JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
B. TECH. CHEMICAL ENGINEERING (R – 13)
CE / ME / CSE / IT / CHE / PE / PCE / AE / AME / MET / MIN

I Year

I Semester		T	P	C	II Semester		T	P	C
1	English – I	3+1	--	3	1	English - II	3+1	--	3
2	Mathematics - I	3+1	--	3	2	Mathematics - II	3+1	--	3
3	Engineering Chemistry	3+1	--	3	3	Mathematics - III	3+1	--	3
4	Engineering Mechanics	3+1	--	3	4	Engineering Physics	3+1	--	3
5	Environmental Studies	3+1	--	3	5	Ethical & Moral Sciences	3+1	--	3
6	Computer Programming	3+1	--	3	6	Engineering Drawing	3+1	--	3
7	Engineering Chemistry Laboratory	--	3	2	7	English – Communication Skills Lab - II	--	3	2
8	English – Communication Skills Lab - I	--	3	2	8	Engineering Physics Laboratory	--	3	2
9	C Programming lab	--	3	2	9	Engineering Workshop & IT Workshop	--	3	2
				24					**24**

II Year

I Semester		T	P	C	II Semester		T	P	C
1	Complex Variables	3+1		3	1	Probability & Statistics	3+1		3
2	Elements of Mechanical Engineering	3+1		3	2	Momentum Transfer	3+1		3
3	Electrical & Electronics Engineering	3+1		3	3	Mechanical Unit Operations	3		3
4	Organic Chemistry	3+1		3	4	Chemical Engineering Thermodynamics-I	3+1		3
5	Chemical Process Calculations	3+1		3	5	Inorganic Chemical Technology	3		3
6	Physical Chemistry	3		3	6	Materials Science & Engineering	3		3
7	Basic Engineering (Mech +Elec) Lab		3	2	7	Momentum Transfer Lab		3	2
8	Physical & Organic Chemistry Lab		3	2	8	Mechanical Unit Operations Lab		3	2
				22					**22**

III Year

	I Semester	T	P	C		II Semester	T	P	C
1	Process Heat Transfer	3+1		3	1	Management Science	3+1		3
2	Organic Chemical Technology	3+1		3	2	Mass Transfer Operations – II	3+1		3
3	Chemical Engineering Thermodynamics-II	3+1		3	3	Process Dynamics & Control	3+1		3
4	Chemical Reaction Engineering – I	3+1		3	4	Process Engineering Economics	3+1		3
5	Mass Transfer Operations-I	3+1		3	5	Chemical Reaction Engineering-II	3+1		3
6	Process Instrumentation	3+1		3	6	IPR & Patents	2		2
7	Process Heat Transfer Lab		3	2	7	Process Dynamics & Control Lab		3	2
8	Mass Transfer Operations Lab-I		3	2	8	Chemical Reaction Engineering Lab		3	2
					9	Mass Transfer Operations Lab-II		3	2
				22					**23**

IV Year

	I Semester	T	P	C		II Semester	T	P	C
1	Transport Phenomena	3+1		3	1	Industrial Safety & Hazard Management	3+1		3
2	Chemical Engineering Plant Design	3+1		3	2	Elective-II ➢ Multicomponent Distillation ➢ Fluidization Engineering ➢ Corrosion & Its Control	3+1		3
3	Process Modelling & Simulation	3+1		3					
4	Biochemical Engineering	3+1		3					
5	Open Elective (For the Students of other Branches) ➢ Industrial Pollution Control Engineering ➢ Design and Analysis of Experiments ➢ Green Fuel Technologies	3+1		3	3	Elective-III ➢ Computational Fluid Dynamics ➢ Optimization of Chemical Processes ➢ Computational Methods in Chemical Engineering	3+1		3
6	Elective –I ➢ Advanced Separation Technology ➢ Nanotechnology ➢ Polymer Technology	3+1		3	4	Elective-IV ➢ Catalysis ➢ Pipeline Engineering ➢ Process Trouble Shooting	3+1		3
7	Process Equipment Design & Drawing (Using Autocad) Lab		3	2	5	Project Work			9
8	Simulation Lab		3	2					
				22					**21**

Total Credits: 48 + 44 + 45 + 43 = 180

R – 13: Chemical Engineering
2nd Year I – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – I Sem.

COMPLEX VARIBLES

UNIT - I
Functions of a complex variable:
Introduction -Continuity – Differentiability – Analyticity – Properties – Cauchy-Riemann equations in Cartesian and polar coordinates. Harmonic and conjugate harmonic functions – Milne – Thompson method
Applications: Potential between parallel plates, coaxial cylinders, potential in angular regions

Subject Category
ABET Learning Objectives a e
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - II
Elementary functions:
Exponential, trigonometric, hyperbolic functions and their properties – General power Z (c is complex), principal value.

Subject Category
ABET Learning Objectives a e
ABET internal assessments 1 6
JNTUK External Evaluation A B

UNIT - III
Complex integration:
Line integral – Cauchy's integral theorem – Cauchy's integral formula – Generalized integral formula -Liouville Theorem - Morera's Theorem
Applications: Circulation along closed curve, conservative fields

Subject Category
ABET Learning Objectives a e k
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - IV
Power series:
Radius of convergence – Taylor's series,-Maclaurin's series -Laurent series- Singular point – Isolated singular point – pole of order m – essential singularity.

Subject Category
ABET Learning Objectives a e
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - V
Residue theorem and applications
Residue- Residue theorem

Applications: Evaluation of integrals of the type (a) $\int_{-\infty}^{\infty} f(x)dx$

(b) $\int_{c}^{c+2\pi} f(cos\theta, sin\theta)d\theta$

(c) $\int_{-\infty}^{\infty} e^{imx} f(x)dx$

(d) Integrals by identation

Subject Category
ABET Learning Objectives a e
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - VI
Conformal mapping:
Transformation by exp z, ln z, z^2, z ^n (n positive integer), Sin z, cos z, z + a/z. Translation, rotation, inversion and bilinear transformation – fixed point – cross ratio – properties – invariance of circles
Application: Potential between Noncoaxial cylinders, Flow around a corner

Subject Category
ABET Learning Objectives a e k
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

Text Books:
1. Erwin Kreyszig, Advanced Engineering Mathematics, 9th Edition, Wiley 2011.
2. Michael Greenberg, Advanced Engineering Mathematics, International Edition, Pearson, 1998.
3. Grewal, B. S., Higher Engineering Mathematics, Khanna Publishers, 2012.

Reference Books:
1. John H. Mathews, Russell W. Howell, Complex Analysis for Mathematics and Engineering, 5th Edition, Jones and Bartlett Publishers, 2006.
2. Saff, E. B and A. D. Snider, Fundamentals of Complex Analysis, 3rd Edition, Pearson, 2003.
3. Dennis G. Zill and Patrick Shanahan, A First course in Complex Analysis with Application, Jones and Bartlett Publishers, 2011.

Subject Category	ABET Learning Objectives	ABET Internal Assessments	JNTUK External Evaluation	Remarks
Theory Design Analysis Algorithms Drawing Others	a) Apply knowledge of math, science, & engineering b) Design & conduct experiments, analyze & interpret data c) Design a system/process to meet desired needs within economic, social, political, ethical, health/safety, manufacturability, & sustainability constraints d) Function on multidisciplinary teams e) Identify, formulate, & solve engineering problems f) Understand professional & ethical responsibilities g) Communicate effectively h) Understand impact of engineering solutions in global, economic, environmental, & societal context i) Recognize need for & be able to engage in lifelong learning j) Know contemporary issues k) Use techniques, skills, modern tools for engineering practices	1. Objective tests 2. Essay questions tests 3. Peer tutoring based 4. Simulation based 5. Design oriented 6. Problem based 7. Experiential (project based) based 8. Lab work or field work based 9. Presentation based 10. Case Studies based 11. Role-play based 12. Portfolio based	A. Questions should have: B. Definitions, Principle of operation or philosophy of concept. C. Mathematical treatment, derivations, analysis, synthesis, numerical problems with inference. D. Design oriented problems E. Trouble shooting type of questions F. Applications related questions G. Brain storming questions	

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – I Sem.

ELEMENTS OF MECHANICAL ENGINEERING

Learning Objectives: The content of this course shall provide the student the basic concepts of various mechanical systems and exposes the student to a wide range of equipment and their utility in a practical situation. It shall provide the fundamental principles of materials, fuels, Steam, I. C. Engines, compressors, hydraulic machines and transmission systems that usually exist in any process plant.

UNIT –I:

Stresses and strains: kinds of – stress-strains, elasticity and plasticity, Hooks law, stress –strain diagrams, modules of elasticity, Poisson's ratio, linear and volumetric strain, relation between E, N, and K, bars of uniform strength, compound bars and temperature stresses.

UNIT– II:

Types of supports – loads – Shear force and bending moment for cantilever and simply supported beams without overhanging for all types of loads.

Theory of simple bending, simple bending formula, Distribution of Flexural and Shear stress in Beam section – Shear stress formula – Shear stress distribution for some standard sections

UNIT-III:

Thin cylindrical shells: stress in cylindrical shells due to internal pressures, circumferential stress, longitudinal stress, design of thin cylindrical shells, spherical shells, change in dimension of the shell due to internal pressure, change in volume of the shell due to internal pressure.

Thick Cylinders: Lame's equation- cylinders subjected to inside and outside pressures columns and Struts.

UNIT-IV:

Steam boilers and Reciprocating air compressors: Classification of boilers, essentialities of boilers, selection of different types of boilers, study of boilers, boiler mountings and accessories.

Reciprocating air compressors: uses of compressed air, work done in single stage and two-stage compression, inter cooling and simple problems.

UNIT-V:

Internal combustion engines: classification of IC engines, basic engine components and nomenclature, working principle of engines, Four strokes and two stroke petrol and diesel engines, comparison of CI and SI engines, comparison of four stroke and two stroke engines, simple problems such as indicated power, brake power, friction power, specific fuel consumption, brake thermal efficiency, indicated thermal efficiency and mechanical efficiency.

UNIT-VI:

Transmission systems:

Belts –Ropes and chain: belt and rope drives, velocity ratio, slip, length of belt , open belt and cross belt drives, ratio of friction tensions, centrifugal tension in a belt, power transmitted by belts and ropes, initial tensions in the belt, simple problems.

Gear trains: classification of gears, gear trains velocity ratio, simple, compound –reverted and epicyclic gear trains.

Outcomes:

After completing the course, the student shall be able to determine:

- The stress/strain of a mechanical component subjected to loading.
- The performance of components like Boiler, I.C.Engine, compressor, steam/hydraulic turbine, belt, rope and gear.
- The type of mechanical component suitable for the required power transmission.

Text Books:

1. Strength of Materials and Mechanics of Structures", B.C.Punmia, Standard Publications and distributions, 9 th edition, 1991
2. Thermal Engineering, Ballaney,P.L., Khanna Publishers, 2003
3. Elements of Mechanical Engineering, A.R.Asrani, S.M.Bhatt and P.K.Shah, B.S. Publs.
4. Elements of Mechanical Engineering, M.L.Mathur, F.S.Metha & R.P.Tiwari Jain Brothers Publs., 2009.

Reference Book:

1. Theory of Machines, S.S. Rattan, Tata McGraw Hil , 2004 & 2009.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
II Year B. Tech. Chemical Engineering – I Sem.

ELECTRICAL & ELECTRONICS ENGINEERING

Learning Objectives: This is a basic course designed to make the student

- learn the basic principles of electrical laws and analysis of networks.
- understand the principle of operation and construction details of DC machines.
- understand the principle of operation and construction details of transformer.
- understand the principle of operation and construction details of alternator and 3-Phase induction motor.
- study the operation of PN junction diode, half wave, full wave rectifiers and OP-AMPs.
- learn the operation of PNP and NPN transistors and various amplifiers.

UNIT - I

Electrical Circuits: Basic definitions, Types of network elements, Ohm's Law, Kirchhoff's Laws, inductive networks, capacitive networks, series, parallel circuits and star-delta and delta-star transformations.

UNIT - II

Dc Machines: Principle of operation of DC generator – emf equation - types – DC motor types – torque equation – applications – three point starter, swinburn's Test, speed control methods.

UNIT - III

Transformers: Principle of operation of single phase transformers – emf equation – losses – efficiency and regulation

UNIT - IV

Ac Machines: Principle of operation of alternators – regulation by synchronous impedance method –principle of operation of 3-Phase induction motor – slip – torque characteristics - efficiency – applications.

UNIT V

Rectifiers & Linear Ics: PN junction diodes, diode applications (Half wave and bridge rectifiers). Characteristics of operation amplifiers (OP-AMP) - Application of OP-AMPs (inverting, non inverting, integrator and differentiator).

UNIT VI

TRANSISTORS: PNP and NPN junction transistor, transistor as an amplifier, single stage CE Amplifier, frequency response of CE amplifier, concepts of feedback amplifier.

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

- analyse the various electrical networks.
- understand the operation of DC generators,3-point starter and conduct the swinburn's Test.
- analyse the performance of transformer.

- explain the operation of 3-phase alternator and 3-phase induction motors.
- analyse the operation of half wave, full wave rectifiers and OP-AMPs.
- explain the single stage CE amplifier and concept of feedback amplifier.

Text Books:

1. Electronic Devices and Circuits, R.L. Boylestad and Louis Nashelsky, 9th Edition, PEI/PHI 2006.
2. Surinder Pal Bali, Electrical Technology: Vol – I Electrical Fundamentals & Vol – II Machines and Measurement, Pearson, 2013.
3. John Bird, Electrical Circuit Theory and Technology, 4th Edition, Elsevier, 2010.

Reference Books:

1. Naidu, M. and S. Kamakshaiah, Electrical Technology, Tata McGraw-Hill, 2006.
2. Rajendra Prasad, Fundamentals of Electrical Engineering, 2nd Edition, PHI Learning, 2009.
3. Nagasarkar, T. K. and M. S. Sukhya, Basic Electrical Engineering, 2nd Edition, Oxford Publications, 2009.
4. Mithal, G. K., Industrial Electronics, 9th Edition, Khanna Publishers, 2000.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B.Tech. Chemical. Engineering -II-Sem.

ORGANIC CHEMISTRY

Learning Objectives: The students will be imparted the knowledge of

- organic reactants, intermediates and their stability- effect of intermediates and steric inhibition on reaction rates and mechanism of the reaction.
- the step wise mechanism of reactions – different intermediates formed in the reactions - the reaction path way in the formation of products.
- reactions which are proceeding through free radical mechanism-effect of heat and light on these chemical reactions.
- the static and dynamic aspects of the three-dimensional shapes of molecules-a foundation for understanding structure and reactivity.
- coal-its constituents - aromatic compounds and their extraction methods - is important.
- synthesis and reactivity of heterocyclics- the recent trends in application of heterocyclic compounds in advanced chemical synthesis.
- the functional groups which that impart colour to the compounds-preparation and uses of these compounds.

UNIT-I
Polar effects – Inductive effect, Electromeric effect, Resonance, Hyper conjugation, Steric Inhibition of resonance – Examples.

UNIT-II
Mechanism and application of following organic reactions: a) Friedel-Craft reaction b) Riemer-Teimenn Reaction c) Beckmann rearrangement d) Aldol condensation e) Perkin Reaction f) Benzoin condensation.

UNIT-III
a) Halogenation of Alkane b) Addition of HBr to Alkene in the presence of peroxide c) Allylic halogenation using N-Bromo succinimide (NBS) d) Thermal halogenation of Alkanes.

UNIT-IV
Stereo isomerism; Optical isomerism; Symmetry and chirality; Optical isomerism in lactic acid and tartaric acid; Sequence rules; Enantiomers, Geometrical Isomerism; E-Z system of nomenclature, conformational analysis of ethane and cyclohexane.

UNIT-V
Sources of aromatic compounds: Aromatics from coal, carbonization of coal, coal gas manufacture and recovery of aromatics, fractional distillation of coal tar, methods of preparation of aromatics from petroleum products (catalytic reforming, high temperature cracking etc.,).

UNIT-VI
Heterocyclic compounds: Nomenclature, preparation, properties and uses of (1) Pyrrole (2) Furan (3) Thiophene (4) Pyridine (5) Quinoline (6) Iso-quinoline.

Dyes - Colour and Constituion; Classification of Dyes; Preparation and uses of (1) Malachite green (2) Rosaniline (3) Congored (4) Bismark brown (5) Fluoroscien.

Outcomes: After successful completion of the course, the students will

- have a basic knowledge of the factors that influence the stability and the reactivity of organic substances.
- be able to conduct a chemical reaction whether it is on lab scale or industrial scale with comlete understanding of its mechanism.
- be able to understand reactions taking place via free radical mechanism particularly in petroleum refining processes
- have knowledge of isomerism, particularly stereoisomerism and the complexity of organic molecules.
- have knowledge of aromatic compounds which are precursors for a number of industrial organic products like drugs, dyes etc.

Text Books:

1. Morrison, R. T., R. N. Boyd and Saibal, Kranti Bhattacharjee, Organic Chemistry, Pearson, 2011.
2. L. N. Ferguson, The Text of Organic Chemistry, 2nd Edition, East-West Press, 2009.

Reference Books:

1. Finar, I. L., Organic Chemistry, Vol 1, Pearsons, 2002.
2. Peter Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Edition, Pearson, 2003.
3. Bansal, R. K., A Textbook of Organic Chemistry, 5th Edition, New Age International, 2007.
4. Agarwal, O. P., Organic Chemistry Reactions and Reagents, 47th Edition, Krishna Prakashan Media (P) Ltd., 2011.
5. Arun Bahl and B. S. Bahl, Advanced Organic Chemistry, S. Chand Publishers, 2010.
6. H. M. Chawla and P. L. Soni, Textbook of Organic Chemistry, Sultan Chand & Sons, 2012.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering-I-Sem.

CHEMICAL PROCESS CALCULATIONS

Learning Objectives: The subject of chemical process calculations is intended to make the students understand mainly the calculations involved in material and energy balances of process units. The students will be trained to

- understand and correctly implement unit conversions in process calculations.
- understand and apply theoretical knowledge towards problem solving.
- analyze and solve elementary material balances in physical and chemical processes.
- analyze and solve elementary energy balances in reactive and non-reactive processes.
- formulate and solve combined material and energy balances.
- realize the relevance of thermodynamics in process calculations.
- carry out complex process calculations using MS Excel.

UNIT-I:
Stoichiometric relation: basis of calculations, methods of expressing compositions of mixtures and solutions, density and specific gravity, Baume and API gravity scales.

Behavior of Ideal gases: Kinetic theory of gases, application of ideal gas law, gaseous mixtures, gases in chemical reactions.

UNIT-II:
Vapor pressure: Liquefaction and liquid state, vaporization, boiling point, effect of temperature on vapor pressure, Antoine equation, vapor pressure plots, estimation of critical properties, vapor pressure of immiscible liquids and ideal solutions, Raoult's law, Non-volatile solutes.

UNIT-III:
Humidity and Saturation: Relative and percentage saturation or dew point, wet bulb and dry bulb temperature, use of humidity charts for engineering calculations.

UNIT-IV:
Material balances: Tie substance, Yield, conversion, processes involving chemical reactions.

