GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
MASS TRANSFER OPERATION-II
SUBJECT CODE: 2160501
B.E. 6th SEMESTER

Type of course: Chemical Engineering

Prerequisite: Mass Transfer Operation-I

Rationale: The objective of this course is to apply the principles of mass transfer operations to specific applications, separation and/or purification processes. The goal is to provide students with the theoretical/analytical aspects to design mass transfer equipments and to deal with complex problems of separations.

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)	
					PA	ALA	ESE	OEP		
3	0	3	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Distillation:** Introduction, Vapor-liquid Equilibria, *P-x-y T-x-y* diagrams, concept of relative volatility and effect of P and T on equilibrium data, Ideal solutions, Raoult's Law as applied to distillation operations, Deviation from ideality, Minimum and maximum boiling azeotropic mixtures, Enthalpy-concentration diagrams. Flash distillation, steam distillation, simple distillation, continuous rectification, Binary systems, Batch fractionation etc., Determination of number of stages by Ponchon and Severit method and McCabe-Thiele method, Concept of minimum, total and optimum reflux ratio, Reboilers, Use of open steam, , Partial condensers, cold hot circulating reflux etc. Azeotropic Distillation, Extractive Distillation, Concept of Multicomponent distillation.	22	41
2	**Humidification Operations:** VLE and Enthalpy for pure substances, Saturated and unsaturated vapour-gas mixtures and related terminologies such as dry bulb temperature, dew point, wet bulb temperature, percentage & relative saturation, adiabatic saturation temperature, humid heat, humid volume etc. Psychometric chart & Psychometric relation for air-water system, adiabatic saturation curves, wet bulb temperature theory, Lewis relation, Adiabatic operation, cooling towers.	11	21
3	**Adsorption and Ion exchange:** Adsorption, Definition and industrial application, Types of adsorption, nature of commonly used adsorbents, Adsorption Equilibria, Single gases and vapors, Adsorption hysterises, Effect of temperature on adsorption, Heat of adsorption, Adsorption of solute from dilute liquid solution, Adsorption from concentrated solutions, Material balance and Freundlich's equation for single	11	20

	stage operation and multistage cross-current operation, counter current operation, Equipments for adsorption such as fluidized bed & Teeter beds, Moving bed & fixed bed unsteady state adsorbers, concept of adsorption wave. Ion-Exchange Principles, Applications, Equilibria and Rate of ion exchange		
4	**Drying:** Equilibrium relationship & hysteresis, various types of moisture in drying, Batch drying, rate of drying, time of drying, Cross-circulation drying, concept of *NoG* and *HoG*, Drying at low temperature, Freeze drying etc. Batch & continuous drying equipments-Tray dryer, Tunnel dryer, Rotary dryers, Spray dryers, Fluidized bed dryer, etc.	10	18

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
15	20	20	10	05	--

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. "Mass transfer operation" by R. E. Treybal, Mc-Graw Hill international, 3rd edition
2. "Mass Transfer" by Sherwood, Pigford & Wilke,Mc-Graw Hill international.
3. "ChemicalEngineering",Volume-2,byCoulson&Richardson, 4th edition
4. Perry's Chemical Engineers hand book, by Perry & Green, Mc-Graw.Hill international, 7th edition
5. Unit Operations of Chemical Engg. By W. L. Mc Cabe, J.C .Smith & Harriott, Mc-Graw Hill international, 6th edition

Course Outcome:

After learning the course the students should be able to:

1. To understand the designing of mass transfer equipments used in the chemical industries.
2. To utilize the technological methods in problem solving of mass transfer operations in industries.
3. To review the practical importance and relevance of mass transfer in chemical industry.
4. To understand the applications of different mass transfer processes.
5. To recognize the selection criteria for mass transfer process and equipments required by the industries.
6. To design various mass transfer equipments.

