GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170516
Semester – VII
Subject Name: Process Auxiliaries and utilities

Type of course: Open Elective

Rationale:

Process auxiliaries and utilities involve the understanding of designing the process plants or creating design layouts of plant. It also includes the fundamentals of chemical engineering viz. development of flow diagrams, importance of various design consideration, various utility systems, and key selection considerations during the development and design of any process. This subject is intended to familiarize students with the basics as well as advanced understanding of various process auxiliaries and utilities used in chemical plant and how they integrate with the process facilities and overall operation.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Contents	Total Hrs
1	Process Auxiliaries: Basic considerations and flow diagrams in chemical engineering plant design. Piping design: Selection of material, pipe sizes, working pressure, basic principles of piping design, piping drawings, pipe installations, overhead installations, Process steam piping, selection and determination of steam – pipe size, Piping insulation, application of piping insulation, weather proof and fire resisting pipe insulation jackets, piping fittings, pipe joints	07
2	Valves: Types of valves, selection criteria of valves for various systems. Pumps: Types of pumps, NPSH requirement, pump location, pump piping, pump piping support.	07
3	Process Utilities: Process Water: Sources of water, hard and soft water, Requisites of industrial water and its uses, Methods of water treatment, Chemical softening, Demineralization, Resins used for water softening, Water for boiler use, cooling purposes, cooling towers, drinking and process water treatment, reuse and conservation of water, waste water treatment and disposal.	06
4	Process heating systems using steam, hot oil, glycol and water, Steam generation and its application in chemical process plants, distribution and utilization, boilers, design of efficient steam heating systems, steam economy, condensate utilization, steam traps, their characteristics, selection and application, waste heat utilization. Process cooling systems, process drains-open and closed. Non-steam heating system: Thermic fluid heater, Down	06

	therm heater, Temperature range, Principle, construction & working.	
5	Air: Air compressors, Vacuum pumps, Air receivers, Distribution systems, Different types of ejectors, Air dryers	**06**
6	Compressors and Vacuum Pumps: Types of compressors and vacuum pumps and their performance characteristics, Methods of vacuum development and their limitations, materials handling under vacuum, lubrication and oil removal in compressors and pumps, instrument air.	**07**
7	Refrigeration and Chilling systems. Oil heating systems, Nitrogen systems, utilities energy consideration and utilities management issues.	**06**

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
07	21	21	07	14	--

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Steam generators and waste heat boilers for process and plant engineers, V Ganapathy, CRC Press, Taylor & Francis Group.
2. Process Utility Systems: Introduction to Design, Operation, and Maintenance, Jack Broughton, IChemE, UK
3. Plant design and Economics for Chemical Engineers, Max S Peters, Klaus D Timmerhaus, Ronald E West. Mc Graw Hill 5th Edition.
4. Process plant layout and piping design, Ed Bausbacher & Roger Hunt, PTR Prentice Hall, UK
5. Efficient Use of Steam, Oilver Lyle Prentice Hall 1963

Course Outcomes: After learning the course the students should be able to:

Sr. No.	CO statement	Marks % weightage
CO-1	To understand the importance of process auxiliaries and utilities in a	20

	chemical industry.	
CO-2	To acquire an overview of key selection considerations of plant utilities	35
CO-3	To understand how the utilities could be integrated with the process facilities and overall operation.	20
CO-4	To understand basic calculation involved in the steam generation, psychometric operation and refrigeration	25

List of Open Source Software/learning website:

- Students can refer to the video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets. Students can develop their own programs/spreadsheets for the solution of problems.
- MIT Open course lecture on Equipment design.
- Literature available for Process design of equipment in plant / industry.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170515
Semester – VII
Subject Name: Piping Design

Type of course: Open Elective

Prerequisite: The student should have basic understanding of fluid mechanics, engineering and mechanical properties associated with the material.

Rationale:
Piping design and engineering is a key area in various streams of engineering. Piping and accessories constitute over 25% of the total capital investment in the chemical process industry, petroleum and petrochemical industry, pharmaceutical industry, power plants, and so on. The present course is intended to familiarize undergraduate students about the fundamental design aspects of piping components and their applications in process industries.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	2	3	70	30	30	20	150

Content:

Sr. No.	Contents	Total Hrs
1	**Fundamentals of piping:** Classification of pipe, Codes and standards, Pipe Fabrication, vibration, its prevention and control in piping systems, Mechanical Properties of material, schedule number, Piping materials and selection	04
2	**Design calculations for piping:** Determination of pipe size, Calculation of pressure drop in pipe, Equivalent length of pipe line for fittings and valves, Energy losses in pipe line, Different types of pumps and their selection criteria, NPSHA & NPSHR, Power required by pump, Calculation of flow measurement in pipe line.	06
3	**Piping component and Flow through pipe line:** Types of Fitting, Different types of flange and gasket, their selection criteria and applications, Different types of valves, their selection criteria and applications, Determination of valve size, Steam separators and steam traps, Calculation of pressure drop for two phase flow through pipe line by using Lockhart and Martinelli correlations, Piping drainage and water hammer in process plant, Calculations for water hammer in pipe line.	07
4	**Mechanical design of piping:** Operating pressure and temperature, Design Pressure & Design Temperature for Piping Systems, Design equation for longitudinal, hoop and allowable stresses, Determinations of thickness required by steel pipe for withstanding	06

	internal and external pressure, Determinations of thickness required by jacketed steel pipe for withstanding external pressure.	
5	**Pipe supports and P & I diagram:** Functions of Supports and selection, Types of loads, Different types of piping support, Determination of support location, Maximum span between the supports suggested by ASME B 31.1, Thermal expansion in pipe line, Different types of expansion joints and their applications, Difference between a PFD and P&ID, Typical P&I diagrams for pumps, distillation column, Reactors and Shell and tube heat exchanger.	**07**

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
07	21	21	07	14	--

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Perry R.H., "Chemical Engineers' Handbook", McGraw-Hill, 2009.
2. Thakore S.B., Bhatt B.I., "Introduction to Process Engineering and Design", 2nd Edition, Tata McGraw Hill Publication, 2017.
3. Nayyar M.L., "Piping Handbook", 7th Edition, Tata McGraw Hill Publication, 2000.
4. Coulson J.M, Richardson J.F and Sinnott, R.K., "Coulson and Richardson's Chemical Engineering", Vol. 6, 4th Edition, Elesevier, New Delhi, 2006.
5. McCabe W.L, Smith J.C, Harriott P., "Unit Operations of Chemical Engineering", Mc Graw Hill Publication
6. Ludwig E., Chemical Process Equipment Design, 3rd Edition, Gulf Publications, 2002.
7. Kellogg, M. W Company., "Design of Piping Systems", Pullman Power Products, New York, 1976.