Material balance calculation involving drying, dissolution and crystallization. Processes involving recycles, bypass and purge.

UNIT-V:
Thermophysics: Energy, energy balances, heat capacity of gases, liquid and mixture solutions. Kopp's rule, latent heats, heat of fusion and heat of vaporization, Trouton's rule, Kistyakowsky equation for non polar liquids enthalpy and its evaluation.

Thermochemistry: Calculation and applications of heat of reaction, combustion, formation and neutralization, Kirchoff's equation, enthalpy concentration change, calculation of theoretical and actual flame temperatures.

UNIT-VI:
Combustion Calculations: Introduction, fuels, calorific value of fuels, coal, liquid fuels, gaseous fuels, air requirement and flue gases, combustion calculations, incomplete combustion, material and energy balances, thermal efficiency calculations.

Out Comes: A student who successfully completes this course will be able to

- learn all background information/charts/datasheets required to carry out process calculations. Some of these are vapor pressure correlations, latent heat correlation, steam tables, psychrometric charts, enthalpy-concentration diagrams etc.,
- formulate and solve simple and moderately complex process calculations associated to industrially prominent chemical processes and technologies.
- conceptualize an integrated methodology that encompasses the knowledge in other subjects (Physical Chemistry, Thermodynamics and Mathematics) and MS Excel for a systematic and structured approach towards chemical process calculations.
- analyze chemical processes through the power of modeling and computation. These include back-calculation methods, inventory losses and revenue related assessment etc.

Text Book:

1. Hougen O A, Watson K.M. and Ragatz R.A., Chemical Process Principles, Part -I, Material and Energy Balances, 2nd Edition, CBS Publishers & distributors, New Delhi (2010).

Reference Books:

1. Basic Principles and Calculations in Chemical Engineering, D.H. Himmelblau, 7th Edition. PHI, New Delhi, 2009.
2. R. M. Felder and R. W. Roussear, Elementary principles of chemical processes, 3rd Ed., Wiley, 1999.
3. N. Chopey, Handbook Chemical Engineering Calculations, 3rd Edition, Mc-Graw Hill, 2004.
4. Bhatt, B. I., Thakore S. B., Stoichiometry, 5th Ed., Tata Mc-Graw Hill Education 2010.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – I-Sem.

PHYSICAL CHEMISTRY

Learning objectives:
The students will learn the basic concepts of distribution law, phase rule, chemical kinetics, solutions, spectro-photometry and separation techniques.

- The distribution law helps in understanding how a solute is distributed between two immiscible solvents; and also in selecting conditions for extraction of solutes (particularly naturally occurring products).
- Phase rule explains the equilibrium existing between the different phases of a heterogeneous system, solubility limits in a ternary system of water and two other liquids; construction of the solubility curve of the system; distribution ratio of the miscible component in the immiscible phases.
- Study of chemical kinetics explains the rates at which chemical reactions occur and also explains theories of reaction rates (Collision theory, Transition state theory) - rates of different chain reactions –Steady state approximation- these are important for chemical engineers to design equipment.
- The study of solutions is to understand the total vapor pressure of ideal or non-ideal mixtures of two volatile liquids as a function of chemical composition, miscibility of liquids, ideal and non ideal solutions – distillation methods– azeotropic mixtures.
- Study of fundamentals of spectroscopy gives an understanding of qualitative and quantitative analysis of substances (functional groups, ions, elements) and also helps in handling the spectrophotometers.
- The study of Chromatography is useful in quantitative and qualitative analysis of mixtures, and also to understand the mechanism by which components are separated on GC and HPLC techniques.

UNIT-I
Distribution Law: Distribution Law – Nernst Distribution Law – Distribution Coefficient – Explanation and Limitations of Distribution Law - Modification of Distribution Law – Determination of Equilibrium Constant from Distribution Coefficient – Applications of Distribution Law.

UNIT-II
Phase Rule: Phase Rule – Terms involved in Phase Rule – Types of Liquids – Derivation of Phase Rule – Phase Diagrams of One Component (Water and Sulphur system), Two Component System – Eutectic Point (Lead Silver System) and three component system. Applications of Phase Rule.

UNIT-III
Chemical Kinetics: Introduction to Chemical Kinetics – Theories of Reaction Rates – Collision Theory – Modified Collision Theory – Absolute Reaction Rate Theory (Transition State Theory) – Reaction between Ions – Influence of Solvent (Double Sphere Activated Complex and Single Sphere Activated Complex) – Influence of Ionic Strength on the Rate of the Reactions - Chain Reactions – Hydrogen and Bromine, Hydrogen and Oxygen (Steady State Treatment) – Explosion Limits.

UNIT-IV

Solutions: Liquid-liquid-ideal solutions, Raoult's law. Ideally dilute solutions, Henry's law. Non-ideal solutions, Vapor pressure - composition and vapor pressure-temperature curves. Azeotropes-HCl-H_2O, ethanol-water systems and fractional distillation. Partially miscible liquids-phenol-water, trimethylamine-water, nicotine-water systems effect of impurity on consulate temperature. Immiscible liquids and steam distillation.

UNIT-V

Spectrophotometry: General features of absorption-spectroscopy, Beer-Lambert's law and its limitations, transmittance, Absorbance, and molar absorptivity; Single and double beam spectrophotometers. Application of Beers-Lamberts law for quantitative analysis of

1) Chromium in $K_2Cr_2O_7$ 2) Mn in $MnSO_4$ 3) Iron (III) with thiocyanate.

UNIT-VI

Separation Techniques:

Solvent extraction: Principle and process, Batch extraction, Continuous extraction and counter current extraction, Application-Determination of Iron (III).

Chromatography: Classification of chromatography methods, Principles of differential migration Adsorption phenomenon, nature of adsorbents, solvent systems, R_f values, factors effecting R_f values.

High Performance Liquid Chromatography (HPLC): Principles and Applications.

Gas Liquid Chromatography (GLC): Principles and Applications.

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

- apply the principles of extraction to the industrial ternary systems.
- have an insight into the process of fractional distillation of petroleum, which is one of the major operations in petroleum refining.
- understand the various reactions that one comes across in petrochemical industry.
- use knowledge of solutions for the separations of liquid mixtures in industry and to develop the theoretical models for solutions.
- implement the analytical methods to determine the quality of substances involved in process industry and thus help to maintain quality of products.

Text Books

1. Laidler, K. J., Chemical Kinetics, 2nd Edition, McGraw-Hill, 1965.
2. Puri, B. R., L. R. Sharma, M. S. Pathama, Principles of Physical Chemistry, Vishal Publishing Company, 2008.
3. Castellan, G. W., Physical Chemistry, 3rd Edition, Narosa Publishing House, 2004.
4. Manas Chanda, Atomic Structure and the Chemical Bond, 4th Edition, Tata-McGraw-Hill, 2000.
5. Bahl, B. S., G. D. Tuli and Arun Bahl, Essentials of Physical Chemistry, 24th Revised Version, Chand & Co, 2000.
6. Kapoor, K. L., A Textbook of Physical Chemistry, Macmillan, 2000.

Reference Books

1. Peter Atkins, Julia de Paula, Physical Chemistry, 9th Edition, Oxford University Press, 2011.
2. John A. Dean, Chemical Separation Methods, Van Nostrand Reinhold, 1969.
3. Kour, H., An Introduction to Chromatography, Pragati Publishers, 2007.
4. Sastry, M. N., Separation Methods, Himalaya Publications, 3rd Edition, 2005.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech Chemical Engineering – I Sem.

BASIC ENGINEERING (Mech + Elec) LABORATORY

Any SIX experiments from each section

Section A: Mechanical Engineering Laboratory:

Learning Objectives:
To impart practical exposure on the performance evaluation methods of various mechanical components like, I. C. Engine, Hydraulic turbine, hydraulic pump, Air compressor etc. and also understand the various processes that can be performed on a lathe machine.

List of Experiments:

1. Draw the valve timing diagram of a 4-stroke diesel engine and port timing diagram of a 2-stroke petrol engine.
2. Perform load test on a 4-stroke C.I. Engine and draw the performance curves.
3. Pattern design and making – for one casting drawing.
4. Taper turning and thread cutting on a Lathe machine.
5. Performance on an Impulse/Reaction Hydraulic Turbine.
6. Performance of Centrifugal/Reciprocating Pump.
7. Find the volumetric efficiency, isothermal efficiency of an Air compressor.

Outcomes:
The student will be able to predict the performance of several mechanical components and operate a lathe machine to produce the required job work.

Section B: Electrical Engineering Laboratory:

Learning Objectives: This course course imparts knowledge to the students

- to learn the estimation of efficiency of a DC machine as motor & generator.
- to learn the estimation of efficiency of transformer at different load conditions & power factors.
- to study the performance of a 3-Phase induction motor by conducting direct test.
- to pre-determine the regulation of an alternator by Synchronous impedance method.
- to understand the speed control of a DC shunts motor.
- to study the performance of a DC shunts motor by conducting direct test.

The following experiments are required to be conducted as compulsory experiments:

1. Swinburne's test on D.C. Shunt machine. (Predetermination of efficiency of a given D.C. Shunt machine working as motor and generator).
2. OC and SC tests on single phase transformer (Predetermination of efficiency and regulation at given power factors)
3. Brake test on 3-phase Induction motor (Determination of performance characteristics)
4. Regulation of alternator by Synchronous impedance method.
5. Speed control of D.C. Shunt motor by
   a) Armature Voltage control b) Field flux control method
6. Brake test on D.C Shunt Motor

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

- estimate the efficiency of a DC machine as motor & generator.

- estimate the efficiency of transformer at different load conditions & power factors.
- understand the performance of a 3-Phase induction motor by conducting direct test.
- pre-determine the regulation of an alternator by Synchronous impedance method.
- control the speed of a DC shunt motor by Field flux control method & Armature Voltage control method.
- understand the performance characteristics of a DC shunt motor by conducting direct test.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – I-Sem.

PHYSICAL & ORGANIC CHEMISTRY LAB

Learning objectives:
Physical and Organic Chemistry Laboratory is intended to help promote understanding of concepts learned in theoretical physical chemistry and organic chemistry. Emphasis will be laid on acquisition of accurate data, data and error analysis and correlating the data to theory. The course will also help develop the student ability to prepare organic compounds independently.

List of Experiments- Physical Chemistry:
1. Determination of density and surface tension of liquids against air at various temperatures using capillary rise method
2. Measurement of Dialectic constants of pure organic liquids
3. Determination of conductance of solutions
4. i. Determination of viscosities of pure liquids and solutions
   ii. Determination of size of the molecule from viscosity measurements
5. Determination of Kinetics of the Reduction of Methylene Blue by Ascorbic Acid.
6. i. Determination of vapor pressure molecular of weight liquid
   ii. Determination of latent heat of vaporization
7. Kinetics of Inversion of using a Polarimeter
8. Determination of VLE of binary mixtures
9. Ternary Liquid Equilibria: Determination of Binomial curve

List of Experiments- Organic Chemistry:
1. Qualitative analysis of simple organic compounds using systematic procedure.
2. Preparation of Organic Medicinal Compounds: i. Aspirin ii. Azodye iii. Aniline
   iv. Acetanilide v. Thiokol Rubber vi.paraacetamol

Out comes:
A student who successfully completes this laboratory should be able to do the following:
- can determine accurate physical, thermodynamical and kinetic properties experimentally.
- apply theoretical principles and mathematical analysis to the data obtained.
- work effectively with others in performing experiments and writing reports.
- understand and Practice ethically correct presentation of data.
- understand and practice proper laboratory safety procedures.
- gain familiarity with a variety of physic-chemical measurement techniques.
- can identify, analyze and synthesize organic compounds.

R – 13: Chemical Engineering
2nd Year II – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – II Sem.

PROBABILITY & STATISTICS

UNIT - I
Random variables and Distributions:
Introduction- Random variables- Distribution function- Discrete distributions (Review of Binomial and Poisson distributions)-
Continuous distributions: Normal, Normal approximation to Binomial distribution, Gamma and Weibull distributions

Subject Category
ABET Learning Objectives a b e k
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - II
Moments and Generating functions:
Introduction-Mathematical expectation and properties - Moment generating function - Moments of standard distributions (Binomial, Poisson and Normal distributions) – Properties

Subject Category
ABET Learning Objectives a e
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - III
Sampling Theory:
Introduction - Population and samples- Sampling distribution of mean for large and small samples (with known and unknown variance) - Proportion sums and differences of means - Sampling distribution of variance -Point and interval estimators for means and proportions

Subject Category
ABET Learning Objectives a e k
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E

UNIT - IV
Tests of Hypothesis:
Introduction - Type I and Type II errors - Maximum error - One tail, two-tail tests- Tests concerning one mean and proportion, two means- Proportions and their differences using Z-test, Student’s t-test - F-test and Chi -square test - ANOVA for one-way and two-way classified data
Subject Category

ABET Learning Objectives a b d e h k
ABET internal assessments 1 2 6 7 10
JNTUK External Evaluation A B D E F

UNIT - V
Curve fitting and Correlation:
Introduction - Fitting a straight line –Second degree curve-exponential curve-power curve by method of least squares.
Simple Correlation and Regression - Rank correlation - Multiple regression

Subject Category
ABET Learning Objectives a d e h k
ABET internal assessments 1 2 6 10
JNTUK External Evaluation A B E

UNIT - VI
Statistical Quality Control Methods:
Introduction - Methods for preparing control charts – Problems using x-bar, p, R charts and attribute charts

Subject Category
ABET Learning Objectives a e k
ABET internal assessments 1 2 6
JNTUK External Evaluation A B E F

Text Books:

1. Richards A Johnson, Irvin Miller and Miller and Freund Johnson E Freund, Probability and Statics for Engineering, 8^{th} Edition, PHI Learning, 2011
2. Sharon L. Myers, Keying Ye, Ronald E Walpole, Probability and statistics for Engineers and Scientists, 8^{th} Edition, Pearson 2007
3. Willam Menden Hall, Robert J. Beaver and Barbara Beaver, Introduction to Probability and Statistics, Cengage Learning, 2009

Reference Books:

1. Sheldon, M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 4^{th} Edition, Academic Foundation, 2011
2. Ronald E. Walpole, Raymond Myers, Sharon L. Myers, Keying E. Ye, Essentials of Probability & Statistics for Engineers and Scientists, Pearson, 2013
3. Johannes Ledolter and Robert V. Hogg, Applied Statistics for Engineers and Physical Scientists, 3^{rd} Edition, Pearson, 2010

Subject Category	ABET Learning Objectives	ABET Internal Assessments	JNTUK External Evaluation	Remarks
Theory Design Analysis Algorithms Drawing Others	l) Apply knowledge of math, science, & engineering m) Design & conduct experiments, analyze & interpret data n) Design a system/process to meet desired needs within economic, social, political, ethical, health/safety, manufacturability, & sustainability constraints o) Function on multidisciplinary teams p) Identify, formulate, & solve engineering problems q) Understand professional & ethical responsibilities r) Communicate effectively s) Understand impact of engineering solutions in global, economic, environmental, & societal context t) Recognize need for & be able to engage in lifelong learning u) Know contemporary issues v) Use techniques, skills, modern tools for engineering practices	13. Objective tests 14. Essay questions tests 15. Peer tutoring based 16. Simulation based 17. Design oriented 18. Problem based 19. Experiential (project based) based 20. Lab work or field work based 21. Presentation based 22. Case Studies based 23. Role-play based 24. Portfolio based	H. Questions should have: I. Definitions, Principle of operation or philosophy of concept. J. Mathematical treatment, derivations, analysis, synthesis, numerical problems with inference. K. Design oriented problems L. Trouble shooting type of questions M. Applications related questions N. Brain storming questions	

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering- II-Sem.

MOMENTUM TRANSFER

Learning Objectives: This course involves the fundamentals of fluid flow by including both theory and the applications of fluid flow in chemical engineering. Basic concepts of fluid mechanics will be taught to make the students to

- understand basic concepts associated to fluid flow such as viscosity, shear, newtonian and non-newtonian fluids etc.
- learn and apply continuity and Navier Stokes equation as a fundamental equation for the analysis of chemical processes.
- learn and apply the concept of boundary layer theory and governing mathematical equations for newtonian and non-newtonian fluid flow.
- learn and apply Bernoulli's equation for various simple and complex cases of fluid flow.
- understand the basic differences between compressible and incompressible fluid flow and suitably adapt, modify and apply suitable correlations for compressible fluid flow.
- have sound knowledge with respect to various important fluid flow related machinery and equipment. Emphasis shall be towards various types of pumps, compressors and blowers.
- master the relevant theory for the application of fluid flow past solid surfaces. Emphasis is towards drag and pressure drop correlations for packed and fluidized beds.
- understand various accessories required for fluid flow such as fittings and valves and their relevance towards variation in pressure drop correlations.
- understand the knowledge related to various fluid flow measuring devices (Venturi, Orifice, Rotameter and Pitot Tube).

UNIT-I:
Basic concepts of Dimensional analysis, nature of fluids, hydrostatic equilibrium, applications of fluid statics.

Fluid flow phenomena-Laminar flow, Shear rate, Shear stress, Rheological properties of fluids, Turbulence, Boundary layers.

UNIT-II:
Basic equation of fluid flow –Mass balance in a flowing fluid; continuity, differential momentum balance; equations of motion, macroscopic momentum balances, Mechanical energy equations.

UNIT-III:
Incompressible Newtonian/Non-Newtonian flow in pipes and channels- shear stress and skin friction in pipes, laminar flow in pipes and channels, turbulent flow in pipes and channels, friction from changes in velocity or direction.

UNIT-IV:
Flow of compressible fluids- Definitions and basic equations, Processes of compressible flow, Isentropic flow through nozzles, adiabatic frictional flow, and isothermal frictional flow.

UNIT-V:
Flow past immersed bodies, Drag and Drag coefficient, flow through beds of solids, motion of particles through fluids.
Fluidization, Conditions for fluidization, Minimum fluidization velocity, Types of fluidization, Expansion of fluidized bed, Applications of fluidization, Continuous fluidization, slurry and pneumatic transport.

UNIT-VI:
Transportation and Metering of fluids- Pipes, fittings and valves, pumps: positive displacement pumps, and centrifugal pumps, fans, blowers, and compressors Measurement of flowing fluids-full bore meters, insertion meters.

Out Comes:
By mastering the fluid mechanics course, the student shall be able to:

- analyze fluid flow in circular and non-circular conduits.
- do calculations associated to the estimation of friction factor and pressure drop in circular conduits.
- do calculations involving Bernoulli's equation for the transport of acidic, alkaline, hydrocarbon and miscellaneous incompressible fluids in pipelines.
- calculate the pressure drops and energy requirements associated to compressible fluid flow in circular and rectangular ducts.
- estimate pressure drop in packed and fluidized beds.
- rigorously carry out various calculations associated to fluid flow in various types of pumps, fans and blowers.
- calculate, analyze and calibrate various flow measuring devices.

Text Books:

1. McCabe,W.L., J.C.Smith & Peter Harriot Unit Operations of Chemical Engineering, McGraw-Hill, 7th Edition, 2001.
2. Christie J. Geankoplis, Transport Processes and Unit Operations, PHI, 2003.