List of Experiments:

Minimum **5** practicals to be performed and remaining time should be allotted to open-ended projects/study reports/latest outcomes in technology study**:-**

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.
6. In the semester student should perform **minimum** 5 set of experiments and complete **<u>one small open ended dedicated project</u>** based on engineering applications. This project along with any performed experiment should be **<u>EVALUATED BY EXTERNAL EXAMINER.</u>**

<u>PRACTICALS (ANYFIVE):</u>

1	To study and verify the Freundlich's Adsorption Isotherm Adsorbing Oxalic Acid and Charcoal
2.	To study the Characteristics of Adsorption for Silica Gel
3.	To measure the vapor pressure of acetone and calculate latent heat of vaporization.
4.	To study the humidification operation and calculate all the terminology's used for air – water contact operation.
5.	To determine pressure drop data and values of mass transfer coefficient for various air and liquid velocities in a counter cooling tower.
6.	a. To Verify Rayleigh's Equation for Differential Distillation b. To plot Fraction of Charge of Distillates V/S Residue Compo.& temperature of distillations
7.	To verify the Equilibrium Relationship for n-Butanol Water System
8.	To verify Henry's Law for Steam Distillation.
9.	To find out the Critical Moisture Content of a given material & find out its equation for constant and filling rate period

Design based Problems (DP)/Open Ended Problem:

Students are free to select any area of science and technology based on chemical engineering applications to define Projects.

Some suggested projects are listed below:

- Separation of components by using simple distillation
- Separation of components by using steam distillation
- To carry out drying by using drying apparatus
- Removal/purification of components using adsorption
- Solving examples based on design of distillation column

Major Equipments:

Distillation column, Dryer, Steam distillation apparatus, Dryer, Adsorption column

List of Open Source Software/learning website:

1) Literature available in any laboratory manual of Mass Transfer Operation-II.
2) Mass Transfer Operations for the Practicing Engineer by Louis Theodore, Francesco Ricci, Wiley Publishers
3) NPTEL
4) Website: academia.edu for laboratory view based e-learning portal for virtual mass transfer operations laboratory

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
PROCESS EQUIPMENT DESIGN-I
SUBJECT CODE: 2160503
B.E. 6thSEMESTER

Type of course: Chemical Engineering

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

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
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
4	0	3	7	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	%Weightage
1	**Process design of piping, Fluid moving devices and Flow meters**: Introduction, Process design of piping, $NPSH_A$ &$NPSH_R$, Power required by pump, evaluation of Centrifugal pump performance when handling viscous liquids, Power required in Fan, Blower and adiabatic compressor, flow meters, Process design of Orifice meter, Rotameter etc	10	14
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, Air cooled heat exchangers and air heaters, plate heat exchangers, etc.	20	27
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	18	25

	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,		
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	17
5	**Process design of Extractor**: Industrial applications of liquid-liquid extraction, choice of solvent, Process design of counter current multistage extractor, Selection criteria among different types of extractor, Process design of mixer-settler type extractor & packed tower type extractor, Guidelines for the design of other types of extractors	12	17

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
7	**21**	**21**	**7**	**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. Ray Sinnott, Gavin Towler, Chemical Engineering Design - Principles, Practice and Economics of Plant and Process Design, Butterworth - Heinemann, 2008.
2. Introduction to Process Engineering and Design by S B Thakore and B I Bhatt, Tata McGraw Hill, 1st Edition, 2007.
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 Outcome:

After learning the course the students should be able to:

1. Design process equipment and modify the design of existing equipment to new process conditions or new required capacity.
2. Build a bridge between theoretical and practical concepts used for designing the equipment in any process industry.
3. Create understanding of equipment design.

4. Review the importance of design concepts in process industry.

List of Experiments:

1. Prediction of Physical properties
2. Estimation of various design parameters for various equipments.
3. Solution of various problem used in the designing of equipments.

Design based Problems (DP)/Open Ended Problem:

Students are free to select any area for designing of equipment based on Chemical engineering applications to define Projects. Some suggested projects are listed below:

- Carry out design of plate / packed type absorber.
- Calculation related to the designing of distillation & extraction column.
- Design of fluid moving machinery (viz. centrifugal pump).
- Project on piping design.
- Design Calculation related to heat exchange equipment and their performance criteria.