Course Outcomes: After learning the course the students should be able to:

Sr. No.	CO statement	Marks % weightage
CO-1	To understand the safety and practical engineering aspects of piping systems.	20
CO-2	To understand the design and principles used in piping system.	35
CO-3	To know the terminology, concepts, equipment, and process used piping network	20

CO-4	To get an idea of pipe support with other accessories and P& I diagram	25

List of Open Source Software/learning website:

- Students can refer to the video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets. Students can develop their own programs/spreadsheets for the solution of problems.
- MIT Open course lecture on Equipment design.
- Literature available for Process design of equipment in plant / industry.

Suggested List of Design Problems for practical/tutorials: (8 to 10 practicals are to be given)

- Prediction/Estimation of various physical properties such as density, viscosity, surface tension, specific heat, thermal conductivity etc.
- Finding suitable material of construction for handling various chemicals.
- Determination of pipe size and pressure drop for various fittings in the pipe line.
- Determination of Power required by centrifugal pump.
- Design of pipe flow measurement devices.
- Determination of valve size for pipe line.
- Determination of pressure drop for two phase flow through pipe line.
- Determination of water hammer in pipe line.
- Design of pipe subjected to internal and external pressure.
- Design of jacketed steel pipe under external pressure.
- Design of piping support.
- P&I diagrams for pumps, distillation column, Reactors, Shell and tube heat exchanger.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170514
Semester – VII
Subject Name: Mechanical Design of Process equipments

Type of course: Open Elective

Prerequisite: The student should have basic understanding of Unit Operations of Chemical Engineering and mechanical properties associated with the material.

Rationale:
Equipment design involves modifications and additions to existing plants or creating design layouts of plant/equipments. With rapid rate of increase in the advancement of knowledge, it is important that the students should know the relevant application for equipment design. It has been observed conclusively that practice in using the reference literature and software has helped the students to secure jobs and also to perform better in profession.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
2	0	2	3	70	30	30	20	150

Content:

Sr. No.	Contents	Total Hrs
1	**Introduction:** Design pressure and temperature, design and allowable stress, Static and rotary equipments, Different types of welding joints, joint efficiency and methods of fabrication of equipment, Radiography, Codes, standard and specification for pressure vessel, Mechanical properties of material.	04
2	**Design of Pressure vessel:** Mechanical design of shell and head subjected to internal and external pressure, Graphical & analytical method for shell and head subjected to external pressure, Shell design for external pressure with & without stiffening ring, Different types of Nozzles and design of reinforcement pad for nozzle by area for area method, Different types of flanges, flange facings, gaskets and their selection criteria, Design of bracket support.	08
3	**Design of Reaction Vessel:** Mechanical design of shell, head, Jacket, coil, agitator, nozzle, etc., Different types of agitators & their selection criteria, Determination of power required for agitation, shaft diameter, blade thickness, etc., Different types of jackets & their selection criteria, Selection between coil & jacket.	05

4	**Design of Storage Tank:** Types of storage tanks, Capacity of storage tank, its diameter & height, Design of fixed roof storage tank, Design of structural supported conical roof as per API 620, Vent sizing for atmospheric and low pressure tanks.	**05**
5	**Design of Shell & Tube Heat Exchangers**: Function of various parts of shell & tube heat exchanger, Mechanical design of Shell, tube, tube sheet, head, channel shell, etc. of shell & tube heat exchanger, Mechanical design of saddle support.	**04**
6	**Design of Distillation and Absorption Column:** Mechanical design of shell, head, tray support for Vertical tall tower, Determination of shell thicknesses at various heights for tray tower & packed tower in case of internal & external pressure, Different types of tray support, Mechanical design of skirt support.	**06**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
07	21	21	07	14	--

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Brownell L.E., Young E.H., "Process Equipment Design", Wiley Eastern, Delhi, 1977.
2. Thakore S.B., Shah D.A., "Illustrated Process Equipment Design", 4th Edition, Atul Prakashan, Ahmedabad, 2018.
3. Bhattacharyya B.C., "Introduction to Chemical Equipment Design: Mechanical Aspects", 5th Edition, CBS Publishers, New Delhi, 2008.
4. Perry R.H., "Chemical Engineers' Handbook", McGraw-Hill, 2009.
5. Joshi M.V., Mahajani V.V., "Process Equipment Design", 3rd Edition, MacMillan, Delhi, 1996.
6. Coulson J.M, Richardson J.F and Sinnott, R.K., "Coulson and Richardson's Chemical Engineering", Vol. 6, 4th Edition, Elesevier, New Delhi, 2006.
7. Dawande S.D., "Process Design of Equipments",Vol 1 & 2, Denett Publications, Nagpur, 2007.
8. Kern D.Q., "Process Heat Transfer", McGraw-Hill, New York, 1965.
9. Ludwig E., Chemical Process Equipment Design, 3rd Edition, Gulf Publications, 2002.

Course Outcomes: After learning the course the students should be able to:

Sr. No.	CO statement	Marks % weightage
CO-1	Design process equipment and modify the design of existing equipment to new process conditions or new required capacity.	20
CO-2	Build a bridge between theoretical and practical concepts used for designing the equipment in any process industry.	35
CO-3	Create understanding of equipment design with mechanical concept.	20
CO-4	Review the importance of design concepts in process industry.	25

List of Open Source Software/learning website:

- Students can refer to the video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets. Students can develop their own programs/spreadsheets for the solution of problems.
- MIT Open course lecture on Equipment design.
- Literature available for Process design of equipment in plant / industry.