Reference Books:

1. Fox, R.W. and A.T.McDonald, Introduction to fluid mechanics, 5th edition, John wiley& sons, 1998.
2. J.M.Coulson and J.F.Richardson, Chemical engineering, Vol-1: Fluid flow, Heat Transfer and Mass Transfer, Pergamon Press, 4th Edition, 1990.
3. Noel De Nevers, Fluid Mechanics for Chemical Engineers, Tata McGraw-Hill, 2011.
4. Bragg R and F. A. Holland, Fluid Flow for Chemical and Process Engineers, 2nd Edition, Hodder Stoughton Educational, 1995.
5. Patrick Abulencia, J and Louis Theodore, Fluid Flow for the Practicing Chemical Engineer, John wiley and Sons, 2009.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – II Sem.

MECHANICAL UNIT OPERATIONS

Learning Objectives: The course introduces the student principles of mechanical operations and their application in chemical process industries. The students will be able to

- understand the fundamentals associated to liquid agitation and mixing.
- gain basic knowledge in particle characterization namely particle size, shape and specific surface.
- have working knowledge of particulate solids handling and mixing
- learn the principles of size reduction and screening
- understand the Principles and concepts of filtration
- understand the functioning of various prominent solid fluid operations related equipment namely gravity settlers, thickeners, classifiers, clarifiers, sedimenters and Cyclones.
- understand the working principle of electrostatic precipitation and flotation and their relevance in industrial practice.

UNIT-I:
Agitation and mixing of liquids: Agitation of liquids, circulation velocities, power consumption in agitated vessels, purpose of Agitation, types of impellers.
Blending and mixing of liquids, suspension of solid particles, dispersion operations.

UNIT –II:
Properties, handling and mixing of particulate solids: Characterization of solid particles, properties of particulate masses, storage of solids and mixing of solids, types of mixers, mixers for non-cohesive solids and mixers for cohesive solids.

UNIT –III:
Size reduction: Principles, criteria for comminution, characteristics of comminution, size reduction equipment-crushers, grinders, ultra-fine grinders, cutting machines, Equipment operation.
Screening: Screening, Industrial screening equipment’s, general factors in selecting a screening equipment, comparison of ideal and actual screens, material balance over a screen and screening efficiency.

UNIT –IV:
Filtration: Cake filters, centrifugal filters, filter aids, clarifying filters, liquid clarification, and gas cleaning.
Principles of cake filtration, principles of clarification and principles of centrifugal filtration.

UNIT –V:
Separations based on motion of particles through fluids: Gravity sedimentation process: gravity classifiers, sorting classifiers, clarifiers and thickeners, Equipment for sedimentation, clarifier and thickener design.
Centrifugal settling process: Separations of solids from gases: Cyclones; Separations of solids from liquids: Hydrocyclones, principles of centrifugal sedimentation, centrifugal classifiers.

UNIT –VI:

Electrostatic separation: Principle, charging by contact electrification, charging by conductive induction, charging by ion bombardment, types of equipment, effect of humidity, applications of process.

Flotation: General description, flotation reagents, applications, flotation machines, capacities, flotation economics.

Out Comes:

A student proficient in Mechanical Unit Operations will have working knowledge associated with

- particle Characterizations and Solids Handling
- mixing and size reduction of solids
- screening and Filtration
- equipments associated to solid fluid mechanical operations such as gravity settlers, thickeners, classifiers, clarifiers, sedimenters and Cyclones.
- electrostatic precipitators and flotation equipment
- industrial case studies associated to mechanical unit operations
- conceptual design of equipments in mechanical unit operations

Text Book:

1. McCabe,W.L.and J.C.Smith and Peter Harriott, Unit Operations in Chemical Engineering, McGraw Hill, 7th Edition. 2001.

Reference Books:

1. Brown, G.G., Unit Operations, CBS Publishers, 1995.
2. Badger,W.L.and J.T.Banchero, Introduction to Chemical Engineering, Tata McGraw-Hill, international Edition, 1997.
3. Narayanan, C.M., abd Bhattacharya,B.C., Khanna Publishers, 2011.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – II Sem.

CHEMICAL ENGINEERING THERMODYNAMICS– I

Learning Objectives:
Basic concepts of thermodynamics will be taught to make the students to study and understand:

- the laws of thermodynamics and their application to engineering systems.
- chemical potentials, Gibbs and Helmholtz Free Energies and real gases.
- the phase behavior and properties of pure fluids and fluid mixtures with applications to the analysis and preliminary design of power plants , refrigeration systems and chemical engineering systems.

UNIT-I:
Introduction: The scope of thermodynamics, defined quantities; temperature, volume, pressure, work, energy and heat.
The first law and other basic concepts: The first law of thermodynamics, thermodynamic state and state functions, enthalpy, the steady-state steady flow process, equilibrium, the reversible process, constant-V and constant-P processes, heat capacity.

UNIT-II:
Volumetric properties of pure fluids: The PVT behavior of pure substances, virial equations, the ideal gas, the applications of the virial equations, Cubic equations of state, generalized correlations for gases. Mollier diagram and steam tables.

UNIT-III:
The second law of thermodynamics: Statements of the second law, heat engines, thermodynamic temperature scales, thermodynamic temperature and the ideal-gas scale, Entropy, Entropy changes of an ideal gas, mathematical statement of the second law.
Thermodynamic properties of fluids including residual and generalized property correlations.

UNIT-IV:
Thermodynamics of flow processes; principles of conservation of mass and energy for flow systems, analysis of expansion processes; turbines, throttling; compression processes – compressors and pumps; calculation of ideal work and last work. Examples on hydrocarbons and natural gas.

UNIT-V:
Production of Power from Heat: Vapor Power Cycle: Simple Steam power cycle, Rankine cycle, and comparison of Rankin & Carnot cycles, Regenerative cycle.

UNIT-VI:
Refrigeration and liquefaction: The Carnot refrigerator, the vapor compression cycle, the comparison of refrigeration cycles, the choice of refrigerant, absorption refrigeration, the heat pump, liquefaction processes.

Out Comes:

After successful completion of this course, the students can obtain a good understanding of the principles of thermodynamics and a proficiency in applying these principles to the solution of a large variety of energy flow and equilibrium problems. The students will be able to

- solve problems using the energy balance appropriate for a system.
- solve problems using the entropy balance appropriate for a system.
- evaluate, manipulate and use thermodynamic partial derivatives.
- correctly use a thermodynamic property chart and steam tables.
- acquire an ability to identify, formulate and solve engineering problems.
- acquire adequate ability to use techniques, skills and modern engineering tools necessary for engineering practice.

Text books:

1. Smith, J.M. and HC Van Ness, M.M.Abbott, Introduction to chemical engineering thermodynamics, 7th Edition, McGraw Hill, 2010.
2. Rao, Y.V.C., Chemical Engineering Thermodynamics, Universities Press India Ltd., 1997.

Reference Books:

1. Koretsky, M.D., Engineering and Chemical Thermodynamics, John Wiley & Sons, 2004.
2. Richard Elliott,J. and Carl T.Lira, Introductory Chemical Engineering Thermodynamics, , 2nd Edition, Prentice Hall, 2012.
3. Stanley Sandler, Chemical, Biochemical and Engineering Thermodynamics, 4th Edition, Wiley India Pvt Ltd, 2006.
4. Vidal,J., Thermodynamics: Applications in Chemical Engineering and the Petroleum Industry, Edition Technip, 2003.
5. Kyle, B.G., Chemical and Process Thermodynamics, 3rd Edition, PHI Learning, 2008.
6. Thomas E. Dauber, Chemical Engineering Thermodynamics, McGraw Hill, 1985.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech. Chemical Engineering – II Sem.

INORGANIC CHEMICAL TECHNOLOGY

Learning Objectives: This course is designed to make the students understand and anlyze

- the functionalities of various unit processes and operations in chemical engineering.
- process technologies associated with sulphur, sulphur acid and nitrogen industries
- process technologies associated to phosphorus, phosphoric and chlor-alkali industries.
- processes associated to cement, ceramic and glass industries.
- processes associated with water, producer and coke oven gases, acetylene, oxygen and nitrogen
- water utility treatment plants.

UNIT-I:
Sulphur and sulphuric acid: Sources of sulphur- sulphuric acid, different processes of manufacturing-contact process, DCDA process for sulphuric acid manufacture.

UNIT-II:
Nitrogen industries: Manufacture of ammonia, nitric acid, urea andammonium nitrate.

UNIT-III:
Phosphorous and phosphoric acid industries: Methods for production of phosphorous and phosphoric acid, manufacture of super phosphate andtriple super phosphate
Chlor-alkali industries- Manufacture of soda ash, caustic soda and chlorine.

UNIT-IV:
Cement: Types of cement, manufacture of Ordinary Portland Cement [OPC], slag cement
Ceramic Industries: basic raw materials, whit waxes, heavy clay products, refractories, enamels and enameled metals, Types and manufacture of glass.

UNIT-V:
Fuel and industrial gases: Production of water gas, producer gas and coke oven gas, production of acetylene, oxygen and nitrogen.

UNIT-VI:
Water: Sources of water, hardness, treatment for different end uses, municipalwater conditioning, industrial waste water treatment.

Out Comes:
A student adept in inorganic chemical technology must

- have a technological know-how of various process equipments and their respective functions in candidate process flowsheets.
- relate the physical and chemical properties of various compounds towards the working principles of various established technologies in industrial flowsheets.
- understand complexity of various process equipments such as furnaces, complex distillation units etc.,
- have conceptual knowledge towards the application of principles of energy efficient, pollution abatement and raw material recovery and reuse in process flow sheets.

- have an overall idea towards various alternate processes for the manufacture of important inorganic products.
- have a working knowledge towards various important issues (safety issues, economics etc.) associated to inorganic chemical technologies.

Text Book:

1. Gopala Rao,M and Marshall Sitting, Dryden's Outlines of Chemical Technology for the 21^{st} Century, 3^{rd} Edition, East West Press, 2010.

Reference Book:

1. Austin, G. T., Shreve's Chemical Process Industries, Tata-McGraw Hill Publishers, 2012.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B.Tech. Chemical Engineering- I-Sem.

MATERIALS SCIENCE & ENGINEERING

Learning objectives: This subject is intended to

- provide all the technical/engineering inputs to the learner to choose or select a suitable materials of construction of chemical/petrochemical process equipment, piping and internals.each device/components has its own specific usage under different process environmental conditions: the course helps the learner.
- judiciously choose the material so that it meets the specific life expectancy by redusing the shutdown frequency.
- minimize the equipment breakdown and increasing the on-stream factor.
- choose/select the material such that it withstands the severe process operating conditions such as cryogenic, high temperature, high pressure, acidic, basic, stress induced chemical/petrochemical environments keeping view the reliability and safety of the process equipment.

UNIT-I:

Classification of engineering materials, Levels of Structure, Structure-Property relationships in materials, Crystal Geometry and non-crystalline (amorphous) states. Lattice -Bravais lattices, crystal systems with examples. Lattice co-ordinates, Miller and Miller- Bravais Indices for directions and places: ionic, covalent and metallic solids; packing factors and packing efficiency, ligancy and coordination number. Structure determination by Brag's X-raydiffraction method.

UNIT-II:

Crystal Imperfections-classification-point defects-estimation of point defects-Dislocations-classification(edge and screw)-surface defects -dislocation motion and its relevance to mechanical and chemical properties –stress-strain relationship and diagrams for different materials(metals, non-metals, rubbers and plastics and polymers)-elastic and plastic deformation-slip -stress required to move a dislocation.Multiplication of dislocations –dislocation reactions, effect on mechanical behavior of materials.Strain hardening/work hardening –dynamic recovery and recrystallization.

UNIT-III:

Fracture and failure of materials: ductile fracture analysis-brittle fracture analysis-fracture toughness-ductile-brittle transition-fatigue fracture-theory, creep and mechanism –methods to postpone the failure and fracture of materials and increase the life of the engineering components /structures.

UNIT-IV:

Solid –liquid and solid-solid equilibria formetals and alloys. Phase rule-phase diagram for pure metals (single component system), alloys (binary systems)-micro structural changes during cooling-Lever rule and its applications-typical phase diagrams-homogeneous and heterogeneous systems, formation of Eutectic, Eutectoid mixtures- non-equilibrium cooling.Binary Systems (phase diagrams) for study: Cu-Ni,Bi-Cd,Pb-Sn, Fe-C ,Al-Cu

UNIT-V:

Materials for chemical and petrochemical industrial process equipment- Effect of alloying on mechanical and chemical behavior of materials, applicationsof heat treatment methods for strengthening of engineering materials.

Composite structures and their advantages over conventional materials–Matrix-reinforcement properties and evaluation of strength properties with different orientation of reinforcement-applications –Nano materials –synthesis and characterization.

UNIT-VI

Stability criteria of materials in chemical/petrochemical industrial environments. Corrosion and Oxidation of materials –basic mechanisms-types of corrosion, Corrosion testing and evaluation Prevailing methods to combat corrosion. Coatings –metallic non-metallic, passivity, cathodic protection.

Out Comes:

After the course, the students will be

- equipped with knowledge to prepare material selection diagram, evaluation of equipment life and prediction of life of the equipment.
- acquiring the abilities to carryout reliability studies.
- ready to carryout equipment failure analysis and propose the remedial measures.

Text Books:

1. Raghavan, V., Materials Science and Engineering; 5th Edition, PHI, New Delhi, 2009.
2. Ravi Prakash, William F.Smith, and Javed Hashemi, Material Science and Engineering, 4th Edition, Tata-McGraw Hill, 2008.

Reference Books:

1 Elements of Material Science and Engineering, Lawrence H. Van Vlack, 6th Edition, Pearson, 2002.
2 Balasubramaniam,R., Callister’s Materials Science and Engineering, Wiley, 2010.
3 Mars G. Fontana, Corrosion Engineering, Tata-McGraw Hill, 2005.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech Chemical Engineering – II Sem.

MOMENTUM TRANSFER LAB

Learning Objectives:
Fundamentals of momentum transfer will be demonstrated in a series of laboratory exercises like determination of discharge coefficient of orifice, venturi, notches, friction factors in pipes, pressure drop in packed and fluidized beds, fluid viscosity, characteristics of centrifugal pump, characterization of fluid flow, verification of Bernoulli's theorem, measurement of point velocities. Hands-on experience and communication skills will be achieved.

List of Experiments:

1. Identification of laminar and turbulent flows; Major equipment - Reynolds apparatus
2. Measurement of point velocities; Major equipment - Pitot tube setup
3. Verification of Bernoulli's equation; Major equipment – Bernoulli's Apparatus
4. Calibration of Rotameter; Major equipment – Rotameter Assembly
5. Variation of Orifice coefficient with Reynolds Number; Major equipment - Orifice meter Assembly.
6. Determination of Venturi coefficient; Major equipment – Venturi meter Assembly
7. Friction losses in Fluid flow in pipes; Major equipment - Pipe Assembly with provision for Pressure measurement
8. Pressure drop in a packed bed for different fluid velocities; Major equipment - Packed bed with Pressure drop measurement
9. Pressure drop and void fraction in a fluidized bed; Major equipment - Fluidized bed with Pressure drop measurement
10. Studying the coefficient of contraction for a given open orifice; Major equipment - Open Orifice Assembly
11. Studying the coefficient of discharge in a V-notch; Major equipment - V-notch Assembly
12. Studying the Characteristics of a centrifugal pump; Major equipment - Centrifugal Pump
13. Viscosity determination using Stoke's law; Major equipment – Terminal Velocity determination column.

Outcomes: After completion of the course**,** students will be able to do the following:

- operate fluid flow equipment and instrumentation.
- collect and analyze data using momentum transfer principles and experimentation methods.
- prepare reports following accepted writing and graphical techniques.
- perform exercises in small teams.
- demonstrate principles discussed in momentum transfer lecture course.
- demonstrate appropriate work habits consistent with industry standards.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
II Year B. Tech Chemical Engineering – II Sem.

MECHANICAL UNIT OPERATIONS LAB

Learning Objectives: This lab course is designed to educate the students in

- tpractical application of the mechanical operations.
- understanding the actual performance of equipment for separation of solids and size reduction.
- performing various experiments on equipment & understanding the theoretical concepts in depth.

List of Experiments:

1. Verification of crushing laws with the actual power ration rising hammer mill.
2. Verification of the combination laws and critical speed of a ball mill.
3. Calculation of the effectiveness of screen in horizontal and inclined position (vibrating screens)
4. Verifications of the laws of size reductions using Rod mill or Jaw crusher.
5. Verification of the Stokes law range and steady the characteristics of different particles in single medium.
6. Determination of the specific cake resistance and medium resistance in a vacuum filter or plate and frame filter press.
7. Study of the sedimentation characteristics of a thickener and design of a continuous thickener.
8. Determination of specific cake resistance and medium resistance of leaf filler.
9. Determination of the froth flotation characteristics in mineral concentration.
10. Determination of the settling rates of particles in hydrocyclones
11. Determination of separation factors of air and hydraulic classifiers.
12. Analysis of various sizes of given material by sieve analysis and determination of Cumulative and Differential Analysis.
13. Verification of the laws of crushing using drop weight crusher and determination of work index.
14. Determination of the size distribution of a given powder sample by air elutriation method.
15. a) Study of hindered settling and sedimentation characteristics of solids in liquid suspension
    b) Determination of thickener cross sectional area using kynch theory.
16. Determination of laws of crushing of a given sample in pulveriser of a given sample and determination of bond's work index

Outcomes: After successful completion of this lab course, the students will be able to do the following:

- operate and explain the function of size reduction equipment, filtration equipment, classifiers, thickeners, solid particle separators, settlers, floatation equipment and particle screening equipment.
- measure and explain the effect of design parameters on the dynamics of the above equipment and performance.
- work in teams to conduct experiments effectively and efficiently.
- collect, correlate, and analyze data with respect to theoretical principles learnt in mechanical operations classes.
- write lab reports to document experimental work.

R – 13: Chemical Engineering

3rd Year I – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

PROCESS HEAT TRANSFER

Learning Objectives:
This course is designed to introduce a basic study of the phenomena of heat transfer to carry out thermal design/ heat transfer process design for heat exchange systems such as process heat exchangers, reboilers, air/utility coolers/condensers, furnaces, boilers, super-heaters, evaporators, driers, cooling towers etc. The principles involve the estimation of overall heat transfer coefficients, heat transfer surface area, pressure drop involved in single-phase and multi-phase flow regimes.
The students will be trained to acquire skills to carry out the detailed mechanical design of heat exchangers such as number tubes, selection of shell and tube material, estimate number of baffles and also provide necessary information regarding TEMA classification.

UNIT-I:
Introduction: Nature of heat flow, conduction, convection, natural and forced convection, and radiation.
Heat transfer by conduction in Solids: Fourier's law, thermal conductivity, steady state conduction in plane wall & composite walls, compound resistances in series, heat flow through a cylinder, conduction in spheres, thermal contact resistance, plane wall: variable conductivity.
Unsteady state heat conduction: Equation for one-dimensional conduction, Semi-infinite solid, finite solid.