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. 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.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
POLLUTION CONTROL & SAFETY MANAGEMENT
SUBJECT CODE: 2160504
B.E. 6th SEMESTER

Type of course: Chemical Engineering

Prerequisite: Environmental Science

Rationale: The Course focuses on types of pollution, its effects and control methodology along with industrial law and acts. Safety management part includes engineering principles and methods required for safety in Industries. This course would educate students to identify and assess hazards in any stage of operation, to quantify and manage them as well.

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)	
					PA	ALA	ESE	OEP		
3	0	0	3	70	20	10	0	0	0	100

Content:

Sr. No.	Content	Total Hrs	% Weightage
A.	**Pollution Control**		
1	**Environmental Protection:** Concept of environment and ecology, various natural cycles in environment and ecology, effect of human activities on environment and ecology. Various types of environmental pollution in general and in chemical and allied industry in particular, sources and causes of environmental pollution, effect of pollution on environment, environmental impact assessment and Environment Impact Statement, methodologies for environmental pollution prevention (including process technology up gradation, development, Invention etc.), control, abatement and treatment and waste disposal. Rules, regulations, laws etc. regarding environmental protection, pollution prevention and control, waste disposal etc. Role of government, semi/quasi govt. and voluntary organizations. Current trends and topics	18	33
2	**Industrial Laws and Act:** Introduction to Industrial laws, Industries Factory act, Energy audit, Environment Audit, Trade union, Labour laws and acts. Industrial Electricity rules, Industrial Dispute Acts, Workmen compensation Act, ESIC Act, Payment and Wages act, Minimum Wages act, Payment of Bonus act, Recent trends and practices in Safe industrial practices	08	15
B.	**Safety Management:**		

1.	**Safety Management:** Development of safety movement, Need for safety 1. General Introduction Historical Background and Growth of Safety Science, Aims of Safety Science, Safety and the Organization, safety audit 2. Basic Concepts of Safety Science. Hazard, Risk, Nature of the accident process, Use of Engineering Fundamentals in safety science. 3. Risk Assessment & Hazard Identification Checklist procedure, Preliminary hazard analysis, What if analysis, Failure mode effect analysis, Hazard and operability (HAZOP) studies, Hazard analysis techniques: Fault tree analysis, Event tree analysis, General outline of DOW index, Risk estimation and management, Major hazard control	10	19
2.	4. Fault and Event Tree Analysis for Risk Prediction 5. Source Models Models of Accidental Release of Toxic/Flammable liquids and vapors, Models of flow of liquids and vapors through pipes. 6. Dispersion Models: Mathematical Models for prediction of Dispersion patterns for toxic/flammable materials released into atmosphere, various types of "plume" and "puff" models of dispersion. 7. Nature of fires and explosion Calculation of Blast damage due to over-pressure, prevention of fires and explosions. 8. Control of Major Chemical Hazards, Emergency Control and disaster planning, On-site and Off-site emergency preparedness. 9. Introduction to various personal protective equipments 10. Instruments for safety : Pressure safety valve, Rupture disc , Interlocks etc.	18	33

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	**20**	**10**	**05**	**05**	**--**

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. Frank P Lees, "Loss Prevention in Process Industries" Volume 1, 2 & 3
2. Industrial Organization and Economics by T.R. Banga & S.C. Sharma
3. "Chemical Process Safety, Fundamentals with Applications", Second Edition by Daniel A. Crowl & Joseph F. Louvar Published by Prentice Hall, Inc. ISBN 0-13-018176-5
4. Environment Engineering by Metcalf and Eddy
5. Environmental Pollution Control Engineering By C.S.Rao

Course Outcome:

After learning the course the students should be able to:

1. Know about types of pollution, its sources, effects and control methodology and thereby environmental protection.
2. Be aware of the Industrial Laws and Act.
3. Know about environmental impact assessment and EIS.
4. Discuss methodology for environmental audit and safety audit.
5. Be aware of the factors that can lead to an accident.
6. Learn different methods of hazard analysis and control of hazards.
7. Discuss source models, dispersion models, fires and fire prevention, explosions and explosion prevention, pressure relief systems, runaway reactions and risk analysis as they apply to chemical process safety, and be able to solve corresponding problems.
8. How to characterize different types of fire and explosions and its control

List of Tutorials:

Students can select any type of industry and learn an existing process used for waste water treatment and can suggest modifications in process to improve efficiency of treatment. Each group is expected to analyze the process of manufacturing of the specific chemical assigned to his/her group, with a special emphasis on safety issues. In addition, each group will be expected to give a power point presentation during last week of semester. The presenter will be selected randomly just prior to the presentation.