Suggested List of Design Problems for practical/tutorials: (8 to 10 practicals are to be given)

- Prediction/Estimation of various physical properties such as density, viscosity, surface tension, specific heat, thermal conductivity etc.
- Finding suitable material of construction for handling various chemicals.
- Design of shell for pressure vessel subjected to internal and external pressure.
- Design of heads for pressure vessel subjected to internal and external pressure.
- Design of nozzle for pressure vessel.
- Design of fixed roof and conical roof storage tank.
- Design of storage tank to store different acids and organic chemicals.
- Design of batch reaction vessel provided with agitator.
- Design of plain, channel and half coil jacket for reaction vessel.
- Design of shell and tube heat exchanger.
- Design of shell for distillation/absorption column under internal and external pressure.
- Design of tray support for the distillation column.
- Design of bracket and skirt support for vertical cylindrical vessel.
- Design of saddle support for horizontal cylindrical vessel.
- Sketches of equipment such as batch reaction vessel, tray column, packed tower, storage tank and shell and tube heat exchanger to be made in drawing sheet.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170513

Semester – VII

Subject Name: Process Modelling, Simulation and Optimization

Type of course: Professional Elective Course

Prerequisite: Basics kknowledge of unit operations, fundamental of process engineering, engineering mathematics and numerical computations.

Rationale: The Process Modelling, Simulation and Optimization of chemical engineering processes is a subject of major importance for the knowledge of transport processes; improved design process and its kinetics. The subject comprises of three parts: modelling, simulation and optimization. Modelling and simulation emphasize on the concept of modelling of chemical engineering processes, parameter estimations, decomposition of networks, application of numerical methods, data regression, convergence promotion, specific-purpose simulation, dynamic simulation, etc. Optimization includes the concept; i.e., how one develops mathematical statements for the objective function (usually economic model) to be minimized or maximized and the equality and inequality constraints (the process model) and selection of optimization technique, which is best suited to the problem characteristics.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**Introduction :** Definition of Modelling, Simulation and Optimization, importance of modelling for simulation and optimization, comparison of design and simulation, scope and applications of modelling, simulation and optimization	3
2	**Modelling Aspects:** Definition of model, process model, deterministic and stochastic process, physical and mathematical modelling, classification of models, process to build a model, degrees of freedom analysis for model, empirical model, selecting functions to fit empirical data, Black-box model	4
3	**Mathematical Modelling of Chemical Engineering Systems:** Introduction, uses of mathematical models, scope of coverage, principles of	3

	formulation, fundamental laws, continuity equations, energy equations, equation of motion, transport equation, equation of state, equilibrium, kinetics.	
4	**Examples of Mathematical Models of Chemical Engineering systems:** flow tank, mixing tank, two heated tanks, PFR, CSTR, series of isothermal constant-hold up CSTR, CSTR with variable holds up, gas-phase pressurized CSTR, non-isothermal CSTR, single-component vaporizer, batch reactor, reactor with mass transfer, ideal binary distillation column, batch distillation with holdup, Solvent Extraction, gas adsorption	**6**
5	**Chemical Process Plant Simulation :** Steady state vs dynamic simulation, lumped system-partitioning equation, tearing equation, simultaneous equation, modular approaches & equation solving approaches, decomposition of networks, partition and tearing applied to process flow sheeting, reachability matrix, selection of property perdition method for simulation, Introduction to Various Professional Simulators and Equation Solver Software	**5**
6	**Basic Concepts of Optimization:** Scope and hierarchy of optimization, examples of applications of optimization, the essential features of optimization problems, general procedure for solving optimization problems, obstacles to optimization, continuity of function, convexity and its applications, interpretation of the objective function in terms of its quadratic approximation, necessary and sufficient conditions for an extremum of an unconstrained function.	**4**
7	**Optimization of Unconstrained Functions:** One dimensional search numerical methods for optimizing a function of one variable, scanning and bracketing procedures, Newton and Quasi-Newton methods of unidimensional search, polynomial approximation methods, how one-dimensional search is applied in a multidimensional problem, evaluation of unidimensional search methods, methods using function values only : Simplex search, Hooke-Jeees and Powell's method; methods that use first derivatives : Newton's method, Marquardt's method, Quasi-Newton methods.	**6**
8	**Linear Programming (LP) and Applications**: Formulation of linear programming models, LP in standard form, principles of simplex method, applications	**5**
9	**Constrained Optimization :** Lagrange's multiplier, Kuhn-Tucker conditions, transformation methods : penalty function, constrained direct search method: complex method, Quadratic approximation methods	**4**
10	**Application of Optimizations:** Examples and case studies of optimization in chemical processes like optimizing recovery of waste heat, optimal shell and tube heat exchanger design, optimal design and operation of binary distillation column, chemical reactor design and operation, optimal location of coal-blending plant, optimization of Glycol-Ethylene Oxide process	**5**

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170513

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
5	10	25	15	10	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. B Wayne Bequette, Process Dynamics: Modeling, Analysis and Simulation, Prentice Hall International Inc.
2. B V Babu, Process Plant Simulations, Gulf Publications.
3. William L. Luyben, Process Modeling, Simulation and Control for Chemical Engineers, McGraw Hill International Editions.
4. R Turton, R C Bailie, W B Whiting and J A Shaeiwitz, Analysis, Synthesis and Design of Chemical Processes, Prentice Hall International In.
5. W D Seider, J D Seader and D R Lewin, Product and Process Design Principles-Synthesis, Analysis, and Evaluation, 2nd ed., John Wiley and Sons Inc.
6. W. F. Ramirez, Computational Methods for Process Simulation, Second Edition, Butterworth Heinemann.
7. Edger, Himmelblau, Lasdon, Optimization of Chemical Processes, McGraw-Hill International Edition.
8. Gordon S. G. Beveridge and Rober S. Schechter, Optimization: Theory and Practice, McGrawHill Book Company.
9. M C Joshi and K M Moudgalya, Optimization: Theory and Practice, Narosa Publishing
10. S. S. Rao, Engineering Optimization: Theory and Practice, Third Edition, Wiley Eastern Ltd.
11. A. Ravindran, K.M. Ragsdell and G.V. Reklaitis, Engineering Optimization: Methods and Applications, Second Edition, Wiley

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement	Marks % weightage
CO-1	Illustrate use of fundamental laws to develop model for Chemical engineering processes.	10

CO-2	Outline the scope of process optimization and its applications to chemical processes.	20
CO-3	Apply mathematical principles and techniques to solve the models for simulation.	20
CO-4	Analyse process plant simulation results using professional simulators.	25
CO-5	Formulate optimization problems and evaluate the solutions.	25