UNIT-II:
Principles of heat flow in fluids: Typical heat exchange equipment, countercurrent and parallel current flows, energy balances, rate of heat transfer, overall heat transfer coefficient, electrical analogy, critical radius of insulation, logarithmic mean temperature difference, variable overall coefficient, multi-pass exchangers, individual heat transfer coefficients, resistance form of overall coefficient, fouling factors, classification of individual heat transfer coefficients, magnitudes of heat transfer coefficients, effective coefficients for unsteady-state heat transfer.

UNIT-III:
Heat Transfer to Fluids without Phase change: Regimes of heat transfer in fluids, thermal boundary layer, heat transfer by forced convection in laminar flow, heat transfer by forced convection in turbulent flow, the transfer of heat by turbulent eddies and analogy between transfer of momentum and heat, heat transfer to liquid metals, heating and cooling of fluids in forced convection outside tubes.

UNIT-IV:
Natural convection: Natural convection to air from vertical shapes and horizontal planes, effect of natural convection in laminar flow heat transfer.
Heat transfer to fluids with phase change: Heat transfer from condensing vapors, heat transfer to boiling liquids.

UNIT-V:

Radiation: Emission of radiation**,** absorption of radiation by opaque solids, radiation between surfaces, combined heat transfer by conduction, convection and radiation.

Evaporators: Types of Evaporators, performance of tubular evaporators, vapor recompression.

UNIT-VI:

Heat Exchange Equipment: General design of heat exchange equipment, heat exchangers, condensers, boilers and calendrias, extended surface equipment, heat transfer in agitated vessels, scraped surface heat exchangers, heat transfer in packed beds, heat exchanger effectiveness (NTU method).

Out Comes: Upon successful completion of this course, the student will be able to:

- understand the basic laws of heat transfer.
- account for the consequence of heat transfer in thermal analyses of engineering systems.
- analyze problems involving steady state heat conduction in simple geometries.
- develop solutions for transient heat conduction in simple geometries.
- obtain numerical solutions for conduction and radiation heat transfer problems.
- understand the fundamentals of convective heat transfer process.
- evaluate heat transfer coefficients for natural convection.
- evaluate heat transfer coefficients for forced convection inside ducts.
- evaluate heat transfer coefficients for forced convection over exterior surfaces.
- analyze heat exchanger performance by using the method of log mean temperature difference.
- analyze heat exchanger performance by using the method of heat exchanger effectiveness.
- Calculate radiation heat transfer between black body surfaces as well as grey body surfaces

Text Books:

1. McCabe, W.L., J.C Smith and Peter Harriott, Unit Operations of Chemical Engineering7th Edition, McGraw-Hill, 2005.
2. Y.V.C.Rao, Heat Transfer, Universities Press (India) Pvt. Ltd., 2001.

Reference Books:

1. D.Q. Kern, Process Heat Transfer, Tata- McGraw-Hill, 1997.
2. Holman, J.P., Heat Transfer, 9th Edition, Tata McGraw-Hill, 2008.
3. Donald Pitts and L.E.Sisson, Schaum's Outline of Heat Transfer, 2nd Edition, McGraw-Hill, 1998.
4. Sukhatme, P., A Text Book on Heat Transfer, 5th Edition, Universities Press (India) Pvt. Ltd., 2005.
5. Binay Dutta, K., Heat Transfer: Principles and Applications, PHI Learning, 2009.
6. Coulson, J.M.; Richardson, J.F.; Backhurst, J.R.; Harker, J.H., Chemical Engineering: Fluid Flow, Heat Transfer and Mass Transfer, Vol.1, 6th Edition, Reed Elsevier India, 2006.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

ORGANIC CHEMICAL TECHNOLOGY

Learning Objectives:

- To have a basic understanding of chemical processes with specific emphasis of unit processes and unit operations.
- To correlate physical and chemical properties of various chemicals/compounds/products to the process units.
- Overview of important chemical processes for the processing/production of carbon containing products.

UNIT-I:
Natural Products Processing: Production of pulp, paper and rayon, Manufacture of sugar, starch and starch derivatives,
Coal Chemicals: Gasification of coal and chemicals from coal.

UNIT-II:
Industrial Microbial Processes: Fermentation processes for the production of ethyl alcohol, citric acid and antibiotics,
Edible Oils: Refining of edible oils and fats, fatty acids, Soaps and detergents.

UNIT-III:
Petroleum Refining and Petrochemical Precursors: Petroleum refining to produce naphtha, fuel hydrocarbons and lubricants.

UNIT-IV:
Processes for the Production of Petrochemical Precursors: ethylene, propylene, butadiene, acetylene, synthetic gas, benzene, toluene and xylene. (Cracking, Catalytic reforming and separation of products)

UNIT-V:
Plastics and Polymers: Production of thermoplastic and thermosetting resins such as polyethylene (HDPE, LDPE), polypropylene, phenolic resins and epoxy resins. Polymers and their applications in engineering practice. (PVC, PTFE, Polystyrene)

UNIT-VI:
Fiber Forming and Electrometric Polymers: Synthetic fibers: polyamides, polyesters and acrylics from monomers, Processes for the production of natural and synthetic rubbers.

Outcomes:

A student with sound knowledge of organic chemical technology shall be able to address the following:

- For a given product, list various competent processes.

- Identify the best process in terms of raw material availability and product demand.
- For the identified best process, have knowledge for the know-how of various processes and unit operations with specific emphasis on the functionality of these sub-processes.
- Correlate fundamental knowledge in various subjects of chemical engineering with organic chemical process technologies.
- Outline various problems associated with organic product production processes and possible technical approaches to overcome them in industrial production and practice.

Text Books:

1. Shreve's Chemical Process Industries, G.T. Austin, 5th Edn., McGraw Hill, New York, 1984.
2. Dryden's Outline of Chemical Technology, M. Gopala Rao and Marshall Sitting, 2nd Edn., Affiliated East-West Press, 1973.

Reference book:

1. A Text Book of Chemical Technology, S.D. Shukla and G. N. Pandey, Vol.2, 2nd Edition, Vikas Publishing House Pvt. Ltd., 1986.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

CHEMICAL ENGINEERING THERMODYNAMICS –II

Learning Objectives:
The student will be able to learn:

- Sensible heat effects and latent heat
- Heat effects of industrial reactions.
- Heat effects for chemical change.
- Estimation of properties of solutions.
- Concept of fugacity and partial molar properties.
- VLE calculations using Raoult's law, modified Raoult's law and generalized method.
- VLE calculations from equation of state.
- Estimation of reaction equilibrium constant and equilibrium conversion for liquid phase reactions, gas phase reactions and industrial reactions.
- Applications of phase rule for reacting and non-reacting systems.

UNIT –I:
Heat effects: Sensible heat effects, Internal energy of ideal gases: Microscopic view, Latent heats of pure substances, heat effects of industrial reactions, heat effects of mixing processes. Standard heat of reaction, Standard heat of formation, Standard heat of combustion, temperature dependence of heat of reaction

UNIT-II:
Solution thermodynamics: Theory: Fundamental property relation, Petrochemical potential as a criterion for phase equilibrium, partial properties, ideal gas mixtures, fugacity and fugacity coefficient for pure species, fugacity and fugacity coefficient for species in solutions, generalized correlations for Fugacity coefficient, The ideal solutions, excess properties.

UNIT-III:
Solution thermodynamics: applications: the liquid phase properties from VLE data, models for the excess Gibbs energy, property changes of mixing

UNIT–IV:
VLE at low to moderate pressures: The nature of equilibrium, the phase rule, Duhems theorem, VLE: Qualitative behavior, the gamma /Phi formulation of VLE, Dew point and bubble point calculations, flash calculations, solute (1)/solvent (2) systems

UNIT–V:
Thermodynamic properties and VLE from equations of state: properties of fluids from the virial equations of state, properties of fluids from cubic equations of state, fluid properties from correlations of the Pitzer type, VLE from cubic equations of state

UNIT–VI:

Chemical Reaction Equilibria: The reaction coordinate, application equilibrium criterion to Petrochemical reactions, the standard Gibb's energy change and the equilibrium constant, effect of temperature on equilibrium constants, relation of equilibrium constants to composition, equilibrium conversion for single reactions, Phase rule and Duhem's theorem for reacting systems.

Outcomes:

After the completion of course, students will be able to

- Estimate heat requirement for any physical change and chemical change.
- Find fugacity coefficient and activity coefficient for a component in a mixture.
- Identify the non-ideal solution model for vapour liquid equilibrium.
- Obtain VLE data using appropriate cubic equations of state.
- Apply phase rule.
- Find reaction equilibrium constant and equilibrium conversion for single reactions and multiple reactions.

Text Books:

1. Introduction to Chemical Engineering Thermodynamics, J.M. Smith, H.C. Van Ness and M.M. Abbott, 7th ed. McGraw Hill, 2005.
2. Chemical Engineering Thermodynamics, Rao Y.V.C., Universities Press (India) Pvt. Ltd., 1997.

Reference Books:

1. Chemical and Process Thermodynamics, BG Kyle, 3rd Edition, Phi Learning, 2008.
2. Introductory Chemical Engineering Thermodynamics, J. Richard Elliott, Carl T. Lira, 2nd Edition, Prentice Hall, 2012.
3. Chemical, Biochemical and Engineering Thermodynamics, Stanley I Sandler, 4th Edition, Wiley India Pvt Ltd, 2006.
4. Molecular Thermodynamics In Fluid Phase Equilibria, J.M. Prausnitz, R.N. Lichtenthaler, E.G.de Azvedo, 3rd Edition, Prentice-Hall, 1998.
5. Engineering and Chemical Thermodynamics, Milo D. Koretsky, Wiley India Pvt Ltd, 2009
6. Thermodynamics: Applications in Chemical Engineering and the Petroleum Industry, J. Vidal, Editions Technip, 2003.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

CHEMICAL REACTION ENGINEERING – I

Learning Objectives:

- To gain an understanding of the definition of reaction rate, the variables affecting the rate of reaction, and the kinetics of homogeneous reactions with respect to concentration dependency and temperature dependency
- To learn about the interpretation of batch reactor data obtained for both constant volume and variable volume batch reactors for determining the kinetics of homogeneous reactions of various types
- To learn the basic concepts of design of ideal reactors in particular batch reactor, plug flow reactor and mixed flow reactor
- To understand the size comparison of single reactors, multiple reactor systems, recycle reactor and autocatalytic reactions
- To gain knowledge of design for reactions in parallel and reactions in series carried out in batch, plug flow and mixed flow reactors. Also, to understand the concept of product distribution in parallel and series reactions
- To study the effects temperature and pressure on reaction kinetics and equilibrium conversion from a thermodynamic point of view
- To understand the design of reactors for non-isothermal, adiabatic and non-adiabatic operations respectively for carrying out single reactions
- To understand how exothermic reactions are carried out in mixed flow reactors as a special case.

UNIT-I:

Overview of chemical reaction engineering: classification of reactions, variables affecting the rate of reaction definition of reaction rate. Kinetics of homogenous reactions- concentration dependent term of rate equation, Temperature dependent term of rate equation, searching for a mechanism, predictability of reaction rate from theory.

UNIT-II:

Interpretation of batch reactor data: constant volume batch reactor:- Analysis of total pressure data obtained in a constant-volume system, the conversion, Integral method of analysis of data– general procedure, irreversible unimolecular type first order reactions, irreversible bimolecular type second order reactions, irreversible trimolecular type third order reactions, empirical reactions of nth order, zero-order reactions, overall order of irreversible reactions from the half-life, fractional life method, irreversible reactions in parallel, homogenous catalyzed reactions, autocatalytic reactions, irreversible reactions in series.

UNIT-III:

Constant volume batch reactor– first order reversible reactions, second order reversible reactions, reversible reactions in general, reactions of shifting order, Differential method of analysis of data.

Varying volume batch reactor: differential method of analysis, integral method of analysis, zero order, first order, second order, nth order reactions, temperature and reaction rate, the search for a rate equation.

UNIT-IV:

Introduction to reactor design: general discussion, symbols and relationship between C_A and X_A; Ideal reactors for a single reaction- Ideal batch reactor, Steady-state mixed flow reactor, Steady-state plug reactors.

Design for single reactions: Size comparison of single reactors, Multiple- reactor systems, Recycle reactor, Autocatalytic reactions.

UNIT-V:

Design for parallel reactions: introduction to multiple reactions, qualitative discussion about product distribution, quantitative treatment of product distribution and of reactor size.

Irreversible first order reactions in series, quantitative discussion about product distribution, quantitative treatment, plug flow or batch reactor, quantitative treatment, mixed flow reactor, first-order followed by zero-order reaction, zero order followed by first order reaction.

UNIT-VI:

Temperature and Pressure effects: single reactions- heats of reaction from thermodynamics, heats of reaction and temperature, equilibrium constants from thermodynamics, equilibrium conversion, general graphical design procedure, optimum temperature progression, heat effects, adiabatic operations, non adiabatic operations, comments and extensions. Exothermic reactions in mixed flow reactors-A special problem, multiple reactions.

Outcomes:

A student on completion of the course would be able to

- Analyze the experimental data obtained from ideal reactors and determine the kinetics of homogeneous reactions of various types for both constant volume and variable volume conditions.
- Design ideal reactors for carrying out homogeneous reactions.
- Compare the performance of various types of reactors including multiple reactor systems and recycle reactors.
- Design suitable reactors for carrying out reactions in parallel and reactions in series.
- Analyze the effects of temperature and pressure on equilibrium constants and equilibrium conversions.
- Design reactors for adiabatic and non-adiabatic operations.

Text Book:

1. Chemical Reaction Engineering, Octave Levenspiel, 3rd Ed. John Wiley & Sons, 1999.

References Books:

1. Elements of Chemical Reaction Engineering, H.S. Fogler, 2nd Edition. PHI, 1992.
2. Chemical Engineering Kinetics, J. M. Smith, 3rd Edition. McGraw- Hill, 1981.
3. Elementary Chemical Reactor Analysis, Aris. R., Prentice-Hall, Englewood Cliffs, 1969.

4. Modeling of Chemical Kinetics and Reactor Design, Coker, A.K., Gulf Professional Publishing, 2001.
5. Fundamentals of Chemical Reaction Engineering, Davis, M.E., and R.J. Davis, McGraw-Hill, 2002.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

MASS TRANSFER OPERATIONS-I

Learning Objectives:
Students will be able to learn:

1. Classification of various mass transfer operations.
2. Diffusional mass transfer for diffusion in solids & fluids and estimation of diffusivities.
3. Estimation of the Mass transfer coefficients for laminar and turbulent flow.
4. Turbulent mass transfer theories and analogy between heat, mass and momentum transfer
5. Equilibrium based separation by distillation and different types of distillation operations.
6. The principles for design of distillation towers making simplified assumptions and also using enthalpy- concentration diagrams.
7. The concepts of equilibrium based separation by absorption and stripping and corresponding data analysis.
8. The concepts for design of equipment for gas-solid operations and gas-liquid operations

UNIT- I:
Introduction to Mass Transfer Operations: Classification of the Mass-Transfer Operations, Choice of Separation Method, Methods of Conducting the Mass-Transfer Operations, Design Principles, Unit Systems.
Molecular Diffusion In Fluids: Molecular Diffusion, Equation of Continuity, binary solutions, Steady State Molecular Diffusion in Fluids at Rest and in Laminar Flow, estimation of diffusivity of gases and liquids, Momentum and Heat Transfer in Laminar flow.

UNIT-II:
Diffusion:Diffusion in Solids, Fick's Diffusion, Unsteady State Diffusion, Types of Solid Diffusion, diffusion through polymers, diffusion through crystalline solids, Diffusion through porous solids & hydrodynamic flow of gases.
Mass Transfer Coefficients: Mass Transfer Coefficients, Mass Transfer Coefficients in Laminar Flow, Mass Transfer Coefficients in Turbulent Flow, eddy diffusion, Film Theory, Penetration theory, Surface-renewal Theory, Combination Film-Surface-renewal theory, Surface-Stretch Theory, Mass, Heat and Momentum Transfer Analogies.

UNIT-III:
Inter Phase Mass Transfer: Concept of Equilibrium, Diffusion between Phases, Material Balances in steady state co-current and counter current stage processes, Stages, Cascades, Kremser – Brown equation.
Distillation-I : Fields of applications, VLE for miscible liquids, immiscible liquids, steam distillation, Positive and negative deviations from ideality, enthalpy-concentration diagrams, flash vaporization and differential distillation for binary and multi component mixtures.

UNIT- IV:
Distillation-II: Continuous rectification-binary systems, multistage tray towers–method of McCabe and Thiele, enriching section, exhausting section, feed section, total reflux, minimum

and optimum reflux ratios, use of steam, total and partial condensers, cold reflux, multiple feeds, tray efficiencies.
Ponchon and Savarit method, the enriching and stripping sections, feed tray location, total reflux, minimum and optimum reflux ratios, reboilers, use of open steam, condenser and reflux accumulators, azeotropic distillation, extractive distillation, comparison of azeotropic and extractive distillation-Distillation in packed towers.

UNIT-V:
Absorption and Stripping: Absorption equilibrium, ideal and non ideal solutions selection of a solvent for absorption, one component transferred: material balances. Determination of number of plates (graphical), absorption Factor, estimation of number of plates by Kremser Brown equation. Continuous contact equipment: HETP &HTU concepts, absorption of one component, determination of number of transfer units and height of the continuous absorber, overall coefficients and transfer units, dilute solutions, overall height of transfer units.

UNIT-VI:
Equipment For Gas-Liquid Operations: Gas dispersed, sparged vessels (bubble columns), mechanical agitated equipments(brief description),tray towers, general characteristics, sieve tray design for absorption and distillation (qualitative treatment), different types of tray efficiencies, liquid dispersed venturi scrubbers, wetted-wall towers, packed towers, counter current flow of liquid & gas through packing, mass transfer coefficients for packed towers, end effects and axial mixing- tray towesrvs packed towers.

Out comes:
After completing the course, the students will be able to:
1. Estimate the diffusivities of gases and liquids for diffusion through solids, liquids and gases.
2. Estimate the mass transfer coefficients for laminar flow and turbulent flow.
3. Design and operate stage wise and continuous contact distillation towers.
4. Design and operate stage wise and continuous gas-liquid contact towers for absorption and stripping.

Text Books:

1. Mass Transfer Operations, R.E. Treybal, 3rdEdition.,McGraw Hill, 1980.
2. Unit Operations of Chemical Engineering, W.L.McCabe, J.C.Smith& Peter Harriott, McGraw- Hill, 6th Edition, 2001.

Reference Books:

1. Coulson and Richardson's Chemical engineering, Vol 1,Backhurst, J.R., Harker, J.H., Richardson, J.F., and Coulson, J.M., Butterworth-Heinemann, 1999.
2. Coulson and Richardson's Chemical engineering, Vol 2, Richardson, J.F. &Harker,J.H. with Backhurst, J.R., Butterworth-Heinemann, 2002.
3. Principles of Mass Transfer and Separation Processes, Binay K. Datta, PHI Learning Private Ltd., 2009.
4. Diffusion: Mass Transfer in Fluid Systems, Cussler, E.L., Cambridge Univ. Press, 1984.
5. Design of Equilibrium Stage Processes, B.D.Smith, McGraw-Hill, 1963.

