20 Hr)**

Separation techniques - General aspects of separation techniques – Role of separation technique in analysis, Classification choice of separation method distribution processes Extraction – Distribution law and derivation, solvents and their choice, Solvent micro-extraction, GPC and UPLC, determination of molecular weights - weight average and number average, analytical and industrial applications. New development in chromatography – Plasma chromatography, super critical fluid chromatography, Ultra Performance Liquid Chromatography – Theory and Practice, Lab-on-a-chip – introduction, merits, limitations, applications vis-à-vis conventional techniques, Chemical microscopy –Electron microscopy – SEM, TEM, AFM - Principle, sample preparation,Reading & interpreting micrograph, Metallurgical microscopic examination, specimen preparation and examination, interpretation of micrographs, other analytical techniques for metallurgical examination

List of Practicals:
Minimum 6 experiments from the following list to be performed:

1. **1.** Preparation of samples for various analytical techniques
2. Study of outcomes of various analytical techniques
3. determination of cell constant, and testing various samples for its conductance
4. Conductometric titration of mixture of acids v/s alkali
5. Chromatographic separation of mixtures using classical techniques (TLC/Column)
6. Chromatographic separation of mixtures using non-classical techniques (HPLC)
7. Chromatographic separation of mixtures using non-classical techniques (GC)
8. Spectrophotometric determination of compounds from given samples
9. Simultaneous determination of two components

10. Extraction of analytes from given samples using sonication
11. Study of ultrasound assisted synthesis
12. Study of kinetics of organic & inorganic compound degradation using ultrasound
13. Conducting potentiometric titrations
14. Designing analytical tools
15. Interpretation of statistical data generated in various analytical techniques.

List of Project areas:
Minimum 1 Projects from list to be completed:

1. Conductometry
2. Spectrophotometry
3. Analytical method development
4. Material synthesis & characterization
5. Study of outcomes of analytical instruments
6. Classical methods of analysis

Text Books:

1. Willard, Merit Dean and Settle; Instrumental Methods of Analysis; IV, CBS Publishers and Distributors, 1986.
2. Kealey, Blackie; Experiments in Modern Analytical Chemistry; Chapman & Hall, 1986.

Reference Books:

 1. J.G. Dick; Analytical Chemistry; McGraw Hill Publishers, 1974.
2. D.A. Skoog; Principles of Instrumental Analysis; Saunders College Pub. Co, III Edn, 1985.

Course Outcomes:
The student will be able to –

1. Identify the technique to be employed for the characterization of a given sample
2. Develop suitable extraction technique for sample preparation
3. Calculate unknown concentration of the target analyte selectively in a given sample
4. Test the samples for the qualitative and quantitative analysis of the analytes
5. Develop methods for the separation and quantification of samples using chromatography
6. Develop analytical ability to solve problems in the analytical world.

CH4094: MAJOR PROJECT 2

Credits: 4   **Teaching Scheme: 0 (TH) + 08 (LAB) Hours / Week**

Contents:
This stage will include comprehensive report on literature survey, design and fabrication of experimental set up and/or development of model, relevant computer programs.

Students may undertake studies in application chemical engineering knowledge for manufacturing project, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. Topics of interdisciplinary nature may also be taken up. The group of students is required to choose the topic in consultation with the Guide.

A technical report is required to be submitted at the end of the term and a presentation made based on the same. Modern audio-visual techniques may be used at the time of presentation.

Text Books:
  1.   B.A. Bhanvase, "Project Writing Manual" Chemical Engineering Department, VIT, Pune

Reference Books: Nil

Course Outcomes:
The student will be able to –
1. Apply Chemical Engineering knowledge.
2. Learn How to Work in Team.
3. Design equipments or process for chemical engineering plants.
4. Carry out research and development work.
5. Apply oral and graphical communication in both technical and non-technical environments.
6. Apply written communication in both technical and non-technical environments.