Suggested list of experiments to be performed (8 to 10 experiments are to be given)

Practical based on the syllabus topics to be planned. The list may include following experiments:

1. Familiarization to tools used for laboratory like Excel Spreadsheet, COCO/DWSIM (open source simulator and MATLAB/SCILAB (computation platform)
2. Solve single and multi-variable optimization problems in Excel Spreadsheet using solver
3. Solve Linear Programming problems in Excel Spreadsheet using solver
4. Estimate kinetic parameters of the reaction using batch reactor data
5. Plot ideal and non-ideal vapour liquid equilibrium (VLE) plots computing data using (i) ideal mixture assumption and (ii) using Van-Laar activity coefficient model
6. Determine composition of vapour and liquid streams in a flash distillation still using VLE data
7. Simulate continuous binary distillation column developing material and enthalpy balance in the column. Compute ideal number of places using optimal reflux ratio.
8. Simulate multicomponent distillation with reboiler and condenser.
9. Develop material and energy balance for adiabatic combustion of methane and simulate the effect of excess air on performance of combustion.
10. Develop simulation of shell and tube heat exchange and evaluate Rating / Design.
11. Develop design and optimization of single and multiple effect evaporator
12. Develop simulation of fed batch reactor to evaluate effect of initial volume and feed recipe on productivity and yield

List of Open Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Student can use DWSIM, COCO, ChemSep open source software for simulation study.
- Students can use Matlab, Scilab or GAMS software for the solution optimization problems.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170512
Semester – VII
Subject Name: Introduction to Computational Fluid Dynamics

Type of course: Professional Elective Course

Prerequisite: Fluid flow operation, Numerical methods in Chemical Engineering

Rationale: The course deals with the numerical solution of equations governing fluid flow in chemical engineering applications. In all these fields, one needs to deal extensively with fluid flow related phenomena and one needs to resolve flow-related features of the processes and equipment. Although the equations governing fluid flow have been formulated, it is only in recent years that these are being solved in the practical applications in which the flow occurs. The course deals with the basic techniques that enable the numerical solution of these equations.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs
1	**Introduction:** Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modeling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools.	5
2	**The Governing Equations of Fluid Dynamics:** Introduction, Models of the Flow, The Substantial Derivative (Time Rate of Change Following a Moving Fluid Element), The Divergence of the Velocity, The Continuity Equation, The Momentum Equation, The Energy Equation, Physical Boundary Conditions	10
3	**Mathematical Behavior of Partial Differential Equations:** Introduction, Classification of Quasi-Linear Partial Differential Equations, A General Method of Determining the Classification of Some Simple CFD Techniques: A Beginning Partial Differential Equations: The Eigenvalue Method, General Behavior of the Different Classes of Partial Differential Equations: Impact on Physical Computational Fluid Dynamics.	10

4	**Basic Aspects of Discretization:** Introduction, Introduction to Finite Differences, Difference Equations, Explicit and Implicit Approaches: Definitions and Contrasts, Errors and an Analysis of Stability	**08**
5	**Application of CFD in design:** practical applications and case study of reactor (PFR and CSTR) design, agitator design, coils and jacket design, design of insulation system, dryer design, furnace design, design of mass transfer contactors, thin-film evaporator, design and simulation of mixing, fluidized bed reactor and combustion chamber.	**12**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	**20**	**25**	**20**	**15**	**10**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Anderson J.D. (1995) Computational Fluid Dynamics: The Basics with Applications,McGraw-Hill, Inc.
2. .Ferziger J.H. & Peric M. (1999) Computational Methods for Fluid Dynamics, Springer, Berlin, Germany.
3. Hirsch C. (1988) Numerical Computation of Internal and External Flows, John Wiley & Sons, New York, USA.
4. Patankar S.V. (1980) Numerical Heat Transfer and Fluid Flow, Hemisphere, Washington D.C., USA.
5. Versteeg H.K. & Malalsekera W. (1995) An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Longman Scientific & Technical, Harlow, Essex, UK.

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement	Marks % weightage
CO-1	relate importance of CFD in design	15
CO-2	to implement numerical solutions for heat, mass and momentum transport equations	35
CO-3	evaluate discretization methods and solution methodology	20

CO-4	apply CFD simulation for design of equipments and operations	30

List of Open Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Student can take MIT Open course lecture on Computational Fluid Dynamics
- Students can use OpenFOAM (open source software) or ANSYS FLUENT or other CFD software.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170511
Semester – VII
Subject Name: Transport Phenomena

Type of course: Professional Elective Course

Prerequisite: Concepts of Fluid Flow Operations, Process Heat Transfer and Mass Transfer Operations.

Rationale: This course will highlight coupling between three transport phenomena with applications in various disciplines in engineering and science, and will demonstrate to the students the common mathematical structure of transport problems.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs
1.	**Introduction to Transport Phenomena:** Classification of Transport Processes, Conservation Laws, Vector and Tensor Calculus	3
2.	**Momentum Transport:** Newton's Law of Viscosity and viscosity estimation, Shell Momentum Balance, Application of Shell Momentum Balance for Flow of Falling Film, Flow Through Circular Pipe, Flow Through annulus, Flow Over Moving Plate, Flow of adjacent immiscible fluids, Equation of Changes: Continuity Equation, Equation Motion, Navier-Stokes Equation.	14
3.	**Steady State Heat Transport:** Fourier's Law of heat conduction and estimation of thermal conductivity, Shell Energy Balance, Applications of Shell Energy Balance for Heat Conduction with Electrical Source, Heat conduction with Nuclear heat source, Heat conduction Viscus heat source, Heat Conduction with Chemical Heat Source, Heat Conduction in a Cooling Fin, Forced Convection, The energy equation.	14
4.	**Mass Transport:** Fick's law of binary diffusion and estimation of diffusivity, Mass and Molar Concentrations, Mass Average and Molar Average Velocity, Mass and Molar Fluxes, Convective Mass and Molar Fluxes, Shell mass balance, Applications of Shell mass balance for Diffusion Through a Stagnant Gas Film, Diffusion with Heterogeneous Chemical Reaction, Diffusion With Homogeneous Chemical Reaction, Diffusion Into a Falling Liquid Film (Gas Absorption, Forced Convection Mass Transfer). The Equations of Continuity For a Multicomponent Mixture.	14

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170511

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
0	14	42	7	7	0

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. R. B. Bird, W. E. Stewart, E. N. Lightfoot. "Transport Phenomena", 2nd Edition, John Wiley & Sons (Asia) pvt. Ltd. 2002.
2. C. J. Geankoplis, "Transport Processes and Separation Process Principles", 4th Edition, PHI Learning Private Limited., New Delhi
3. W. J. Thomson, "Introduction to Transport Phenomena", Prentice Hall, 2000.