6. Staged Cascades In Chemical Processing, P.L.T.Brian, Prentice-Hall, 1972.
7. Equilibrium Staged Separations, Phillip C.Wankat, Prentice-Hall PTR, 1988.
8. Equilibrium-Stage Separation Operations in Chemical Engineering, E.J.Henley and J.D.Seader, John Wiley & Sons, 1981.
9. Transport Processes and Unit Operations by Christie J. Geankoplis, 4th Edition, PHI, 2009.
10. Separation Processes, C.J. King, 2nd Edition, McGraw- Hill, 1980.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

PROCESS INSTRUMENTATION

Learning Objectives:

- To learn the basic elements of an instrument and its static and dynamic characteristics
- To study the various types of industrial thermometers
- To learn the basic concepts of various types of composition analysis
- To learn the various types of instruments for measurement of pressure, vacuum, head, density, level and flow measurement
- To get an overview of various recording, indicating and signaling instruments, transmission of instrument readings, instrumentation diagrams, control center, process analysis and digital instrumentation.

UNIT-I:

Fundamentals: Elements of Instruments, static and dynamic characteristics-Basic concepts of response of first order type instruments.

Industrial Thermometers 1: Mercury in glass thermometer-Bimetallic thermometer-Pressure spring thermometer, Static accuracy and response of thermometry.

UNIT-II:

Industrial Thermometers 2: Thermo electricity-Industrial thermocouples-Thermo couple wires-Thermo couple wells and response of thermo couples; Thermal coefficient of resistance-Industrial resistance-Thermometer bulbs and circuits-Radiation receiving elements-Radiation photo electric and optical pyrometers.

UNIT-III:

Composition analysis: Spectroscopic analysis by absorption, emission, mass and color measurement spectrometers-Gas analysis by thermal conductivity, analysis of moisture.

Pressure, vacuum and head: Liquid column manometers-Measuring elements for gauge pressure and vacuum-indicating elements for pressure gauges-Measurement of absolute pressure-Measuring pressure in corrosive liquids-Static accuracy and response of pressure gauges.

UNIT-IV:

Density and specific gravity measurements- direct measurement of liquid level-Pressure measurement in open vessels-Level measurements in pressure vessels-Measurement of interface level-Density measurement and level of dry materials.

UNIT-V:

Flow Meters: Headflow meters-Area flow meters-Open channel meters-Viscosity meters-Quantity meters-Flow of dry materials-Viscosity measurements.

UNIT-VI:

Recording instruments-Indicating and signaling instruments-Transmission of instrument readings-Controls center-Instrumentation diagram-Process analysis-Digital instrumentation.

Outcomes: The students will be able to

- Understand the basic elements of an instrument and its characteristics
- Become familiar with various types of instruments for measurement of various process variables like temperature, pressure, vacuum, head, level, composition, flow and density
- Get a clear perspective of various recording, indicating, signaling instruments, transmission of instrument readings
- Get an understanding of instrumentation diagrams, control center, process analysis and digital instrumentation

Text Book:

1. Industrial Instrumentation, Donald P.Eckman, CBS, 2004.

Reference Books:

1. Principles of Industrial Instrumentation, Patranabis, 2nd Edition, Tata McGraw-Hill, 1996.
2. Process Control and Instrumentation Technology, Curtis D. Johnson, 3rd Edition, Prentice Hall, 1988.
3. Process Instrumentation Applications Manual, Bob Connell, 2nd Edition, McGraw-Hill, 1995.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

PROCESS HEAT TRANSFER LAB

Learning Objectives: Fundamentals of process heat transfer will be demonstrated in a series of laboratory exercises like determination of thermal conductivities of composite wall and metal rod, natural convective and forced convective heat transfer coefficients, both film and overall coefficients, Stefen-Boltzman constant, emissivity of a metal plate etc. Students will achieve hands-on experience and acquire communication skills while conducting experiments in a team.

List of Experiments:

1. Determination of total thermal resistance and thermal conductivity of composite wall.
2. Determination of thermal conductivity of a metal rod.
3. Determination of natural convective heat transfer coefficient for a vertical tube.
4. Determination of critical heat flux point for pool boiling of water.
5. Determination of forced convective heat transfer coefficient for air flowing through a pipe
6. Determination of overall heat transfer coefficient in double pipe heat exchanger.
7. Study of the temperature distribution along the length of a pin-fin under natural and forced convection conditions
8. Estimation of un-steady state film heat transfer coefficient between the medium in which the body is cooled.
9. Determination of Stefan – Boltzmann constant.
10. Determination of emissivity of a given plate at various temperatures.

Out Comes: Upon successful completion of this lab course, the student will be able to:

- understand the basics of experimental techniques for heat transfer measurements.
- operate the heat transfer equipment like heat exchangers
- process experimental data and obtain correlations to predict heat transfer coefficients for design of heat transfer systems.
- conduct the experiments at R & D level in the industry
- understand the professional and ethical responsibilities in the field of heat transfer.
- produce a written laboratory report.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - I Sem.

MASS TRANSFER OPERATIONS LAB - I

Learning Objectives:

The objective of mass transfer laboratory is to help the students in understanding the basic concepts of mass transport process; to make the students familiar with the most of the separation equipment on laboratory scale; to acquaint with the experimental procedures for the determination of transport properties; further, the students will have hands on experience in handling and operation of different types of mass transfer equipment.

Experiments:

1. Estimation of diffusivity coefficients: (a) vapors (b) solids
2. Distillation, a) Steam distillation b) Differential distillation
3. HETP evaluation in Packed Towers
4. Vapor Liquid Equilibria
5. Evaluation of Mass transfer coefficients
   (a) Surface Evaporation (b) Wetted wall column
6. Equilibrium Analysis of Carbon dioxide absorption in alkaline solutions.
7. Deoxygenation of tap water:
   a. Determination of the overall mass transfer coefficient based on gas phase resistance.
   b. Determination of the individual mass transfer coefficient based on gas phase resistance.
   c. Determination of relationship between mass transfer coefficients and the gas flow rates.
8. Aeration of tap water:
   a. Determination of the overall mass transfer coefficient based on liquid phase resistance.
   b. Determination of the individual mass transfer coefficient based on liquid phase resistance.
   c. Determination of relationship between mass transfer coefficients and the gas flow rates.

Outcomes:

The student will be able to:

- Recognize the various modes of mass transfer to determine the mass transfer rates using Fick's law for estimating the diffusion coefficients.
- Design and conduct experiments; analyze and interpret data related to mass transfer.
- Visualize and understand mass transfer operations.
- Work in teams accommodating the contributions of team members having a variety of skills and perspectives.
- Identify, formulate and solve mass transfer problems.
- Attain proficiency in written, graphical and communications.
- Use techniques, skills, and modern engineering tools necessary for engineering practice.

R – 13: Chemical Engineering
3rd Year II – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering – II Sem.

MANAGEMENT SCIENCE

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

MASS TRANSFER OPERATIONS-II

Learning Objectives:
Student will be able to learn about:

- Equilibrium separations based on liquid-liquid contact along with data analysis from equilibrium diagrams represented in triangular and rectangular coordinates.
- Equilibrium liquid-liquid separation using multistage counter current contactors.
- Different liquid- liquid extraction equipments like continuous contact equipments, agitated extractors, centrifugal extractors along with supercritical fluid extraction and fractional extraction.
- Basic concepts of leaching using single and multistage leaching operations.
- Usage of psychometriccharts and design of humidifiers and cooling towers.
- Mechanism of batch drying and details of batch and continuous drying.
- Basic concepts of adsorption and construction of adsorption isotherms.
- Different types of adsorbers like fixed bed, moving bed and fluidized bed absorber.
- Details of different pressure driven, concentration driven, electro potential driven membrane separation processes and different types synthetic types membranes and modules.

UNIT-I:
Liquid-Liquid Operations: fields of usefulness, liquid-liquid equilibrium, equilateral triangular co-ordinates, choice of solvent, stage wise contact, multistage cross-current extraction, Multi stage counter current without reflux-multi stage counter current with reflux,.
Extraction Equipment: Differential (continuous contact) extractors, spray towers, packed towers, mechanically agitated counter-current extractors, centrifugal extractors, dilute solutions, super critical fluid extraction, fractional extraction.

UNIT- II:
Leaching: Fields of applications, preparation of solid for leaching, types of leaching, leaching equilibrium, single stage and multi stage leaching calculations, constant under flow conditions, equipment for leaching operation.
Humidification Operations: Vapor pressure curve, definitions, psychometric charts, enthalpy of gas-vapor mixtures, humidification and dehumidification, operating lines and design of packed humidifiers, dehumidifiers and cooling towers, spray chambers.

UNIT- III:
Drying: Equilibrium, definitions, drying conditions- rate of batch drying under constant drying conditions, mechanisms of batch drying, drying time through circulation drying.

Classification Of Drying Operations: Batch and continuous drying equipment, material and energy balances of continuous driers, rate of drying for continuous direct heat driers.

UNIT-IV:

Adsorption-I: Adsorption, types of adsorption, nature of adsorbents, adsorption equilibrium, single gases and vapors, adsorption hysteresis, effect of temperature, heat of adsorption, vapor and gas mixtures- one component adsorbed, effect of change of temperature or pressure. Liquids, adsorption of solute from dilute solution, the Freundlich equation, adsorption from concentrated solutions, adsorption operations, stage wise operation, application of Freundlich equation to single and multistage adsorption (cross current & counter current).

UNIT-V:

Adsorption-II: Adsorption of vapor from a gas, fluidized bed, continuous contact, steady state moving bed adsorbers, unsteady state–fixed bed adsorbers, adsorption wave, elution, adsorption-desorption operations- thermal desorption of gases, activated carbon solvent recovery, pressure swing and vacuum swing adsorption (qualitative treatment), regeneration with purge and desorbent. Ion-Exchange: Principles of ion exchange, techniques and applications, ion-movement theory, ion exclusion.

UNIT-VI:

Membrane Separation Processes: Basic principles of membrane separation, classification of membrane processes – pressure driven, concentration gradient driven, electric potential driven processes – brief introduction on reverse osmosis, nanofiltration, ultrafiltration, microfiltration, pervaporation, dialysis, membrane extraction, electrodialysis. Types of synthetic membranes – microporous, asymmetric, thin-film composite, electrically charged and inorganic membranes. Membrane modules - industrial applications.

Outcomes:

After completing the course the student will be able to:

- Analyse liquid-liquid equilibrium data.
- Design single stage and multi stage liquid extractors.
- Make calculations using psychometric charts for humidification and drying operations.
- Prepare the adsorption isotherm, screen and design adsorption equipment.
- Identify and analyse the membrane separation processes based on the driving force.
- Identify the membranes and design membrane modules for particular use.

Text Books:

1. Mass transfer operations by R.E. Treybal, 3rd Edition, McGraw Hill, 1980.
2. Unit Operations of Chemical Engineering, W.L. McCabe, J.C. Smith & Peter Harriott, McGraw- ill, 6th Edition, 2001.
3. Membrane Separation Processes, KaushikNath, PHI, 2008

Reference Books:

1. Coulson and Richardson's Chemical engineering, Vol 1,Backhurst, J.R., Harker,J.H.,Richardson, J.F., and Coulson,J.M., Butterworth-Heinemann, 1999.
2. Coulson and Richardson's Chemical engineering, Vol 2, Richardson, J.F. &Harker,J.H. with Backhurst, J.R., Butterworth-Heinemann, 2002.

3. Principles of Mass Transfer and Separation Processes, Binay K. Datta, PHI Learning Private Ltd., 2009.
4. Diffusion: Mass Transfer in Fluid Systems, Cussler, E.L., Cambridge Univ. Press, 1984.
5. Design of Equilibrium Stage Processes, B.D.Smith, McGraw-Hill, 1963.
6. Staged Cascades In Chemical Processing, P.L.T.Brian, Prentice-Hall, 1972.
7. Equilibrium Staged Separations, Phillip C.Wankat, Prentice-Hall PTR, 1988.
8. Equilibrium-Stage Separation Operations in Chemical Engineering, E.J.Henley and J.D.Seader, John Wiley & Sons, 1981.
9 Transport Processes and Unit Operations by Christie J. Geankoplis, 4th Edition, PHI, 2009.
10. Separation Processes, C.J. King, 2nd Edition, McGraw- Hill, 1980.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

PROCESS DYNAMICS & CONTROL

Learning objectives:

- To understand and be able to describe quantitatively the dynamic behavior of process systems.
- To learn the fundamental principles of control theory including different types of controllers and control strategies.
- To learn how to estimate the stability limits for a system, with or without control.
- To calculate and use the frequency response of a system.
- To describe quantitatively the behavior of simple control systems and to design control systems.
- To gain a brief exposure to advanced control strategies.
- To learn how to tune a control loop and to apply this knowledge in the industry/laboratory.
- To learn the different types of control valves and design of the control valve**.**

UNIT-I:
Introduction to process dynamics and control, Response of First Order Systems - Physical examples of first order systems
Response of first order systems in series, higher order systems: Second order and transportation lag.

UNIT-II:
Control systems Controllers and final control elements, Block diagram of a Petrochemical rector control system.

UNIT-III:
Closed loop transfer functions, Transient response of simple control systems.

UNIT-IV:
Stability Criterion, Routh Test, Root locus, Transient response from root locus, Application of root locus to control systems Introduction to frequency response, Control systems design by frequency response.

UNIT-V:
Advanced control strategies, Cascade control, Feed forward control, ratio control, Smith predictor, dead time compensation, internal model control.

UNIT -VI:
Controller tuning and process identification. Control valves.

Outcomes:

At the completion of the course a student should be able to:

- Describe a process, how it works and what the control objectives are.
- Describe processes with appropriate block diagrams.
- Numerically model a process.
- Identify the stability limits of a system.
- Apply the advance control strategies.
- Tune process controllers.
- Experimentally determine the dynamic behavior of a process.
- Design and operate control valves.

Text Book:

1. Process Systems Analysis and Control by D.R. Coughanowr, 2nd ed. McGraw Hill, 1991

Reference Books:

1. Chemical Process Control, G. Stephanopolous, Prentice Hall, 1984
2. Coulson and Richardson's Chemical Engineering, Volume 3, 3rd Edition: Chemical and Biochemical Reactors and Process Control, Richardson J. F. et.al, Elsevier India, 2006.
3. Automatic Process Control, Donald P. Eckman, John wiley, Reprint 2011.
4. Process Dynamics and Control, Dale Seaborg, Thomas F. Edgar, Duncan Mellichamp, 2nd edition, Wiley India Pvt. Ltd., 2006.
5. Principles of Process Control. Patranabis, 3rd Edition McGraw-Hill Education Pvt. Ltd., 2012.
6. Industrial Process Control Systems, 2nd Edition, Dale R. Patrick, Stephon, W. Fardo, CRC Press, 2009.
7. Modern Control Systems, 11th Edition Dorf, Pearson, 2008.
8. Modern Control Engineering, Katsuhiko Ogata, 5th Edition, Prentice Hall, 2010.
9. Principles and Practices of Automatic Process Control, Carlos A. Smith, Armando B. Corripio, 3rd International Edition, John Wiley and Sons, 2005.
10. Process control: Concepts, Dynamics & Control, S. K. Single, PHI Learning, 2009.
11. Process control, Peter Harriott, Tata McGraw-Hill 1964. (10th reprint 2008).
12. Computer-Aided Process Control, S. K. Singh, PHE Learning, 2004.
13. Essentials of process control, William L. Luyben, Michacl L. Luyben, McGraw-Hill, 1997.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

PROCESS ENGINEERING ECONOMICS

Learning Objectives:

- To understand the various terms and activities related to economics which can be useful during economical evaluation of any chemical process industries.
- To understand the concepts and calculations involving time value of money, present and future worth of property
- To have the knowledge about capital recovery, depreciation and depreciation calculations
- To understand the methodology of cost estimation including fixed and variable costs by considering the concept of cost indices.
- To understand the concept of balance sheet, profit and loss accounting and income statement
- To understand the concept of profitability evaluation of project and select the best process alternative based on its economic evaluation
- To understand the concept of rate of return and payout time, and replacement of existing facilities
- To have knowledge of the economic balance in evaporation, fluid flow, heat and mass transfer, cyclic operations, reactors and inventory in process operations
- To learn about the economic analysis of a complete process
- To learn about multivariable input-output analysis for analyzing the production of chemical products

UNIT-I:
Introduction: The process industries – capital and interest – economics and the process engineer.
Value of Money – Equivalence: Value of money – equations for economic studies – equivalence – example problems – the bond problem.

UNIT-II:
Amortization: Capital recovery – depreciation – straight-line method, sinking-fund method, fixed percentage method – interest in depreciation calculations – depreciation accounting – depletion
Capital Requirements for Process Plants: Cost indices – equipment costs – the Williams six-tenths Factor – service facilities – buildings and other non-process items – capital requirements for complete plants-approximate cost estimates-detailed cost estimates – total and process investment – the balance sheet – sources of capital.

UNIT-III:
Costs, Earnings, Profits and Returns: Variable costs – fixed costs-explanation of individual items of fixed costs-interest as an Item of cost – using cost data-cost studies-the Income statement-income statement ratio – profits and earnings-a discussion of theoretical economy and accounting-analysis of the income statement – economic production charts – capacity factors – incremental costs – differential analysis of economic production charts

Economics of Selecting Alternates: Annual cost method – present worth method – equivalent alternates.

UNIT-IV:

Rates of Return and Payout Time – Replacements: Rate-of-return method – payout-time method – effect of source of capital – nonproductive investments and taxes – consideration of capacity factor – replacement of existing facilities – irreducible factors in economic analyses.

Economic Balance: Economic balance in evaporation – economic vessel design – economic balance in fluid flow, heat transfer and mass transfer - economic balance with two variables, combined operation-combined operations with one variable- combined operations with two variables, combined operations with alternates

UNIT-V:

Economic Balance in Cyclic Operations: Batch operations (fixed cycle time) – batch operations (variable cycle time) – multiple equipment units – semicontinuous operations.

Economic Balance in Reactors: Economic analysis for variable feed and product grades, variable recovery – economic balance for waste stream concentrations – economic balance for yield in process operations-yield in a batch reactor (catalytic or noncatalytic)-yield in continuous multistage reactors (noncatalytic)- yield in a flow reactor (catalytic)

UNIT-VI:

Economic Balance and Inventory in Process Operations: Semicontinuous operations – batch operations – non-repetitive operations – process inventory considerations – the general case of inventory – general summary of economic balance.

Economic Analysis of A Complete Process: Operating plants-appraised value-earning value-stock and bond value – proposed plants-capital requirements-estimated annual returns – evaluation – reliability of cost estimates.

Outcomes: After the course work, the students will be able to

- become familiar with various aspects related to economics and can apply them for economic evaluation of chemical process and decide its economic feasibility
- Analyze cash flow sequences and solve problems involving time value of money
- Calculate profitability, rate of return of investments and cost estimation.
- Read and understand corporate financial statements (Balance sheet, income statement, cash flow statement).
- Choose projects/equipment from a set of possible alternatives.
- Assess the impact of depreciation, taxation and other economic factors on the project's feasibility.
- Develop policies for assets replacement.
- Assess alternative financing modes.
- Make financially prudent decisions in everyday life.
- Calculate optimal sizes of new chemical processes and subsequent expansion of capacity.
- Describe multivariable input-output analysis.