List of Open Source Software/learning website:

Softwares:

- PollutionTech - Air Pollution Control Software
- Safety Management Software, MSDS Software, CSafe, DR software's ChemGes, Periscope software, MAUS OHS Planning software (Occupational, Health & Safety Planner), CINTELLATE
- 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 softwares. Students can develop their own programs for the solutions of problems.
- Websites: www.safetyforlife.com.au, SmartOHS.com.au

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
CHEMICAL REACTION ENGINEERING – I
SUBJECT CODE: 2160506
B.E. 6th SEMESTER

Type of course: Chemical Engineering

Prerequisite: Basic knowledge of material and energy balances in chemical engineering applications, laws of thermodynamics.

Rationale: This subject introduces concepts of reaction rate, derivation of rate expressions from reaction mechanism, ideal reactor types, integral method of analysis, differential method of analysis, principles of chemical reactor analysis and design, experimental determination of rate equations, design of batch and continuous reactors, how to choose the most appropriate reactor for a given feed, optimization of selectivity in multiple reactions, consideration of temperature and pressure effects, etc.

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)	
					PA	ALA	ESE	OEP		
3	0	3	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Introduction to Reaction Engineering:** Classification of reactions, definitions of reactions rate, variables affecting reaction rate, speed of chemical reactions.	4	**7**
2	**Kinetics of homogenous reactions:** Simple reactor types, the rate equation, concentration dependent term of rate equation. Molecularity and order of reaction. Rate constant *k*, representation of an elementary and nonelementary reaction. Kinetic models for nonelementary reactions. Testing kinetic models. Temperature dependant term of rate equations from Arrhenius theory and comparison with collision and transition state theory. Activation energy and temperature dependency. Predictability of reaction rate from theory.	8	15
3	**Interpretation of Batch reactor data:** Constant volume batch reactor, analysis of total pressure data, Integral and differential methods of analysis of data for constant volume and variable volume cases. Temperature and reaction rate, search for a rate equation.	12	23
4	**Introduction to reactor design & Ideal reactors for single reaction:** Mass and energy balances around a volume element. Ideal batch reactor, steady-state mixed flow reactor, steady-state plug-flow reactor, holding and	8	15

	space time for flow reactors, space-time and space velocity. Introduction to semi batch reactor.		
5	**Design of reactor for single reactions:** Size comparison of single reactors, multiple reactor systems, recycle reactor and autocatalytic reactions.	4	7
6	**Design for parallel reactions:** Introduction to multiple reactions, qualitative and quantitative treatment of product distribution and of reactor size, the selectivity.	4	7
7	**Potpourri of multiple reactors:** Irreversible first order reactions in series. Quantitative treatment, for plug flow or batch reactor and mixed flow reactor, their performance characteristics, kinetic studies and design. First order followed by zero order reaction, zero order followed by first order reaction, successive irreversible reactions of different orders, reversible reactions, irreversible series-parallel reactions.	7	13
8	**Temperature and pressure effects:** Single Reactions: Calculations of heats of reaction and equilibrium constants from thermodynamics, equilibrium conversion, general graphical design procedure. Optimum temperature progression, Energy balances equations in adiabatic and non-adiabatic case. Exothermic reaction in mixed flow, Rules for choice of reactors and optimum operation of rectors. Multiple Reactions: Product distribution and temperature.	7	13

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	25	21	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. Octave Levenspiel, Chemical Reaction Engineering, 3rd Edition, Wiley-India Pvt. Ltd.
2. H. Scott Fogler, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall of India Pvt. Ltd
3. J.M. Smith, Chemical Engineering Kinetics, 2nd edition, McGraw-Hill.
4. L. D. Schmidt, the Engineering of Chemical Reactions, Oxford Press.