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

Sr. No.	CO statement	Marks % weightage
CO-1	Analyze transport equations using vector and tensor calculus.	10
CO-2	Estimate transport properties such as viscosity, conductivity and diffusivity.	10
CO-3	Solve transport problems using shell balance methods.	35
CO-4	Develop equation of changes from conservation laws for momentum, energy and mass transport.	25
CO-5	Compare the mechanisms of transport processes	20

List of Open Source Software/learning website:

- SWAYAM and NPTEL courses available on Transport Phenomena
- MIT Open course lecture on Transport Phenomena
- OpenFOAM, SimFlow etc. softwares

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170510
Semester – VII

Subject Name: Process Intensification

Type of course: Professional Elective Course

Prerequisite: Basics of heat transfer, mass transfer and reaction engineering

Rationale: Process intensification is the paths for development of more sustainable chemical processes. Process intensification leads to a substantially smaller, cleaner, safer, and more energy efficient technology. Process intensification concerns engineering methods and equipment only; development of a new chemical route or a change in composition of a catalyst is not covered under process intensification. Process intensification consists of the development of novel apparatuses and techniques to bring improvements in manufacturing and processing, substantially decreasing equipment size/production-capacity ratio, energy consumption, or waste production; ultimately resulting better sustainable technologies. Process intensifying equipment covers novel reactors, intensive mixers, and heat-transfer and mass-transfer devices. Process intensifying methods covers new or hybrid separations, integration of reactions and separations, heat exchange, phase transition and/or new process-control methods such as intentional unsteady-state operations.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs
1	**Introduction to process Intensification** History of Process Intensification, Definitions and Interpretations of Process Intensification, Fundamentals of Process Intensification – Principles, Approaches, Domains, and Scales, Techniques of Process Intensification (PI) Applications, The philosophy and opportunities of Process Intensification, Main benefits from process intensification, Process Intensifying Equipment, Process intensification toolbox, Techniques for PI application.	5
2	**Novel Reactors:** Introduction to spinning disc reactor, Rotor stator reactors: the STT reactor, Taylor–Couette reactor, Rotating packed-bed reactors, Oscillatory baffled reactors (OBRs), Micro-reactors (The catalytic plate reactor (CPR), HEX-reactors), Hydrodynamic	8

	Cavitation Reactors	
3	**Intensive mixers:** Introduction to special types of mixers, Ultrasound mixers, Mixing in intensified equipment, Chemical Processing in High-Gravity Fields Atomizer, Ultrasound Atomization, Nebulizers, High intensity inline mixers reactors; Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor stator mixers	**6**
4	**Structured Catalysts and Reactors:** Introduction to catalyst, Overview of structured reactors, Monolithic Catalysts and Reactors, Gauzes, Structured Packings, Foams, Three-Levels-of-Porosity (TLP) Reactors, Membrane-Enclosed Catalytic Reactor (MECR), Environmental Catalysis, Hydrodynamics and Mass Transfer in Monoliths	**7**
5	**Hybrid Separation :** Distillation – dividing wall columns, Short path distillation, Membrane distillation, Extractive distillation, Adsorptive distillation, Membrane absorption/stripping, Adsorptive membranes (membrane chromatography), Membrane extraction, Supercritical separation, Barriers and future prospects	**6**
6	**Integration of reaction and separation:** Heat Integrated Distillation Trains, Reactive distillation, Reactive extraction, Reactive absorption, Fundamentals of process modeling in integrated systems, Case studied such as Absorption of NOx, Coke Gas Purification, Methyl Acetate Synthesis, Synthesis of Methyl Tertiary Butyl Ether	**7**
7	**New Heat Exchangers:** Plate heat exchangers, Graphite plate heat exchangers, Spiral heat exchangers, Printed circuit heat exchangers, The Chart-flow heat exchanger, Flat tube-and-fin heat exchangers, Microchannel heat exchangers, Polymer film heat exchanger, Foam heat exchangers, Mesh heat exchangers, Selection of heat exchanger technology, Integrated heat exchangers in separation processes	**6**

Plasma

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
5	10	25	15	10	5

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170510

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Process Intensification Engineering for Efficiency, Sustainability and Flexibility by David Reay, Colin Ramshaw, Adam Harvey. Elsevier Science, 2013
2. Reengineering the Chemical Process Plants, Process Intensification by Stankiewicz, A., Moulijn, (Eds.), Marcel Dekker, 2003.
3. Process Intensification for Green Chemistry, Engineering Solutions for Sustainable Chemical Processing by Kamelia Boodhoo, Adam Harvey, Willey 2013

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement	Marks % weightage
CO-1	identify process intensification for the enhancement of chemical processes	15
CO-2	apply intensified reactors and/or separators in process industries	35
CO-3	analyze scale up issues in the process industries.	25
CO-4	solve process challenges using intensification technologies	25

List of Open Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Heat Exchanger Network synthesis, design and analysis can be performed in HINT open source software. Student can use DWSIM, COCO, ChemSep open source software also.
- Students can use recent research articles published in Chemical Engineering and Processing: Process Intensification, Elsevier.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170509
Semester – VII
Subject Name: Nanoscience and Technology