Text Book:

1. Process Engineering Economics, H.E. Schweyer, McGraw-Hill, New York,1955.

Reference Books:

1. Plant Design and Economics for Chemical Engineers, M. S. Peters and K. D. Timmerhaus, McGraw Hill, 4th Ed., 1991.
2. Cost and Optimization Engineering, F.C. Jelen, McGraw-Hill, International ed., 1997.
3. Process Engineering Economics, James R. Couper, Marcel Dekkar, Inc., 2003
4. Introduction to Process Economics, F.A. Holland, F. A. Watson, J. K. Wilkinson, 2nd Edition, John Wiley & Sons, 1983.
5. Schaum's outline of engineering economics, Jose Sepulveda, William Souder, Byron Gottfried, McGraw-Hill, 1984.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

CHEMICAL REACTION ENGINEERING – II

Learning Objectives:

- To understand the basics of non-ideal flow and the concepts of RTD and conversion in non-ideal flow
- To learn the basics of diagnosing reactor ills
- To get acquainted with the dispersion model, the tanks-in-series model and the convection model for laminar flow and their applications in petrochemical reactions and conversions
- To understand the effects of earliness of mixing, segregation and RTD on conversions for a self-mixing fluid and mixing of two immiscible fluids
- To gain an overview of catalysis, catalysts, catalytic reaction mechanisms and rate limiting step
- To understand the basic concepts of heterogeneous reactions and to study the effect of mass and heat transfer resistance on the overall rate for reactions with porous catalyst particles
- To learn the experimental methods for finding rates in solid-catalyzed reactions
- To gain an insight into deactivating catalysts, mechanism of deactivation, rate and performance equations involving deactivation
- To understand the kinetics of fluid-fluid reactions and fluid-particles
- To study the shrinking core model for spherical particles of unchanging and changing sizes
- To learn about determining the rate controlling step in non-catalytic fluid particle reactions

UNIT-I:

Basics of non-ideal flow: E, the age distribution of fluid, the RTD, conversion in non-ideal flow reactors, diagonizing reactors ills (qualitative discussion only).

UNIT-II:

The dispersion model- axial dispersion, correlations for axial dispersion, Petrochemical reaction and dispersion.

The tanks in series model- pulse response experiments and the RTD, Petrochemical conversion.

The convection model for laminar flow- the convective model and its RTD, Petrochemical conversion in laminar flow reactors.

UNIT-III:

Earliness of mixing, segregation and RTD- self-mixing of a single fluid, mixing of two miscible fluids.

Catalysis and catalytic reactors- catalysts, steps in a catalytic reactions, synthesizing a rate law, mechanism and rate limiting step. (From chapter 6 Fogler).

UNIT-IV:

Heterogeneous reactions- introduction.

Solid catalyzed reaction: pore diffusion resistance combined with surface kinetics, porous catalyst particles, heat effects during reaction, performance equations for reactors containing porous catalyst particles.

UNIT-V:

Solid catalyzed reactions: Experimental methods for finding rates.

Deactivating catalysts- mechanisms of catalyst deactivation, the rate and performance equations.

UNIT-VI:

Fluid-fluid reactions: kinetics- the rate equation.

Fluid-particle reactions: kinetics- selection of a model, shrinking core model for spherical particles of unchanging size, rate of reaction for shrinking spherical particles, extensions, determination of rate controlling step.

Outcomes:

A student on completion of the course would be able to

- Carry out RTD studies on non-ideal flow reactors and determine the conversions obtained.
- Fit the experimental data to dispersion model, tanks-in-series model and the convection model and to predict the conversions that can be obtained using the above models.
- Predict the effect of earliness of mixing, segregation and RTD on conversion.
- To determine the kinetics of solid catalyzed reactions, fluid-fluid reactions, and fluid-particle reactions.
- To carry out experiments for determining the rates of solid-catalyzed reactions.
- To determine the rate of deactivation in solid-catalyzed reactions.
- To determine the rate controlling step in fluid-particle reactions.

Text Book:

1. Chemical Reaction Engineering by Octave Levenspiel 3rd ed. Wiley Eastern Ltd.

Reference Books:

1. Elements of Chemical Reaction Engineering, H.S. Fogler, 2nd Edition. PHI, 1992.
2. Chemical Engineering Kinetics, J. M. Smith, 3rd Edition. McGraw- Hill, 1981.
3. Elementary Chemical Reactor Analysis, Aris. R., Prentice-Hall, Englewood Cliffs, 1969.
4. Modeling of Chemical Kinetics and Reactor Design, Coker, A.K., Gulf Professional Publishing, 2001.
5. Fundamentals of Chemical Reaction Engineering, Davis, M.E., and R.J. Davis, McGraw-Hill, 2002.
6. Chemical Reactor Theory: An Introduction, Denbigh K.G., and J.C.R. Turner, 3rd Ed., Cambridge University Press, 1984.
7. Chemical Reactor Analysis and Design, Froment, G.B., and K.B. Bischoff, 2nd Ed., Wiley, 1990.
8. An Introduction to Chemical Engineering Kinetics and Reactor Design, C.G. Hill Jr., John Wiley, 1977.
9. Chemical Reaction Engineering: A First Course, Metcalfe, I.S., Oxford University Press, 1997.
10. Chemical Reaction Engineering and Kinetics, Missen, R.W., C.A.Mims and B.A. Saville, Wiley, 1998.

11. The Engineering of Chemical Reactions, Schmidt, L.D., Oxford University Press, New York 1998.
12. Chemical reactor design, Peter Harriott, Marcel Dekkar, 2002.
13. Reaction Kinetics for Chemical Engineers, Stanley M.Walas. Uni Publishers, 1989.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

IPR & PATENTS

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

PROCESS DYNAMICS & CONTROL LAB

Learning Objectives:

- To calibrate and determine the time lag of various first and second order instruments.
- To determine the response in single and two capacity systems with and with-out interaction.
- To understand the advanced control methods used for complex processes in the industries. Different experiments like Flow, level and cascade control can be configured and studied.
- To study the open loop (Manual control) and the on/off controller, Proportional controller, PI controller, PD controller, PID controller, Tuning of controller (Open loop and close loop methods), and to study the stability of the system (Bode plot).
- To understand the control valve operation and its flow characteristics.
- To determine the damping coefficient and response of U-tube manometer.

Experiments:

1. Calibration and determination of time lag of various first and second order instruments.
   Major equipment - First order instrument like Mercury-in-Glass thermometer and overall second order instrument like Mercury-in-Glass thermometer in a thermal well.
2. Experiments with single and two capacity systems with and without interaction.
   Major equipment- Single tank system, Two-tank systems (Interacting and Non-Interacting).
3. Level control trainer
   Major equipment - Level control trainer set up with computer.
4. Temperature control trainer
   Major equipment -Temperature control trainer with computer.
5. Cascade control
   Major equipment -Cascade control apparatus with computer.
6. Experiments on proportional, reset, rate mode of control etc.
   Major equipment – PID control apparatus
7. Control valve characteristics
   Major equipment – Control valve set up.
8. Estimation of damping coefficient for U-tube manometer
   Major equipment - U-tube manometer.

Outcomes:

The student will be able to

- Estimate the dynamic characteristics of first and second order systems.
- Apply the advanced control methods used for complex processes in the industries.
- Screen and suggest controllers like On/off, P, PI, PD and PID for process systems.
- Identify the stability of the system.
- Screen and suggest the types of control valves.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

CHEMICAL REACTION ENGINEERING LAB

Learning Objectives:

- To determine the order of reaction and rate constant using batch reactor, CSTR, and PFR and analyze the data by differential and integral methods.
- To determine the activation energy and specific reaction rate constant of a reaction of a known order using a batch reactor.
- To determine the rate constant and to study the effect of residence time on conversion in CSTR and PFR.
- To compare the experimental and theoretical values for space times and volumes of reactors when CSTR in series.
- To determine the RTD and dispersion number for packed bed and tubular reactors using tracer.

Experiments:

1. Determination of the order of a reaction using a batch reactor and analyzing the data by (a) differential method (b) integral method.
2. Determination of the activation energy of a reaction using a batch reactor.
3. To determine the effect of residence time on conversion and to determine the rate constant using a CSTR.
4. To determine the specific reaction rate constant of a reaction of a known order using a batch reactor.
5. To determine the order of the reaction and the rate constant using a tubular reactor.
6. CSTRs in series- comparison of experimental and theoretical values for space times and volumes of reactors.
7. Mass transfer with chemical reaction (solid-liquid system) –determination of mass transfer coefficient.
8. Axial mixing in a packed bed. Determination of RTD and dispersion number for a packed-bed using tracer and Determination of RTD and dispersion number in a tubular reactor using a tracer.

Outcomes: The students will be able to:

- Design experiments for the determination of the order of the reaction and reaction rate constant for new reaction systems by using batch, CSTR and PFR.
- Analyze and interpret the given reaction data by using various methods.
- Calculate the effect of flow rate; reactants on conversion in reactors (CSTR/PFR) in series.
- Distinguish the effect of residence time on conversion in CSTR and PFR.
- Use the experimental kinetic data for reactor design.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
III Year B. Tech. Chemical Engineering - II Sem.

MASS TRANSFER OPERATIONS LAB – II

Learning Objectives:

The objective of mass transfer laboratory is to help the students in understanding the basic concepts of mass transport process; to make the students familiar with the most of the separations in leaching, liquid-liquid extraction, humidification, drying and adsorption; to acquaint with the experimental procedures for the determination of transport properties; further, the students will have hands on experience in handling and operation of different types of mass transfer equipment.

Experiments:

1. Determination of binodal curve and tie line data for ternary liquid equilibrium
2. Leaching of dium carbonate from a mixture of sand + sodium carbonate using water in a single stage and three stage system (cross - current & counter-current):
   (a) Determination of mass transfer coefficients and (b) Rate of mass transfer
3. (a) Hydrodynamics of Spray column. (b) Extraction studies in sieve tray and packed columns.
4. (a) Determination of wet bulb and dry bulb temperatures (b) Construction of psychometric chart (c) Performance of cooling tower
5. Studies in batch and continuous drying.
6. Studies on the adsorption of acetic acid from aqueous solutions by charcoal/ activated carbon to determine the constants of the Freundlich and Langmuir isotherms.
7. Studies on continuous adsorption of acetic acid from aqueous solutions in activated carbon bed to determine the break-through response cureve.

Outcomes:

The student will be able to:

- Design and conduct experiments; analyze and interpret data related to mass transfer in leaching, liquid-liquid extraction, humidification and adsorption.
- Visualize and understand mass transfer operations.
- Work in teams accommodating the contributions of team members having a variety of skills and perspectives.
- Identify, formulate and solve mass transfer problems.
- Attain proficiency in written, graphical and communications.

Use techniques, skills, and modern engineering tools necessary for engineering practice.

R – 13: Chemical Engineering
4^{th}Year I – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

TRANSPORT PHENOMENA

Learning Objectives:

The student will be able to learn:

- The estimation of transport properties like mass diffusivity, thermal conductivity and viscosity.
- To identify and solve various momentum transport problems based on shell momentum balance approach.
- To identify and solve various heat transport problems based on shell energy balance approach.
- Concepts of concentration distribution in solids and in laminar flow based on shell mass balance approach.
- The derivation of the equation of continuity & equation of motion in Cartesian coordinates and curvilinear coordinates.
- The unsteady state velocity profile, temperature profile and concentration profiles for laminar flow conditions.
- Basic concepts of turbulent flow transport.

UNIT-I:

Viscosity and the mechanisms of momentum transfer: Newton's law of viscosity (molecular momentum transport), generalization of Newton's law of viscosity, pressure and temperature dependence of viscosity, molecular theory of the viscosity of gases at low density, molecular theory of the viscosity of liquids.

Thermal conductivity and the mechanisms of energy transport: Fourier's law of heat conduction (molecular energy transport), temperature and pressure dependence of thermal conductivity, and theory of thermal conductivity of gases at low density.

Diffusivity and the mechanisms of mass transport: Fick's law of binary diffusion (molecular mass transport), temperature and pressure dependence of diffusivities, theory of diffusion in gases at low density.

UNIT-II:

Shell momentum balances and velocity distributions in laminar flow: shell momentum balances and boundary conditions, flow of a falling film, flow through a circular tube, flow through annulus, flow of two adjacent immiscible fluids, creeping flow around a sphere.

UNIT-III:

Shell energy balances and temperature distributions in solids and laminar flow: shell energy balances; boundary conditions, heat conduction with an electrical heat source, heat conduction with a nuclear heat source, heat conduction with a viscous heat source, heat conduction with a Petrochemical heat source, heat conduction through composite walls, heat conduction in a cooling fin, forced convection, free convection.

UNIT-IV:

Concentration distributions in solids and laminar flow: shell mass balances; boundary conditions, diffusion through a stagnant gas film, diffusion with a heterogeneous Petrochemical reaction, diffusion with a homogeneous Petrochemical reaction, diffusion into a falling liquid film (gas absorption), diffusion into a falling liquid film (solid dissolution), diffusion and Petrochemical reaction inside a porous catalyst.

UNIT-V:

The equations of change: Derivation of the equation of continuity in Rectangular and Polar coordinates, the equation of motion, the equation of energy, the equation of continuity of a component in multi component mixture (in rectangular coordinates only), the equations of change in terms of the substantial derivative.

Use of equations of change to solve one dimensional steady state problems of momentum, heat and component transfer

UNIT –VI:

Unsteady state one-dimensional transport of momentum, heat and component transfer.

Introduction to Turbulent transport, Time smoothing of equation change, Models for turbulent flux (explanation of equations only).

Outcomes:

After completion the course, the student will be able to

- Determine diffusivity, thermal conductivity and viscosity at low and high pressure.
- Derive momentum flux and velocity distribution for typical geometries.
- Derive heat flux and temperature distribution for typical geometries.
- Derive mass flux and concentration distribution for typical geometries.
- Derive unsteady state velocity profile, temperature profile and concentration profile.
- Derive equation of change for turbulent transport.
- Analyze the momentum, heat and transport problems involved in process equipment.

Text Books:

1. Transport Phenomena by Bird R.B., Stewart W.C., Lightfoot F.N., 2nd ed. John Wiley, 1960.

Reference Books:

1. Transport Processes: Momentum, Heat and Mass, C. J. Geankoplis, PHI, Allyn and Bacon Inc., 2ndRevised Edition, 1983.
2. Transport Phenomena for Engineers by L. Theodore, International text Book Company, 1971.
3. Transport Phenomena- A Unified Approach, Robert S. Brodkey, Harry C. Hershay, McGraw-Hill International Edition, 1988.
4. Transport Phenomena and Unit Operations-A combined Approach, Richard G. Griskey, John Wiley, 2002.
5. Mass Transport Phenomena, Christie J. Geankoplis, Ohio State Univ Bookstore, 1984.
6. Modeling in Transport Phenomena: A Conceptual Approach, Ismail Tosun, Elsevier, 2002.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

CHEMICAL ENGINEERING PLANT DESIGN

Learning Objectives:

- To get an overview of plant design and to study the general design considerations
- To understand the development of design database-process creation, process design, process flow diagrams, piping & instrument diagrams.
- To learn the general procedure for flow sheet synthesis and development.
- To understand the basic concepts of materials handling equipment and design.
- To learn the basic theory of heat transfer in heat exchangers and design of heat exchangers.
- To understand the selection of suitable separation process.
- To learn about reactor design procedure and selection of reactor and catalysts.

UNIT-I:

Overview of plant design: General overall design considerations-Process design development-Flow sheet development-Computer aided design-Cost estimation

General design considerations: Environmental protection-Plant location-Plant layout-Plant operation & control.

UNIT-II:

Development of design: Development of design database-Process creation-Process design-Process flow diagrams-Process design-Piping & instrument diagrams.

Flow sheet synthesis and development: General procedure-Process information-input/output structure-Function diagrams-Operations diagrams-Process flow sheet - Algorithmic flow sheet generation.

UNIT-III:

Materials-handling equipment & design: Basic concepts-Piping in fluid transports processes-Pumping of fluids-Compression and expansion of fluids-Compression and expansion of fluids-Agitations and mixing of fluids-Flow measurement- Storage & containment of fluids-Transport of solids-handling of solids.

UNIT-IV:

Heat transfer equipment design: Basic theory of heat transfer in exchangers-Determination of heat transfer coefficients and pressure drops-Selection of heat exchanger type-Design of key heat exchanger types-Optimum design of heat exchangers.

UNIT-V:

Separation equipment design: Selections of suitable separation processes-Equipment for distillation, absorption, stripping, humidification and filtration.

UNIT-VI:

Reactor equipment design: Reactor and catalyst equipment-Selection of catalysts-Types of reactors-Selection of reactors-Design of reactor systems-Procedure for reactor design.

Outcomes:

- Understand the basic principles of plant design and the general design considerations.
- Ability to develop process design, flow diagrams, piping and instrumentation diagrams, including flow sheet synthesis and development.
- Gain basic insights into the design of equipment pertaining to materials handling, heat transfer, separation processes, and reactors, both catalytic and non-catalytic.

Text Book:

1. Plant Design & Economics for Chemical Engineers, Max Peteres, Klaus D. Timmerhaus, Ronald West, 5th Edition, Tata McGraw-Hill, 2011.

Reference Books:

1. Chemical Engineering Design, R.Sinnot and Gavin Towler, 5th Edition, Butterworth-Heinmann, 2009.
2. Applied Process Design for Chemical & Petro Chemical Plants, E.E Ludwizg, Vol-1,2 & 3, Gulf professional publishing, 3rd Edition, Elsevzier,2001.
3. Chemical Process Equipment Selection & Design, J.R. Couper, W.R.Penny, J.R. Fair, & S. M. Walas, Revised 2nd Edition, Butterworth-Heinemann, 2010.
4. Introduction to Process Engineering and Design, S.B.Thakore and B.I.Bhatt, Tata McGraw-Hill, 2007.
5. Chemical Processing Engineering: Design & Economics, H.Silla, Marcel Dekkar, Inc., 2003.
6. A Guide to Chemical Engineering Process Design & Economics, Gael D.Ulrich, Process Publishing, 1984.
7. Process Engineering and Design Using Visual Basic, Arun Datta, CRC Press, 2008.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

PROCESS MODELING & SIMULATION

Learning Objectives:

Existing and ongoing trends in chemical engineering require systematic analysis of complex chemical processes through the medium of process modeling and simulation. The following objectives need to be achieved through the course on process modeling and simulation:

- Basic philosophy of process model development and simulation for chemical engineering processes.
- Theory of numerical methods applicable for the solution of linear and non-linear system of equations.
- Theory of numerical differentiation, integration and regression.
- Modeling of chemical processes using partial differential equations.

UNIT-I:

Mathematical models for chemical engineering systems-Fundamentals-Introduction to fundamental laws.

UNIT-II:

Examples of mathematical models of chemical engineering systems- Constant volume CSTRS- Two heated tanks-Gas phase pressurized CSTR-Non isothermal CSTR.

Examples of single component vaporizer- Batch reactor-Reactor with mass transfer-Ideal binary distillation column- Batch distillation with holdup.