Course Outcome:

After learning the course the students should be able to:

- Build basic knowledge of classification of reactions.
- Understand kinetics of competing reactions and their influence on product yield and selectivity.

- Understand fundamentals of kinetics including definitions of rate and forms of rate expressions and relationships between moles, concentration, extent of reaction and conversion.
- Derive batch, CSTR, and PFR performance equations from general material balances.
- Do size and performance calculations on isothermal plug, mixed, and batch reactors for a homogeneous and heterogeneous reaction from given rate data or a rate expression.
- Develop skills to choose the right reactor among single, multiple, recycle reactors etc.
- Understand and apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation.

List of Experiments:

1	To determine the activation energy of the reaction between sodium thio-sulphate and HCl using Arrhenius Equation.
2	To determine order of reaction for the reaction between sodium thiosulphate and HCl
3	To measure the kinetics of a reaction between ethyl acetate and sodium hydroxide under condition of excess ethyl acetate at room temperature.
4	To determine the kinetics of the reaction between ethyl acetate and sodium hydroxide at room temperature by the integral method of analysis.
5	To determine the activation energy and frequency factor for reaction between ethyl acetate and sodium hydroxide at room temperature & at different temperature.
6	To determine the kinetics of the reaction between ethyl acetate and sodium hydroxide at room temperature by the differential method of analysis.
7	To determine the kinetics of the reaction between n- butyl acetate and sodium hydroxide at room temperature by the integral method of analysis.
8	To determine the kinetics of the reaction between n- butyl acetate and sodium hydroxide at room temperature by the differential method of analysis

Open Ended Projects:

Minimum **5** practicals to be performed and remaining time should be allotted to open-ended projects / study reports / latest outcomes in technology study **:-**

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.
6. In the semester student should perform **minimum** 5 set of experiments and complete **one small open ended dedicated project** based on engineering applications. This project along with any performed experiment should be **EVALUATED BY EXTERNAL EXAMINER.**

Open Ended Project Fields:

- Non working models of batch, plug and mixed flow reactors.
- Designing reactors for exemplary reactions.
- Analyzing reactor data for higher order reactions.
- Studies related to advancements in reaction kinetics.

List of Open Source Software/learning website:

- NPTEL lecture series
- Literature available on Chemical Reaction Engineering.
- MIT Open course lecture on Chemical Reaction Engineering.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
ADVANCED SEPARATION TECHNIQUES
SUBJECT CODE: 2160507
B.E. 6th SEMESTER

Type of course: Chemical Engineering.

Prerequisite: None.

Rationale: Separation techniques are integral unit operation in most of the modern chemical, pharmaceutical and other process plants. There are many standard and conventional separation techniques available in the market and these techniques are quite common and the relevant technologies as well as well developed and well studied. On the other hand, newer separation processes, like, membrane based techniques, chromatographic separation, super critical fluid extraction, etc., are gaining importance in modern days plants. The present course is designed to emphasize on these novel separation processes. The course is designed for an elective subject of final year undergraduate students.

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)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

L- Lectures; T- Tutorial/Teacher Guided Student Activity; P- Practical; C- Credit; ESE- End Semester Examination; PA- Progressive Assessment

Content:

Sr. No.	Topic	Teaching Hours	Weightage (%)
1.	**Super Critical Extraction** Working Principal, Advantage & Disadvantages of supercritical solvents over conventional liquid solvents, Advantage & Disadvantages of supercritical extraction over liquid- liquid extraction, Decaffeination, ROSE process, Commercial applications of supercritical extraction.	06	08
2.	**Short path Distillation:** Concept & working of short path Distillation Unit (SPDU), Difference between short path Distillation & molecular distillation, applications of SPDU.	06	08
3.	**Reactive & Catalytic Distillation:** Concept, Advantage & Disadvantages, BALE & KATMAX packingManufacturing of MTBE and ETBE and it's comparision with conventional techniques.	07	10