Type of course: Professional elective course

Prerequisite: None

Rationale:
To provide an idea on the fundamentals of nanotechnology with a approach towards the synthesis, characterization and applications of nanomaterials. Nanotechnology is a new and rapidly emerging branch. It is a field of research and originality related to creation of new materials and devices. Students will learn the concept of nanotechnology, different techniques for synthesizing nanomaterials, characterization of nanomaterials and its applications in different fields.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs	%weightage
1	**Introduction to Nanotechnology:** Introduction, definition, history, effects of nanoscience and nanotechnology in different fields.	03	**10**
2	**Properties of nanomaterials:** Size and shape and based properties, colour, melting point, density of states, band gap and magnetism.	07	**15**
3	**Nanoparticles synthesis:** Top down and bottom-up approach, colloids, emulsions, micelles, polymers, mechanical attrition and high energy ball milling.	07	**15**
4	**Nanomaterials characterization:** Scanning electron microscopy, Transmission electron microscopy, Fourier transform infrared spectroscopy, Energy dispersive spectroscopy, Atomic force microscopy, X-ray diffraction, Dynamic light scattering, UV-Vis spectrophotometer.	10	**20**
5	**Fabrication:** Lithography, chemical vapor deposition, physical vapor deposition, sol-gel synthesis, molecular self-assembly, crystal growth, epitaxy, etching, masking.	10	**20**
6	**Applications of nanotechnology in chemical industry:** Catalysis, fuel cells, drug delivery and diagnostics, coatings, nanocomposite polymers, fluid inks, dyes, block copolymers, dendrimers, carbon nanotubes applications.	08	**20**

Text Books:

1. Nanoscale materials in Chemistry, K.J. Klabunde, Wiley, 2001.
2. Introduction to Nanotechnology, C.P. Poole Jr. and F.J.Owens, Wiley, 2003.

3. Nanotechnology, M. A. Ratner and D. Ratner, Pearson, 2003.
4. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, C.N.R Rao, Achim Müller, A. K. Cheetham, Wiley, 2004.

References:

1. Hand book of Nanostructured Materials and Nanotechnology, H. Nalwa, Vol. 1 to 5, Academic Press, 1999.
2. Hand book of Nanotechnology, B. Bhusan, Springer, 2004.
3. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects, D. Schodek, P. Ferreira, M.F. Ashby, 2009.

Other references

List of Open Source Software/learning website: https://nptel.ac.in/courses/118/104/118104008/

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	**15**	**15**	**5**	**5**	**0**

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze, E: Evaluate, C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Course Outcomes:

Sr. No.	CO statement	Marks % weightage
CO-1	To understand the principles of nanotechnology	**10**
CO-2	To understand the properties of nanomaterials	**15**
CO-3	To gain the knowledge of nanoparticles synthesis by different methods	**15**
CO-4	To understand the characterization of nanomaterials by various techniques	**20**
CO-5	To acquire the knowledge on the nanotechnology fabrication methods	**20**
CO-6	To study the applications of nanotechnology in chemical industry:	**20**

List of Open Source Software/learning website: Students can refer to video lectures available on various websites including NPTEL.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170507
Semester – VII
Subject Name: Computer Aided Process Synthesis

Type of course:

Prerequisite: Basics of heat transfer, mass transfer and reaction engineering

Rationale: The design-synthesis activities focuses on the practical application of the fundamentals and integrates the considerations of numerous options to form a complete manufacturing system. The design engineer need to know the basics of fluids, heat transfer, separations, and reactor engineering for selection of the steps as individual operations and their integration to form an efficient process synthesis. Energy integration is the most important component of process synthesis for design optimization. Heat Integration, reactor network, separation trains, batch scheduling are the focus areas for effective process synthesis. The study of this course will help students to take their understanding of basic subjects to a new and higher level.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**The Design Process:** Objectives, Design Opportunities, Steps in Product Process Design, Environmental, Protection, Safety Considerations, Engineering Ethics, Role of Computers	3
2	**Reactor Design and Reactor Network Synthesis:** Objectives, Reactor Models, Reactor Design for complex configurations, Reactor Network Design using the Attainable Region	5
3	**Synthesis of Separation Trains:** Objectives, Introduction, Phase Separation of Reactor Effluent, Criteria for Selection of Separation Methods, Selection of Equipment, Sequencing of Ordinary Distillation for the Separation of Nearly Ideal Fluid Mixtures, Heuristics for Determining Favourable Sequences, Marginal Vapour Rate Method, Complex and thermally coupled distillation, Sequencing of Ordinary Distillation for the Separation of nearly Non-Ideal fluid mixtures	8

4	**Synthesis of Heat Exchanger Networks:** Objectives, Basic Heat Exchanger Network Synthesis (HENS), Minimum Utility Targets, Temperature Interval Method, Hohmann / Lochart Composite Curves (HCC), Grand Composite Curves (GCC), Pinch Design Approach to Inventing a Network, Networks for Maximum Energy Recovery, Minimum Number of Exchangers, Stream Splitting, Threshold and Optimum Approach Temperature, Derivation of Network Superstructures for Minimization of Annual Costs, Multiple Utility Design Problems	**16**
5	**Energy Integrated Distillation Processes:** Heat Integrated Distillation Trains, Impact of Pressure, Multi Effect Distillation, Heat Pumping, Vapour Recompression and Reboiler Flashing, Positioning of Heat Engines and Heat Pumps	**6**
6	**Design and Scheduling of Batch Processes:** Objectives, Introduction, Design of Batch Process Units, Design of Reactor-Separator Processes, Design of Single Product Processing Sequences, Design of Multi-Product Processing Sequencing	**7**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
5	10	25	15	10	5

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Lorens T. Biegler, E. Ignacio grossmann, Arthur W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall International.
2. Warren D. Seider, J. D. Seader, Daniel R. Lewin, Product and Process Design Principles: Synthesis, Analysis, and Evaluation, 2nd Edition, Wiley.
3. Robin Smith, Chemical Process: Design and Integration, Wiley.
4. James M. Douglas, Conceptual Design of Chemical Processes, McGraw Hill International, 1988.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170507

Course Outcomes:

After successful completion of the course, student will be able to

Sr. No.	CO statement	Marks % weightage
CO-1	identify minimum hot and cold utilities and develop heat exchanger networks using pinch design approach.	30
CO-2	develop reactor network synthesis using attainable region	10
CO-3	analyze various alternatives for heat integration of distillation columns	20
CO-4	design batch processes using cycle time for a single/multi product plants	15
CO-5	develop HENs using various tools	25

Suggested list of experiments to be performed (8 to 10 experiments are to be given)

Practical based on the syllabus topics to be planned. The list may include following experiments:

1. Minimum utility target and pinch point using temperature interval method
2. Minimum utility target and pinch point using HCC & GCC method in MS Excel
3. Minimum utility target and pinch point using HINT software
4. Minimum utility target and pinch point using LP in MS Excel
5. Minimum utility target and pinch point using LP in GAMS
6. Design of heat exchanger network using HINT Software
7. Application of GAMS to solve MILP model for HENS with minimum number of heat exchangers for minimum utility targets using expanded transhipment model
8. Attainable region for PFR & CSTR for Van De Vusse reaction system
9. Reactor network synthesis for manufacture of maleic anhydride
10. Design and scheduling of batch process
11. Sequencing of multiple distillation columns

List of Open Source Software/learning website:

- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets.
- Heat Exchanger Network synthesis, design and analysis can be performed in HINT open source software. Student can use spreadsheet software for most calculations. Students can develop their own programs/spreadsheets. Student can use DWSIM, COCO, ChemSep open source software also.
- Students can use Scilab/GAMS software for the solution of LP, NLP, MILP optimization problems

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170502
Semester – VII
Subject Name: Process Equipment Design

Type of course: Professional Core Course

Prerequisite: The student should have basic understanding of Unit Operations of Chemical Engineering.

Rationale: Equipment design involves determination of all linear dimensions of equipment like diameter, length, etc. It also includes determination of thickness and weight of different parts of equipment. Readymade software's are available for the design of equipments. However, to use these soft wares effectively and correctly fundamental knowledge of this subject is required. With rapid rate of increase in the advancement of knowledge, it is important that the students should know also about the latest development in the design of equipments. Students who like to work as Design Engineer, Process Engineer or as Process Development Engineer, knowledge of this subject is essential. It is also useful for Production Engineer working in process plant for trouble shooting of problem related to operation of equipment.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	2	5	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**Process design of Piping and Pumps:** Introduction, Process design of piping, $NPSH_A$ & $NPSH_R$, Power required by pump, Power required in Fan, Blower and adiabatic compressor, flow meters, Process design of Orifice meter, Rotameter etc	10
2	**Process design of Heat Exchangers:** Shell & Tube heat exchangers, Functions of various parts of shell & Tube Heat exchanger, General design method of shell & tube heat exchanger, Criteria of selection among Fixed Tube sheet, U Tube & Floating Head heat exchanger, Process design of without phase change heat exchanger, Process design of condenser, Criteria of selection for Horizontal and vertical condenser, Process design of Kettle type & Thermosyphon Reboilers and vaporizes, Tinker's flow model.	12

3	**Process design of Distillation Column:** Introduction, Criteria of selection, Selection of equipment for distillation, Distillation column design, Selection of key components for multi- component distillation, Determination of operating pressure for distillation column, Advantages & disadvantages of vacuum distillation, Determination of nos. of theoretical stages for binary distillation by McCabe Thiele method Determination of nos. of theoretical stages for multi-component distillation by Fenskey- Underwood-Gilliland's method, Selection of trays, Calculations for tower diameter & pressure drop of sieve tray tower, Checking of conditions for weeping, down comer flooding, liquid entrainment, etc, tray efficiency, Jet Flooding & down comer Flooding, Different types of weirs & down comers of tray tower, their selection criteria.	12
4	**Process design of Absorbers**: Introduction, Criteria for selection among different types of absorption equipment, Process Design of packed tower type absorber: Determination of actual amount of solvent, Selection of packing, Determination of tower diameter & pressure drop, Determination of *NtoG*, *HtoG* & height of packing, Process design & selection criteria of liquid distributors, redistributors & packing support, Process design of Spray chamber or spray tower type absorber, Venturi Scrubber.	12
5	**Mechanical design of Pressure Vessel:** Selection of material of construction, Concept of internal & external design pressure, design stress & design temperature, Different types of equipments, Static & rotary equipments, Different types of static equipments, Different types of welding joints, Joint efficiency, Radiography. Mechanical design of shell, head, Jacket, coil, agitator, nozzle, etc.,	14

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
0	**10**	**25**	**30**	**20**	**15**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Introduction to Process Engineering and Design by S B Thakore and B I Bhatt, McGraw Hill, 2nd Edition, 2015.
2. Ray Sinnott, Gavin Towler, Chemical Engineering Design - Principles, Practice and

Economics of Plant and Process Design, Butterworth - Heinemann, 2008.
3. Brownell and Young, Process Vessel Design, Wiley Eastern, 1977.
4. M. S. Peters and K. D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 4th ed., McGraw - Hill, New York, 1991.
5. Ludwig, E. E., Applied process design for chemical and petrochemical plants , volume 1,2 & 3, Third Edition, Butterworth- Heinemam,1997
6. TEMA Standards.
7. Don W. Green, Robert H. Perry, Perry's Chemical Engineers' Handbook, 8th Edn., McGraw -Hill, New York, 2008
8. James R. Couper, James R. Fair & W. Roy Penney, Chemical Process Equipment - Selection and Design, 2 ndEdn., Butterworth - Heinemann, 2010.

Course Outcomes:

After learning, the course the students should be able to:

Sr. No.	CO statement	Marks % weightage
CO-1	Design process equipment and modify the design of existing equipment to new process conditions or new required capacity.	30
CO-2	Build a bridge between theoretical and practical concepts used for designing the equipment in any process industry.	30
CO-3	Create understanding of equipment design.	20
CO-4	Review the importance of design concepts in process industry.	20

List of Experiments:

1. Prediction of Physical properties
2. Process design of shell and tube heat exchanger
3. Process design of packed tower type absorber
4. Process design of tray tower type distillation column
5. Process design of packed tower type distillation column
6. Mechanical design of pressure vessel

List of Open Source Software/learning website:

- Open source software like DWSIM, COCO, ChemSep can be used for property prediction and design.
- Students can refer to video lectures available on the websites including NPTEL lecture series.
- Students can refer to the CDs available with some reference books for the solution of problems using software/spreadsheets. Students can develop their own programs/spreadsheets for the solution of problems.
- MIT Open course lecture on Equipment design.
- Literature available for Process design of equipment in plant / industry.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170501
Semester – VII
Subject Name: Chemical Reactions Engineering II

Type of course: Professional core

Prerequisite:
Chemical reaction engineering- 1.