UNIT-III:

Numerical methods for simulation-I: Iterative methods-Bisection, false position, Newton–Raphson, successive approximation methods- Comparison of iterative methods-Solution of linear simultaneous algebraic equations- Computation of eigen values and eigen vectors- Gauss elimination method- Gauss-Jordan and Gauss-Seidel's method.

UNIT-IV:

Numerical methods for simulation-II: Numerical integration by trapezoidal and Simpson's rules-Numerical solution of differential equations-Euler method, Runge-Kutta fourth order method-Milne predictor corrector method.

Interpolation, Lagrange interpolation-Forward difference-Backward difference and central difference interpolation methods-Least square approximation of functions-Linear regression-Polynomial regression.

UNIT-V:

Computer simulation examples: Gravity flow tank- Three CSTRs in series-Binary distillation column- Batch reactor-Simulation of Non-isothermal CSTR-VLE dew point, bubble point calculations - Countercurrent heat exchanger.

UNIT-VI:

Application of solution of partial differential equations in simulation: Techniques for convective problems-Unsteady state steam heat exchanger-Techniques for diffusive problems-Unsteady state heat conduction in a rod.

Outcomes: After the course, the students will have

- Ability to formulate simple and complex mathematical models to simulate chemical engineering processes such as reactors and distillation columns.
- Working knowledge of numerical methods for simulation to solve system of linear and non-linear system of equations.
- Fundamental and working knowledge of general numerical integration and differentiation approaches.
- Working knowledge of linear and non-linear regression.
- Coding of various process models in competent software platforms such as MATLAB etc.,
- Theoretical and Working knowledge of chemical engineering process models with partial differential equations.

Text Books:

1. Process Modeling, Simulation and Control for Chemical Engineers by W. L. Luyben, McGraw Hill, 2nd Edition, 1990.
2. Numerical Methods for Engineers, S.K. Gupta, New Age International, 1995.
3. Computational Methods for Process Simulation, W.F.Ramirez, 2nd Edition, Butterworth-Heinmann, 1997.

Reference Books:

1. Modeling and Simulation in Chemical Engineering, Roger G.E. Franks, Wiley-Interscience, 1972.
2. Chemical Engineering: Modeling, Simulation and Similitude, T.G. Dobre, J. G. Sanchez Marcano, Wiley-VCH., 2007.
3. Applied Mathematics and Modeling for Chemical Engineers, R. G. Rice, D. D. Do, John Wiley & Sons, 1995.
4. Chemical Process Modeling and Computer Simulation, Jana Amiya K. 2nd Edition, PHI learning, 2011.
5. Numerical Simulation of Fluid Flow and Heat, Mass Transfer process, N. C. Markatos, D. G. Tatchell, M. Cross; Springer, 1986.
6. Process Simulation, W. Fred Ramirez, Lexington Books, 1977.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

BIOCHEMICAL ENGINEERING

Learning Objectives:

- To have an overview of the basic structure and function of important cell types, RNA and DNA, amino acids and proteins
- To learn about enzyme structure, function and kinetics of enzyme catalyzed reactions
- To learn about immobilization of enzymes, industrial applications and understand immobilized enzyme kinetics
- To learn about the kinetics of cellular growth, models for cellular growth, and thermal death kinetics of cells and spores
- To understand the various metabolic pathways, biosynthesis, transport across cell membranes, end products of metabolism and stoichiometry of cell growth and product formation
- To get acquainted with design and analysis of various bioreactors and also to have an overview about fermentation technology

UNIT-I:
Introduction to Microbiology: Biophysics and the cell doctrine, the structure of cells, Important cell types, from nucleotides to RNA and DNA, amino acids into proteins.

UNIT-II:
Kinetics of Enzyme catalyzed reaction: The enzyme substrate complex and enzyme action, Simple enzyme kinetics with one and two substrates, other patterns of substrate concentration dependence, Modulation and regulation of enzyme activity, other influences on enzyme activity.

UNIT-III:
Immobilized Enzyme technology: Enzyme immobilization, Industrial processes, utilization and regeneration of cofactors, Immobilized enzyme kinetics: Effect of external mass transfer resistance, Analysis of intra-particle diffusion and reaction.

UNIT-IV:
Kinetics of cellular growth in batch and continuous culture, Models for cellular growth – Unstructured, structured and cybernetic models, Thermal death kinetics of cells and spores.

UNIT-V:
Introduction to metabolic pathways, Biosynthesis, Transport across cell membranes, End products of metabolism, Stoichiometry of cell growth and product formation.

UNIT–VI:
Design and analysis of Biological reactors: Batch reactors, fed-batch reactors, Enzyme catalyzed reactions in CSTR, CSTR reactors with recycle and cell growth, Ideal plug flow reactors, Sterilization reactors, Sterilization of gases, packed bed reactors using immobilized

catalysts. Fermentation technology: Medium formulation, Design and operation of a typical aseptic, aerobic fermentation process.

UNIT–VII:

Transport phenomena in Bioprocess systems: Gas-liquid mass transfer in cellular systems, determination of oxygen transfer rates, overall k_La' estimates and power requirements for sparged and agitated vessels, scaling of mass transfer equipment, heat transfer.

UNIT – VIII:

Downstream Processing: Strategies to recover and purify products; Separation of insoluble products-filtration and centrifugation; cell disruption-mechanical and non-mechanical methods; **Separation of soluble products:** liquid-liquid extractions, membrane separation (dialysis, ultra filtration and reverse osmosis), chromatographic separation-gel permeation chromatography, electrophoresis, final steps in purification – crystallization and drying.

Outcomes:

The expected outcomes are that the student

- Will become familiar with basic cell structure and biomolecules.
- Understand the basic principles of gene expression, translation, transcription, regulation and protein synthesis, RNA and DNA
- Grasp the mechanisms and energetics of biomolecule and cell conformation and differentiation, ionic transport and cell communication
- Develop a clear picture of what enzymes are, what their functions are and analyses the kinetics of enzyme catalyzed reactions.
- Demonstrate a clear understanding of immobilized enzyme technology and the kinetics involved.
- Apply the above knowledge to the basic analysis and design of bioreactors.

Text Books:

1. Biochemical Engineering Fundamentals, J.E.Bailey and D.F.Ollis, 2nd Edition, McGraw Hill, 1986.
2. Bioprocess Engineering, Michael L. Shuler and Fikret Kargi, 2nd Edition, Prentice Hall, 2002.

Reference books:

1. Biochemical Engineering, James M.Lee, Prentice-Hall-1992.
2. Biochemical Engineering, Aiba, Humphrey and Mells, Academic press, 1973.
3. Bioprocess Engineering principles, Pauline M. Doran, Academic Press, 2012.
4. Biochemical Engineering, H.W. Blanch and D.S. Clark, Marcel Dekker, 1997.
5. Introduction to Biochemical Engineering, D.G.Rao, Tata McGraw-Hill, 2008.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

OPEN ELECTIVE
INDUSTRIAL POLLUTION CONTROL ENGINEERING

Learning objectives:

- Pollution is a worldwide, global problem. In an industrially developing country like India, industrial pollution is going to be a potential threat to the public health and it's good. The issue is to be emphatically addressed to the future generation for their welfare. Industrial growth cannot be under mined and the environmental pollution resulting due to phenomenal industrial growth is to be monitored with extreme care and caution. This course, essentially deals with the technology and techniques to reduce the dangerous levels of pollutants in the atmosphere.
- The student is informed about the emissions from chemical industries, and guidelines set by the environmental protection agencies for maintaining clean-air. Standards for the level of pollutants from the industries have been given for subsequent monitoring.
- For monitoring, the student is required to know the characterization of industrial effluents, BOD, COD, TOC values, methods of determination of these characteristic, for all types of pollutants from all chemical and petroleum industries.
- Having given information about the characterization, the student is made conversant with various methods of treatment- primary as well as tertiary treatments. The course offers latest techniques such as Ion exchange, RO, Ultra filtration, along with the conventional systems already existing.
- Treatment of wastewaters (in the effluent streams) - Processes, Methods and equipment needs are presented for their subsequent applications.
- Monitoring methods are taught for pollution control. Sampling methods for acquiring samples and their analysis are discussed.
- The student is acquainted with the various control methods and equipment required for control has been discussed for suitably designing the appropriate process and equipment for a given industrial pollutant.

UNIT-I:
Types of emissions from Chemical industries and Effects of environment, Environment legislation, Type of pollution and their sources, Effluent guidelines and standards.

UNIT-II:
Characterization of effluent streams, Oxygen demands and their determination (BOD, COD, and TOC), Oxygen sag curve, BOD curve mathematical, Controlling of BOD curve, Self-purification of running streams, Sources and characteristics of pollutants in fertilizer, paper and pulp industry, petroleum and petroleum industry.

UNIT-III:

Methods of Primary treatments: Screening, Sedimentation, Flotation, Neutralization, and methods of tertiary treatment.

Brief studies of Carbon absorption, Ion exchange, Reverse osmosis, Ultra filtration, Chlorination, Ozonation, treatment and disposal

UNIT-IV:

Introduction to waste water treatment, Biological treatment of wastewater, Bacterial and bacterial growth curve, Aerobic processes, Suspended growth processes, Activated aerated lagoons and stabilization ponds, Attached growth processes, Trickling filters, Rotary drum filters, and Anaerobic processes.

UNIT-V:

Air pollution sampling and measurement: Types of pollutant and sampling and measurement, ambient air sampling: Collection of gaseous air pollutants, Collection of particulate air pollutants. Stack sampling: Sampling system, Particulate sampling, and gaseous sampling.

UNIT-VI:

Air pollution control methods and equipments: Source collection methods: raw material changes, process changes, and equipment modification.

Cleaning of gaseous equipments particulate emission control: Collection efficiency, Control equipment like gravitational settling chambers, Cyclone separators, fabric filters, ESP. Scrubbers and absorption equipment

Outcomes:

- A course of this nature makes the student socially conscious about the methods for a clean environment. After knowing the technology of reducing pollutant levels in the environment, he can deal with the efficient treatment of effluent streams, (liquids, solids and gaseous streams) and design water / sewage treatment systems at an affordable cost.
- The information given in the course may help the student to monitor the environmental pollutants in the respective industry and try to implement the techniques and methods highlighted in the above course to the best of his ability.

Text Book:

1. Environmental Pollution and Control Engineering, Rao C. S., Wiley Eastern Limited, India, 1993.

Reference Books:

1. Pollution Control in Process Industries, S.P. Mahajan, TMH., 1985.
2. Waste Water Treatment, M.Narayana Rao and A.K.Datta, 3rd Edition, Oxford and IHB, 2008.
3. Industrial Pollution Control and Engineering, Swamy AVN, Galgotia publications, 2005.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

OPEN ELECTIVE
DESIGN AND ANALYSIS OF EXPERIMENTS

Learning Objectives:

- The general philosophy of designing and carrying experiments and analyzing the data generated from experiments.
- Factorial and fractional factorial designs and their relevance to simultaneously increase experimentation efficiency and reduce cost.
- Mathematical methodologies for the efficient analysis of the data generated from experimentation to instill confidence in the data for utilization towards industrial process modeling and simulation efforts.
- Linear and non-linear regression analysis.
- Overview of various software packages for statistical design and analysis of experiments.

UNIT-I:
Introduction to probability, Probability laws, Baye's theorem, Probability distributions, Parameters and statistics

UNIT-II:
Normal and t-distributions, Central limit theorem, Random sampling and declaration of independence significance tests

UNIT-III:
Randomization and blocking with paired comparisons significance tests and confidence interval for means, variances, proportions and frequencies.

UNIT-IV:
Analysis of variance, Experiments to compare k-treatment means

UNIT-V:
Two-way factorial designs, blocking, Yate's algorithm
Fractional factorial designs at two levels, Concept of design resolution

UNIT-VI:
Simple modeling with least squares (Regression analysis), Matrix versions of normal equations

Course Outcomes

A student with sound knowledge in this course shall be able to do the following tasks:

- Design an experiment with minimal experimental runs and maximum diversity in the data obtained.
- Analyze obtained data for its consistency to represent the natural phenomena associated in the experiment

- Improve experimental approaches by rigorous data analysis
- Utilization of probability and statistical knowledge to define and refine experimental data consistency.
- Develop process models using linear and non-linear regression for experimental data. Analyze the competence of regressed models to represent experimental data.

Text Book:

1. Statistics for Experimenters, G.E.P. Box, William G. Hunter and J.S. Hunter, John Wiley & Sons. 1978.

Reference Books:

1. Design and Analysis of Experiments, D.C. Montgomery, 2^{nd} Edition John Wiley and Sons, 1984.
2. Design of Experiments in Chemical Engineering: A Practical Guide, Zivorad R. Lazic, Wiley – VCH, 2005.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

OPEN ELECTIVE
GREEN FUEL TECHNOLOGIES

Learning Objectives:
The students will be imparted the knowledge of:

- Various green fuel technologies available worldwide.
- Production of Bio-ethanol from crops, molassel and cellulosic bio mass.
- Production of Bio-diesel from plant seeds, algae, and by utilizing supercritical process.
- Methane gas production utilizing bio digesters.

UNIT-I
Introduction: Plant based biofuels- World biofuels scenario- Thermochemical conversion of biomass to liquids and gaseous fuels.

UNIT-II
Bioethanol from crops – Cane sugar: Production of ethanol from molasses - Bioethanol from starchy biomass: Production of starch Saccharifying enzymes - Hydrolysis and fermentation.

UNIT-III
Bioethanol from lignocellulosic biomass: Pretreatment of the substrates-Production of Cellulases and Hemicellulases- Hydrolysis and fermentation.

UNIT-IV
Biodiesel production technologies and substrates- Lipase-catalyzed preparation of biodiesel-Biodiesel production with supercritical fluid technologies; Biodiesel from algae: Algaculture-Challenges-Algaculture for biodiesel production

UNIT-V
Biodiesel from different plant seeds: Palm oil diesel production and its experimental test on a diesel engine - Biodiesel production using karanja (pongamia pinnata) and jatropha (jatropha curcas) seed oil - Biodiesel production form rubber seed oil and other vegetable oils.

UNIT-VI
Microbial production of methane: Different types of bio-digesters and biogas technology in India.

Outcomes:
The students will have basic knowledge on:

- What are green fuel technologies
- How bio-ethanol, bio diesel & Methane are produced from crops, cellulosic biomass, plant seeds & bio digester.

TEXT BOOKS:

1. Hand book of Plant Based Biofuels, Ashok Pandey, CRC Press, 2009.
2. Biofuels Engineering Process Technology, Caye M. Drapcho, Nghiem Phu Nhuan, Terry H. Walker, McGraw-Hill, 2008.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

Elective-I

ADVANCED SEPARATION TECHNOLOGY

Learning Objectives:

- Theoretical and working knowledge of various industrial separation processes
- Theoretical knowledge of advanced distillation with special emphasis towards complex and dividing wall distillation columns.
- Theoretical knowledge of Heat integration of distillation columns
- Theoretical knowledge of Azeotropic distillation; extractive and pressure swing distillation
- Process model development for industrial separation technology
- Elementary knowledge of membrane separation processes

UNIT-I:

Characteristics of Separation Processes: Mass and energy agents, Equilibrium processes and rate governed processes, Selection of separation processes factors influencing the choice of a separation process, Degree of freedom analysis for an absorber, two product distillation column, pattern of change in concentration and temperature distribution along the column for binary and multicomponent multistage separations.

Thermodynamic analysis of Processes: Concept of availability and lost work, Calculations on lost work for a simple two product distillation column.

UNIT-II:

MESH models for computer solution (only teach hoe the equations are arranged to ease a computer solution, no simulation). Heat integrated and divided wall distillation columns to minimize energy consumption.

UNIT-III:

Azeotropic distillation, Extractive distillation and Pressure swing distillation, How to select entrainers for Azeotropic and Extractive distillation, Industrial applications of these distillation techniques.

Residue curve Maps: Introduction, Explaining the concepts using ternary diagrams, Direct and indirect splits, distillation boundaries, Identifying feasible and infeasible products in distillation and their use in selecting entrainers for distillation.

UNIT-IV:

Reactive distillation: Introduction, Industrial applications and mathematical model development (Only the model development no simulation)

Batch distillation: Introduction, Industrial applications and mathematical model development using Fenske assumption (Only the model development no simulation).

UNIT-V:

Introduction to Multicomponent Absorption; Industrial applications; Model development for Kremser equation solvent loss. Introduction of adsorbers, cryogenic separations, supercritical fluid extraction, chromatographic separations.

UNIT-VI:

Introduction to Membrane Separation Technologies; Types of membrane materials; Types of membrane processes: Gas permeation, Reverse osmosis, Microfiltration, Ultrafiltration, Nanofiltration, Electro-dialysis, dialysis; Membrane process models: Solution-diffusion model; Resistances and series model; Concept of concentration polarization; Process design calculations and industrial applications.

Outcomes:

A student proficient in the Advanced Separation Technology course shall be able to address the following:

- For a given separation problem, identify the most relevant separation technology based on physical properties.
- Thermodynamic analysis of distillation columns.
- Working knowledge of complex and dividing wall distillation columns; heat integrated distillation columns; azeotropic, extractive and pressure swing distillation columns.
- For the identified separation technology, carry out process mass balances and design calculations.
- Prominent industrial applications of advanced separation technologies.
- Possible scope for membrane technologies in process industries.

Text Books:

1. Separation Process, C. Judson King, Mc Graw Hill, 1982.
2. Separation Processes Design, J. Sieder and E.J. Henley, Wiley John Sons Publishers, 1998.
3. Membrane Separations, M.H.V. Mulder, Springer Publications, 2007.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

Elective – I
NANOTECHNOLOGY

Learning Objectives:

- Properties of Nano-materials
- Characterization of nano-materials
- Synthesis approaches for nano-materials from chemistry perspective
- Synthesis technologies for nano-materials from process perspective
- Applications of nano-science, nano-technology and nano-materials

UNIT-I:
The big world of Nano-materials: History and scope, can small things make a big difference? Classification of Nano structured material, fascinating nano structures.
Unique properties of nano-materials: micro structures and defects in nano crystalline materials, effects of nano dimensions on materials behavior.

UNIT-II:
Synthesis Routes: Bottom-up approaches, Top-down approaches, Consolidation of nano powders.

UNIT-III:
Applications of Nano-materials: Nano electrons, micro and nano electro mechanical systems, nano sensors, nano crystal, food and agriculture industry, cosmetics, consumers goods, structure and engineering automotive industry, water treatment, and environment, nano medical applications, textiles, paints, energy, defenses and space applications, structure applications.

UNIT-IV:
Tools to characterize Nano- materials: X-ray diffraction (XRD), Small Angle X-ray Scattering (SAXS), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), Field Ion Microscopy (FIM), 3-Dimensional Atom Probe (3-DAP), Nano-indentation.

UNIT-V:
Classification of Nano-materials; Inter molecular forces in organic polymerics, Aqueous, Biological, Vander-waal, Electro static, Double layer forces in acid phase and acid base systems.

UNIT-VI:
Depletion interactions, Hydro phobic forces layering, Mesoscale thermodynamics of Nano scale particles. Gibbs treatment of interfaces, Mesoscale fluid dynamics, thin films.