4.	**Pressure Swing Distillation:** Concept & Working, Advantage & Disadvantages of PSD over azeotropic and Extractive Distillation, Applications	04	6
5.	**Membrane separation technique:** Principles, mechanisms, cross flow, membrane materials and various membrane modules used in membrane separation processes, Classification, application & advantages of membrane separation processes.	08	11
6.	**Pressure Swing Adsorption:** Concept & Working, Advantages & Disadvantages of PSA over cryogenic distillation, four step PSA, six step PSA, Purification of hydrogen, oxygen, Nitrogen & other commercial applications of PSA.	07	10
7.	**Melt crystallization:** Concept, phase equilibrium, different techniques, commercial applications	06	8
8.	**Reverse Osmosis:** Concept of osmosis and reverse osmosis, different types of membrane modules and membrane material for R.O., Advantages and commercial applications of R.O.	06	9
9.	**Ultrafiltration and nano filtration:** Concept & working principal ultrafiltration Vs Conventional filtration, Ultrafiltration membranes and modules, Commercial applications of ultrafiltration and nano filtration.	08	10
10.	**Pervaporization:** Working principal, Advantages, Production of absolute alcohol and other commercial applications.	05	7
11.	**Membrane Reactor:** Concept & working, Various modules of membrane used for membrane reactor, Advantages & Disadvantages, applications under research	05	7
12.	**Membrane or Osmotic Distillation:** Working Principal, Various applications, etc.	04	6

Text Books:

1. "Membrane separation Processes" by Kaushik Nath, PHI pvt. Ltd., 2008
2. "Introduction to process Engineering & Design" by S.B. Thakore & B.I Bhatt, Tata McGraw-Hill Ltd.,2007

Reference Books:

1. Perry Chemical Engineers Handbook' 7th Edition by R.H Perry and D. Green.
2. Ullman's Encyclopedia of Industrial Chemistry.
3. "Encyclopedia of Chemical Engineering" by Kirk & Othmer.
4. "Natural Extracts using supercritical carbon dioxide" M. Mukhopadhyay

Suggested Specification table with Marks (Theory):

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

Course Outcome: After learning the course the students should be able:

1. To built advanced concepts of separation techniques used in chemical industries.
2. To understand the principles and functioning advanced separation techniques.
3. To utilize the advanced separation technique in problem solving where conventional techniques are not fruitful and require replacement.
4. To understand the applications of advanced separation techniques as per industrial requirement..
5. To recognize the selection criteria between advanced separation techniques and conventional separation techniques.

List of Experiments:

Minimum **5** practicals to be performed and remaining time should be allotted to open-ended projects/study reports/latest outcomes in technology study:-

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.

6. In the semester student should perform **minimum** 5 set of experiments and complete one small open ended dedicated project based on engineering applications. This project along with any performed experiment should be **EVALUATED BY EXTERNAL EXAMINER.**

List of Practicals:

1.	Perform separation techniques using reactive distillation.

2.	Perform separation using membrane modules.
3.	Perform separation techniques using supercritical extraction
4.	Preparation of membrane modules for reverse osmosis.
5.	Perform separation techniques using short path distillation.

Design based Problems (DP)/Open Ended Problem:

Open Ended projects in Advanced analytical techniques may include:

1. Review chart of application of advanced separation techniques in process industries.
2. Fabrication of reactive catayltic distillation unit.
3. Fabrication of short path distillation.
4. Fabrication and perfomance evaluation of different types of filtration membranes,
5. Fabrication of membrane module

List of Open Source Software/learning website:

- **S**tudents can refer to video lectures available on various websites including NPTEL.
- Students can refer to the CDs which are available with some reference books for the solutions of problems using softwares. Students can develop their own programs for the solutions using excel, Chemical and other simulation softwares.

ACTIVE LEARNING ASSIGNMENTS:

Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
BIOCHEMICAL ENGINEERING
SUBJECT CODE: 2160508
B.E. 6th SEMESTER

Type of course: Department Elective – I

Prerequisite: Basics of Mass Transfer Operations and Reaction Kinetics

Rationale: This subject is an integration of chemical engineering with biological systems. It deals with kinetics of biological reactions, designing of biological reactors and recovery mechanisms of biochemical products.