Rationale:
The course is intended to familiarize the students with concepts of gas-solid catalytic and non-catalytic reactors and gas-liquid reactors, concepts of catalysis kinetics and mechanistic aspects of catalysts, design and rating of catalytic reactors and design aspects of Gas-Liquid Reactors

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	Heterogeneous Reactions: Introduction: Rate steps involved in heterogeneous systems, Overall rate expression for linear and non linear process, contacting patterns for two-phase systems.	7
2	Fluid-Fluid systems: Rate equation, rate equation for straight mass transfer, kinetic regimes of mass transfer and chemical reaction, rate equation for mass transfer and chemical reactions, film conversion parameter, fluid-fluid reactor design.	7
3	Fluid-Particle systems: Fluid partial reaction kinetics, selection of a model, Shrinking Core Model for unchanging and changing size spherical partials, Diffusion through gas film and through ash layer controlling, Chemical reaction controlling, Shrinking core model, its limitations, Determination of rate controlling step.	7
4	Introduction to Catalysis, Catalysts, Physical properties of catalyst, surface area, void volume, solid density, pore volume distribution, Classification and preparation of catalyst, catalyst promoters. Catalyst inhibitors, Catalyst poisons, Nature and Mechanism of Catalytic reactions.	7
5	Solid-Catalyzed reactions: Kinetics: Adsorption isotherms and rates of adsorption and desorption. Kinetic regimes, rate equations for surface kinetics, Pore diffusion, determining rate controlling step, experimental methods for finding rates, product distribution in multiple reactions.	7

6	Catalytic reactions, introduction to LHHW (Langmuir-Hinshelwood-Hougen-Watson) kinetic model. Introduction to Catalytic Reactors: Packed bed catalytic reactors, fluidized bed reactors, trickle beds, slurry reactors. Design concepts, Mass transfer correlations for various reactors, Isothermal and non-isothermal interphase effectiveness factor	**10**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
14	26	23	7	0	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. H. Scott Fogler, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall of India Pvt. Ltd
2. Froment, G.B., and K.B. Bischoff, 1990, Chemical Reactor Analysis and Design, 2nd Ed., Wiley, New York
3. O. Levenspiel, Chemical Reaction Engineering, 3rd Edn, Wiley & Sons (1999).
4. Carberry, J.J., 1976, Chemical and Catalytic Reaction Engineering, McGraw-Hill, New York.

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

Sr. No.	CO statement	Marks % weightage
CO-1	To understand the nature and mechanism of catalytic reactions.	25
CO-2	To identify regions of mass transfer control and reaction rate control and calculate conversion	25
CO-3	To predict the rate controlling step for the fluid - particle reactions	25
CO-4	To develop conceptual framework for designing catalytic reactors.	25

List of Open Source Software/learning website:

Preparation of power-point slides, which include videos, animations, Pictures, graphics for better understanding theory – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus of Chemical Reaction engineering -1 is covered.

Suggested list of experiments to be performed (8 to 10 experiments are to be given)

The analysis will include various experiments with the objective of sample preparation, measurement of concentration, prediction of kinetics and modeling of kinetics data. Along with prediction of errors in experimentation and compare experimental data with models

1	Determination of properties of solids (pertaining to catalyst development and application)
2	Experiment on the Adsorption of oxalic acid (or any other suitable organic compound) on activated Carbon.
3	Study the effect of surface area on adsorption.
4	To conduct any experiment involving heterogeneous catalysis in the fixed bed reactor
5	Synthesize detailed reaction networks for catalytic reactions on solid catalyst surfaces, such as zeolites or TiO_2
6	Experiment on determining the mass transfer zone and an absorber's mass balance and efficiency
7	Experiment on predicting breakthrough curves in adsorption of any selected system with environmental application
8	Experiment on detection of the influencing factors contact time, temperature and mode of operation.
9	Experiment on fluidized bed catalytic reactor.
10	Kinetic modeling study of heterogeneously catalyzed chemical synthesis reactions.
11	Catalytic oxidation experiment to demonstrate the principles of i) reaction rate determination, ii) reactor design, iii) heterogeneous catalysis, etc

List of Open Source Software/learning website: Software:

Students can refer to video lectures available on the websites including NPTEL, Students can refer to the CDs which are available with some reference books for the solution of problems using software. Students can develop their own programs for the solutions of problems.

Open Ended Projects:

1. In the beginning of the academic term, faculties will have to allot their students at least one Open-ended Project / Study Report / Latest outcome in technology.
2. Literature survey including patents and research papers of fundamental process

- Design based small project **or**
- Study report based on latest scientific development or
- Technology study report/ modeling/ simulation/collection report **or**

- Computer based simulation/ web based application/ analysis presentations of basic concept field which may help them in chemical engineering.

3. These can be done in a group containing maximum **three** students in each.
4. Faculties should cultivate problem based project to enhance the basic mental and technical level of students.
5. Evaluation should be done on approach of the student on his/her efforts (not on completion) to study the design module of given task.

GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170001
Semester –VII
Subject Name: Summer Internship

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
0	0	4	2	0	0	80	20	100

The duration of internship will be two weeks. It will be after completion of 6th Semester and before the commencement of Semester VII.

Following five options can be opted by the students:

1. Offline internship in industry - Internship in industry subjected to permissions from Government and concern Industry subject to the conditions of following the SOP issued by Government and written consent of the student and parents. Student is supposed to produce joining letter and relieving letter once the internship is over in case of Offline internship in any industry.
2. Online internship in industry / other agencies
3. Seminar by student under mentorship of a faculty. The topic shall be as per UG Syllabus topics
4. Preparation of consolidated report on survey of materials used in the respective branch of the student. The work should include the study of catalogues, price list specifications, properties, usage notes and other technical details and drawings etc, Work shall be carried out under the guidance of faculty. A detailed report shall be submitted. It shall be done by only one student. It is to be completed individually.
5. A Mini Project- on some suitable topic related to respective branch. It can be small fabrication / experimental results/ simulations / Programmes/ application development etc depending on the branch of the student. Preferably a single student should do it.

Other guidelines:

- Student has to prepare detailed report and submit to his/her college. A copy of report can be kept in the departments for record.
- Each student must be assigned a faculty as a mentor from the college and an Industry expert as co-mentor.
- The evaluation of the work done by students will be carried out after 2 weeks by the internal and external examiner.
- External examiner will evaluate for 80 marks and internal examiner will evaluate for 20 marks.
- The presentation by student in the presence of all student is desirable.

Student should produce successful completion certificate in case of offline / online internship in industry.