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)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

Course Contents:

Sr. No.	Topics	Teaching Hours	Weightage %
1	**Introduction to Biochemical Engineering** Historical background, interdisciplinary approach, Integrated bioprocess systems, Unit Operations in Bioprocess	5	7
2	**Microbial Growth Kinetics** Batch Culture, Continuous Culture – Multistage systems, Feedback systems, Fed Batch Culture – Variable volume, fixed volume, Cyclic. Applications.	15	21
3.	**Design of Fermentor** Introduction, Basic Functions, Body construction, Aeration and Agitation, Maintenance of aseptic conditions, Control of parameters, Valves and steam traps, Variants of fermentation vessels.	16	22
4.	**Aeration and Agitation** Introduction, Oxygen requirement in fermentations, Oxygen supply, Determination of K_{La} values, Fluid rheology, Factors affecting K_{La} values, Balance between oxygen demand and supply, Scale up and Scale down.	16	22
5.	**Basic Outline of fermentation process and purification of fermentation products** Introduction, Range of fermentation process, Components of fermentation process, Disruption of cells, precipitaiton, fitration, Centrifugation, Liquid Liquid Extraction, Chromatography, Membrane processes, Drying, Crystallization	20	28

Suggested Specification table with marks (Theory):

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

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.

Reference Books:

1. Principles of Fermentation Technology, by Whitaker, Peter F Stanbury, S. Hall and A. Whitaker, Publisher: Butterworth-Heinemann; 2nd edition.
2. Bioprocess Engineering Principles by Pauline Doran, Publisher: Elsevier Science & Technology Books.
3. Introduction to Biochemical Engineering by D. G. Rao, Tata McGraw-Hill Education, 2005.
4. Biochemical Engineering and Biotechnology by Ghasem D. Najafpour, Publisher: Elsevier Science & Technology Books**.**

Course Outcome:

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

- Develop a fundamental understanding interdisciplinary approach of bioprocess systems.
- Compare batch, fed batch and continuous systems.
- Understand different parts of bioreactor and its working.
- Evaluate different mass transfer operations used in biochemical industries.

List of Experiments:

1. Determination of Oxygen Transfer rate.
2. Determination of K_{La} value.
3. To obtain growth curve of bacteria under batch culture.
4. To obtain growth curve of bacteria under fed batch culture.
5. To carry out precipitation of protein.
6. To perform column chromatography.
7. To perform drying operation.
8. To perform crystallization operation.

Open Ended Problems:

Students are free to select any project related to Biochemical engineering based on its application in the field of Biotechnology. Some of the suggested projects are:

- To perform formulation of some bioproducts.

- To perform downstreaming of some bioproducts.

List of Open Source Software/learning website:

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. Students can develop their own flowsheets for demonstration of various fermentation processes and the downstreaming process.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.

GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (05)
BIOTECHNOLOGY
SUBJECT CODE: 2160509
B.E. 6th SEMESTER

Type of course: Department Elective – I

Prerequisite: Basics of Biology and Chemistry

Rationale: This subject is an integration of chemistry with biological systems. It deals with basic aspects of biological systems, their operations and their applications.

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)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

Sr. No.	Content	Total Hrs.	% Weightage
1	**Introduction to Biotechnology and rDNA technology.** Introduction, Old and New Biotechnology, an Interdisciplinary Activity, Scope and Importance, Commercial Potential, Biotechnology in India. Introduction to rDNA technology and genetic engineering, bastic techniques and tools. Applications of rDNA technology.	5	7
2	**Animal Biotechnology** Introduction, The Immune System, Monoclonal Antibodies and Cell Culture Products, In Vitro Fertilization and Embryo Transfer, Babies of a Specified Sex, Animal Cloning, Genome Maps, DNA Fingerprinting in Forensic Medicine	6	8
3	**Plant Biotechnology** Introduction, History of Tissue Culture Techniques, General Techniques and terminologies. Different culturing techniques, micropropogation, Somaclonal variation, Germplasm conservation.	5	7
4	**Biotechnology and Heath care** Introduction, Disease Prevention (Vaccines), Disease Diagnosis, Disease Treatment, Gene Therapy, Immunodeficiency's, Cancer 417, Forensic Medicine.	6	8
5	**General and Industrial Microbiology**	12	17

	Introduction, Historical Landmarks, Isolation and Screening of Microorganisms, Maintenance of Isolates/Strains, Inoculum Development, Sterilization, Strain Improvement, Process Development, Downstream Processing, In Situ Recovery of Products, Applications, Metabolite Production, Biotransformation, Recovery of Metals, Biocontrol Agents, Biofertilizers, Genetically Engineered Microbes (GEMS)		
6	**Enzyme Technology** Introduction, Historical, Coenzymes and Cofactors, Enzymes Vs. Catalysts, Enzymes Vs. Whole Cells, Production of Enzymes, Classification and Nomenclature, Chemical Energetics, Mechanism of Enzyme Action, Enzyme Kinetics, Nontraditional Enzymes, Immobilization of Enzymes, Uses of Enzymes in Solution, Uses of Immobilized Enzymes, Enzyme Reactors, Biosensors, Enzyme Engineering, Bi- and Poly –Functional Enzymes, Safety and Regulatory Aspect.	8	11%
7	**Foods and Beverages** Introduction, Fermented Foods, Cheese Production, Use of enzymes in Food Industry, Use of Lactase in Dairy Industry, Enzymes in fruit Juice and Brewing Industries, Microbial Biomass, Mushrooms, Single Cell Protein	7	10
8	**Fuel Biotechnology** Introduction, Useful Features of Biofuels, Undesirable Features of Biofuels, Areas for Future Research Focus, Energy Crops, Modes of Utilization of Biomass, Biogas, Bioethanol, Biobutanol, Biodiesel, Biohydrogen	5	7
9	**Environmental Biotechnology** Introduction, Wastes and Pollutants, Hazards from Wastes and Pollutants, Waste Treatment, Landfill, Aerobic Waste Water Treatment, Anaerobic Treatment of Waste Water, Biodegradation of Xanobiotic Compounds, Bioremediation, Water Quality	8	11
10	**Biosafety** Introduction, Historical 615, Definitions, Objectives of Safety Guidelines, Risk Assessment, Containment, Planned Introduction of Genetically Modified Organisms (GMOs) Biosafety during Industrial Production, Biosafety Guidelines in India.	5	7
11	**Intellectual Property Rights** Introduction, Intellectual Property, Protection of Intellectual Property Rights, Choice of IPR Protection, International Harmonization of Patent Laws, Protection of Biotechnological Inventions, Plant Breeder's Rights (PBR), Management of IPR, Benefits from IPR, Problems From IPR.	5	7

Suggested Specification table with marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	20	15	10	10	05

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.

List of Experiments:

1. To perform monochrome staining.
2. To perform callus culture
3. Screeing of potential micro organism
4. Sterilization techniques
5. Development of Inoculum
6. Production of bioethanol through fermentative method.
7. Production of biomass in laboratory
8. Basic techniques for waste water analysis.

Reference Books:

1. Basic Biotechnology by Colin Ratledge and Bjorn Kristiansen, Cambridge University Press, 3rd Edition.
2. Biotechnology by B. D. Singh, Kalyani Publisher.
3. Principles of Fermentation Technology, by Whitaker, Peter F Stanbury, S. Hall and A. Whitaker, Publisher: Butterworth-Heinemann; 2nd edition.
4. Plant Biotechnology by Dr. P. K. Gupta, Rastogi Publication.

Course Outcome:

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

1. Develop a fundamental understanding interdisciplinary approach of Biotechnology and Chemical Engineering.
2. Understand different branches of biotechnology and its applications in real field.

Open Ended Problems:

Students are free to select any project related to Biochemical engineering based on its application in the field of Biotechnology. Some of the suggested projects are:

1. To design downstreaming process using fundamentals of industrial biotechnology and chemical engineering.
2. To perform biodegredation of chemical compouns using combination of chemical and biological methods.

List of Open Source Software/learning website:

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. Students can develop their own flowsheets for demonstration of various fermentation processes and the downstreaming process.

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.