Outcomes:

A student proficient in nanotechnology shall be able to do the following tasks

- Sound knowledge of chemistry specific approaches for nano-material synthesis
- Working knowledge of various nano-particle fabricating technologies
- Prominent applications of nano-technology
- Working principles of various characterization methods for nano-technology
- Identify and Quantify various intermolecular forces that exist at the nano-scale
- Working knowledge of thermodynamics at the nano-scale

Text Books:

1. Text book of Nano-Science and Nano-Technology, Murthy B.S., Shankar P., Baldev Raj, B. B. Rath and James Murday, Universities Press India Limited, Hyderabad, 2013(Units-I –IV).
2. Nano Materials & Introduction to synthesis, properties and application, Dieter Vollath, wiley vch, 2006 (Units-V–VI).

Reference Book:

1. Introduction to Nano-science and Nanotechnology, K.K. Chattopadhyay and A. N. Banerjee, PHI, 2009.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

Elective –I
POLYMER TECHNOLOGY

Learning Objectives:

The student will be able to learn:

- Basic fundamentals of polymer technology and classification of polymers.
- Different methods of polymerization and comparison between among them.
- Kinetics of addition polymerization.
- Different methods to measure molecular weight and size of a polymer.
- Crystallinity of polymers and determination of properties of polymers with deformation.
- Thermodynamics of polymer mixtures like Flory Huggins theory, free volume theory, free volume theory with diffusion.
- Role of additives like antioxidants, plasticizers, lubricants, stabilizers, inhibitors in polymers.
- Description of manufacture of few typical polymers.
- Polymer processing methods like Moulding, extrusion, calendaring and also composites and compounding.

UNIT-I:

Introduction; definitions: Polymer & macro molecule, monomer, functionality, average functionality, co-polymer, polymer blend. Plastic and resin.

Classification of polymers: Based on source, structure, applications, thermal behavior, and mode of polymerization.

Methods of Polymerization: Mass or Bulk polymerization process, Solution polymerization process, Suspension polymerization process and emulsion polymerization method comparison of merits and demerits of three methods.

UNIT-II:

Mechanism and Kinetics of Addition or Chain Polymerization: Free radical addition polymerization- Ionic addition polymerizations- Coordination polymerization- Ordination or Step growth or Condensation polymerization.

Measurement of molecular weight and size: End group analysis, Colligative property measurement, light scattering, ultra centrifugation, solution viscosity and molecular size and gel permeation chromatography, poly-electrolytes.

UNIT-III:

Polymer structure and physical properties: The crystalline melting point, the glass transition temperature, Properties involving large deformations, Properties involving small deformations, Property requirements and polymer utilization.

Thermodynamics of polymer mixtures: Introduction, criteria for polymer solubility, The Flory Huggins theory, free volume theories, free volume theory of diffusion in rubbery polymers, gas diffusion in glassy polymers, polymer-polymer diffusion.

UNIT-IV:

Degradation of Polymers, Role of the following additives in the polymers: Fillers and reinforcing fillers ii) Plasticizers iii) Lubricants iv) Antioxidants and UV stabilizers v) Blowing agents vi) Coupling agents vii) Flame retardents viii) Inhibitors.

UNIT-V:

Brief description of manufacture, properties and uses of i) Polyethylene (HDPE&LDPE), ii) Poly propylene iii) Polyvinylchloride iv) Polystyrene v) Polytetra floroethylene vi) Polymethyl methacrylate vii) Polyvinyl acetate & Polyvinyl alcohol.

UNIT-VI:

Polymer Processing: Molding, Extrusion, other processing methods (calandering, casting, coating, foaming, forming, laminating), multi-polymer systems and composites, additives and compounding.

Outcomes:

After the completion of the course will be able to

- Classify the polymers.
- Know the different methods of polymerization
- Find kinetics of addition polymerization
- Determine the molecular size and weight of polymers.
- Find glass transition temperature, phase diagrams and crystallinity of polymers.
- Find the effect of additives in polymers.
- Describe the manufacture of few typical polymers.
- Identify appropriate polymer processing methods.

Text Books:

1. Polymer Science and Technology, Joel R. Fried, Prentice Hall, 2003.
2. Textbook of Polymer Science, Billmeyer, F. W. Jr. 3rd Edition, John Wiley & Sons, 1984.
3. Textbook of Polymer Technology – I & II, R. Sinha, Biotech Pharma Publications, 2012.

Reference Books:

1. Introduction to Plastics, J.H. Brison & C.C. Gosselin, Newnes, London 1968.
2. Polymeric Materials, C.C.Winding & G.D.Hiatt Mc Graw Hill Book Co. 1961.
3. Polymer Science, Vasant R. Gowariker, N V Viswanathan, Jayadev Sreedhar, New Age International, 1986.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

PROCESS EQUIPMENT DESIGN & DRAWING LAB
(Using AUTOCAD)

Learning Objectives: The student will be trained in the following fundamentals:

- Understanding of standard symbology used to represent various pipes, valves and fittings and their use in development of P &ID (Piping & Instrument Diagram)
- Understanding of standard symbology used to represent various instruments, sensing elements, impulse lines, local & digital (DCS) instruments, pneumatic /electronic signals, controllers, control valves, complex control loops etc.
- Understanding of standard symbology used to represent process equipment.
- Preparation of standard Process Flow Diagrams using AUTOCAD with required details for Process Design.
- Preparation of standard Piping & Instrument Diagrams (P&IDS) using AUTOCAD, with required details for design of piping, instrument systems.
- Mechanical design & drawing of Heat & Mass Transfer & Storage Equipment.

Experiments

1. Drawing of flow sheet symbols.
2. Drawing of instrumentation symbols.
3. Drawing of piping & instrumentation diagrams.
4. Drawing of flow diagram of a process.
5. Mechanical aspects chemical equipment design and drawing of following equipment:
   a) Double pipe heat exchanger
   b) Shell and tube heat exchanger
   c) Absorber
   d) Distillation column with Auxiliaries
   e) Spherical Storage Vessel.

Outcomes: The student shall be able to carry out the following tasks independently:

- Create & use standard symbols for pipes, valves, fittings along with auxiliary details such as insulation, heat tracing and ultimately create pipeline numbering /specification system with details such as line size, metallurgy, rating, service, external (insulation / heat tracing) condition etc., suitable for given application.
- Create & use standard (ISA / ASME) symbols for sensing elements, instruments, signals & control loops, control valves etc.
- Draw standard Process Flow Diagram (PFD) in AUTOCAD using the steady state Simulation output (flow diagram and Heat & Material balance) with flagged stream numbers & basic stream conditions such flow, phase, pressure & temperature conditions.
- Draw a detailed Piping & Instrumentation Diagram (P&ID) in AUTOCAD as per the standard / specified details with piping specifications, instrumentation starting from sensing element to complete control loops, basic details of the equipment including nozzles, design conditions of the equipment, standard symbology to represent minor piping such as drains, instrument lead-lines etc.

- Carryout mechanical design & draw of (a) Shell & tube and Double Pipe Exchangers (b) Distillation columns & absorber and (c) Spherical storage vessel using the process design data.

Text Book:

1. Joshi's Process Equipment Design by V.V. Mahajani, S.B. Umarji, 4th Edition, Macmillan Publishers, 2009.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - I Sem.

SIMULATION LAB

Learning Objectives: The student is trained in the following fundamentals:

- Characterization of Petroleum fractions by combining hydrocarbon light-ends (represented by pure components) and heavy- ends (represented by distillation cuts) to generate pseudo-components i.e., input data
- Application & understanding of suitable Thermodynamic models for predicting the properties of various hydrocarbons, sour systems & electrolytes.
- Creation of suitable flow chart with pipe segments, valves, mixers, splitters, flash drums, two / three phase separators, reactors, columns, heat exchanges, columns and various other unit operations for the give application.
- Steady state simulation of the plant /equipment & hydraulic systems for (a) performance prediction / adequacy check called "rating" and (b) and for design purpose called 'sizing"
- Generate output date files with stream data (heat & material balance), equipment duty / design features, hydraulic capacity etc.

The following experiments have to be conducted using C/C++/ Simulink using MATLAB/UNISIM:

1. Benzene-Toluene distillation Column
2. Ethylbenzene-Styrene distillation Column
3. Flash Distillation
4. Non isothermal CSTR
5. Crude Distillation Unit
6. Hydraulic Sizing including two-phase systems
7. Thermal sizing and rating of Shell & tube heat exchanger
8. Interacting system- two tank liquid level
9. Non interacting system-two tank liquid level
10. Plug flow reactor
11. Double Pipe Heat Exchanger
12. Amine Absorber for CO_2 and H_2S.

Outcomes: The student shall be able to carry out the following tasks independently:

- Create input file for given raw data (pure components & distillation cuts) by appropriate pseudo-cut, thermodynamic model selection for hydrocarbon & sour applications
- Create additional components suitable for usage of Utility streams (Steam, Boiler Feed water, Air etc.) as appropriate for the requirement.
- Simulate a process plant using a basic process flow diagram /scheme by building a simulation flow chart /environment and converging the model (a) reflecting the actual plant operating conditions, while rating and /or troubleshooting and (b) meeting the desired objectives, while designing or sizing.
- Use techniques to converge of recycle loops with minimal iterations and apply suitable accuracy margins for convergence.

- Use three-phase separation / decant techniques for moisture bearing hydrocarbons as appropriate.
- Use appropriate tray efficiencies (from literature) for various distillation applications and optimizing reflux ratio / Reboiler duties / number of trays for a given product specifications.
- Size /rate the pipeline& pumping systems for single /two phase applications and evaluate multiphase pipelines for slug /dump conditions etc.
- Carryout detailed thermal sizing or rating of shell & tube exchangers as per TEMA specifications and API guidelines.
- Generate Heat & Material Balance of the streams with required physical & chemical properties from converged simulation.

Generate sized equipment data sheets as per the industry standards with required information for detailed design / manufacture.

R – 13: Chemical Engineering
4th Year II – Semester Syllabus

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

INDUSTRIAL SAFETY & HAZARD MANAGEMENT

Learning Objectives:

- To educate in HSE in handling and storage of hazardous chemicals and in safe operation of unit operations/ unit processes like reactions, distillations, compression/expansion, and absorption/desorption etc.
- To learn the principles of designing equipment eliminating the possibilities of fire, explosion, toxic releases etc.
- To learn how to overcome hazardous situations during installation, pre-commissioning, commissioning, normal operation and/or during execution of any maintenance work.
- To learn various techniques and measures available to investigate industrial accident.

UNIT-I:

Introduction: Safety programs - Engineering ethics - Accident and loss statistics - Acceptable risk - Public perceptions - The nature of the accident process - Inherent safety.

Toxicology: How toxicants enter biological organisms - How toxicants are eliminated from biological organisms - Effects of toxicants on biological organisms - Toxicological studies - Dose Vs response - Models for dose and response curves - Relative toxicity - Threshold limit values.

UNIT-II:

Industrial hygiene: Government of India regulations and OSHA - Industrial hygiene identification - Evaluation - Control.

Source models: Introduction to source models - Flow of liquid through a hole - Flow of liquid through a hole in a tank - Flow of liquids through pipes - Flow of vapor through holes - Flow of gases through pipes - Flashing liquids - Liquid pool evaporation or boiling - Realistic and worst-Case releases.

UNIT-III:

Toxic release and dispersion models: Parameters affecting dispersion - Neutrally buoyant dispersion models - Pasqual-Gifford model - Dense gas dispersion-Case Study.

UNIT-IV:

Fires and explosions: Classification of fires - The fire triangle - Distinction between fires and explosions – Definitions - Flammability characteristics of liquids and vapors - Limiting oxygen concentration and Inerting - Flammability diagram - Ignition energy – Autoignition – Auto oxidation - Adiabatic compression - Ignition sources - Sprays and mists – Explosions. Case Study.

Designs to prevent fires and explosions: Inerting - Static electricity - Controlling static electricity - Explosion-Proof equipment and instruments – Ventilation - Sprinkler systems - Miscellaneous designs for preventing fires and explosions.

UNIT-V:

Introduction to reliefs: Relief concepts – Definitions - Location of reliefs - Relief types - Relief scenarios - Data for sizing reliefs - Relief systems.

Relief sizing: Conventional spring-Operated reliefs in liquid service - Conventional spring-Operated reliefs in vapor or gas service - Rupture disc reliefs in liquid service - Rupture disc reliefs in vapor or gas service - Deflagration venting for dust and vapor explosions - Venting for fires external to process vessels - Reliefs for thermal expansion of process fluids.

UNIT-VI:

Hazards identification: Process hazards checklists - Hazards surveys - Hazards and operability studies - Safety reviews - Other methods.

Risk assessment: Review of probability theory - Event trees - Fault trees - QRA and LOPA.

Accident investigations: Learning from accidents - Layered investigations - Investigation process - Investigation summary - Aids for diagnosis - Aids for recommendations.

Outcomes: After the course, the students will become knowledgeable in the following:

- Accessing the various hazards involved in handling hydrocarbons in Oil & Gas sector. Visualization of all possible safety issues at all the phases of industry by applying the techniques like Hazop, QRA etc.
- Steps to be followed during design stages to overcome possible safety threats.
- Measurement and monitoring of safety index.
- Fire preventing/Firefighting systems.
- Accident investigation process-Root causes analysis.

Text Book:

1. Chemical Process Safety: Fundamentals with Applications, Daniel A. Crowl, Joseph F. Louvar, 3rd Edition, Prentice Hall, 2011.

Reference Books:

1. Safety and Accident Prevention in Chemical Operations, H.H.Fawcett and W.S.Wood, 2nd Edition, John Wiley & Sons, New York 1982.
2. Guidelines For Process Safety: Fundamentals in General Plant Operations, Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1995.
3. ILO – OSH 2001.
4. Government of India: The Factories Act 1948, amended 1954, 1970, 1976 and 1987; The manufacture, storage and import of hazardous chemicals rules, 1989; The Explosives Act 1884; The Petroleum Act 1934; National policy on safety, Health and environment at workplace, Government of India; Constitutional provisions of occupational safety and health, The Constitution of India.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

ELECTIVE – II
MULTICOMPONENT DISTILLATION

Learning Objectives:
The student will be able to learn:

- VLE calculations like determination bubble point and dew point for multicomponent systems using K-values and relative volatility.
- Different shortcut procedures to calculate the equilibrium stages for given separation.
- Various rigorous calculations methods like Lewis Matheson method, Thiele –Geddes method, BP method, Tridiagonal Matrix method.
- Multicomponent flash vaporization, steam distillation and differential distillation.
- Basic concepts and details of azeotropic distillation and extractive distillation.
- Concepts for tray design and tray column sizing.
- Different packing types, packing hydraulics.
- Calculations for packing efficiency, concept of HTU and HETP concepts.

UNIT-I:
Introduction to distillation: Vapor liquid equilibrium (VLE) - K-Values and relative volatility-ideal and non-ideal systems-effect of temperature, pressure and composition on K-values and volatility-Phase diagrams-Calculations of bubble points and dew points- Azeotropes- Key fractionation concepts – Approximate material balance.

UNIT-II:
Short Cut Methods for Stage and Reflux Requirements: Pseudobinary systems-Hengstebeck method; Emperical Methods: Various methods for calculation of minimum reflux ratio- Feneske equation for minimum number of stages- FUG method-Erbar and Maddox method-Krkbride equation for feed plate location-Distribution of non-key components: Hengstebeck and Geddes method.

UNIT-III:
Rigorous Distillation Calculations: Basic concepts –Rigorous computational methods- Lewis-Matheson method and its variations-Thiele- Geddes method and its variations- B.P.method - Tridiagonal matrix method- Computations using computer programming.

UNIT-IV:
Multicomponent single stage operations: Flash vaporization- Raleigh distillation and steam distillation.
Azeotropic and extraction distillation: Concepts- Configurations and case studies.

UNIT-V:
Tray design and operations: The common tray types-Tray capacity limits-Tray hydraulic parameters- Flow regimes on trays.

Tray column sizing & tray efficiency: Tray design and tray efficiency fundamentals- Predictions of tray efficiency.

UNIT-VI:

Packing design and operations: Packing types- Classifications-Packing objectives- Packing hydraulics- Comparing tray and packing-Sizing of packed column.

Packing efficiency & predictions: The transfer unit concept-The HETP concept – Factors affecting HETP – HETP Predictions- Mass transfer models – Rules of thumb – Data interpolation.

Outcomes:

After the completion of the course the student will be able to:

- Determine bubble point and dew point for multicomponent mixtures using K-values and relative volatility.
- Determine minimum reflux ratio, minimum no. of stages, feed tray location, and distribution of key components using various shortcut methods.
- Determine the number of stages in multi-stage multicomponent towers by various rigorous calculation methods.
- Make calculations of multicomponent single stage operations like flash vaporization, differential distillation and steam distillation.
- Carry out the design of azeotropic distillation and extractive distillation systems
- Design a tray and packed columns accounting efficiency terms.

Text Books:

1. Distillation Design, Henry Kister, McGraw-Hill, 1992.
2. Distillation, Mathew Van Winkle, McGraw-Hill, 1967.

Reference Books:

1. Fundamentals of Multicomponent Distillation, C. D. Holland, McGraw-Hill, 1997.
2. Distillation Principles and Processes, Sydney Young, White Mule Press, 2011.
3. Elements of Fractional Distillation, C.S. Robinson, E. R. Gilliland, 4th Edition, 1950.
4. Distillation Design in Practice, L. M. Rose, Elsevier, 1985.
5. Distillation Tray Fundamentals, M. J. Lockett, Cambridge University Press, 2009.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

Elective –II
FLUIDIZATION ENGINEERING

Learning Objectives:
The student will be able to learn:

1. Base concepts of fluidization and its advantages and disadvantages.
2. Various industrial applications of fluidized bed.
3. Different regimes of fluidization and flow maps.
4. Geldeart classification of particles.
5. Estimation of minimum fluidization velocity.
6. Davidson model and K-L model.
7. Basic concepts of turbulent and fast fluidized bed.
8. Vertical & horizontal movement of solids.
9. Estimation of gas interchange coefficients.
10. Heat and mass transfer from the bubbling bed model.

UNIT-I:
Introduction: The phenomenon of fluidization-Liquid like behaviour of a fluidized bed-Comparison with other contacting methods-Advantages and disadvantages of fluidized beds.

UNIT-II:
Industrial applications of fluidized beds: Coal gasification-Gasoline from other petroleum fractions; Gasoline from natural and synthesis gases-Heat exchange-Coating of metal objects with plastics-Drying of solids-Synthesis of phthalic anhydride-Acrylonitrile-Polymerization of olefins-FCCU-Fluidized combustion of coal-Incineration of solid waste- Activation of carbon-Gasification of waste- Bio-fluidization.

UNIT-III:
Fluidization and mapping of regimes: Minimum fluidization velocity-Pressure drop vs. Velocity diagram-Effect of temperature and pressure on fluidization-Geldart classification of particles- Terminal velocity of particles- Transport disengaging height-Turbulent fluidization-Pneumatic transport of solids-Fast fluidization-Solid circulation systems- Voidage diagram-Mapping of regimes of fluidization.

UNIT-IV:
Bubbles in dense bed: Single rising bubbles- Davidson model for gas flow at bubbles-Evaluation of models for gas flow at bubbles.
Bubbling fluidized beds: Experimental findings- Estimation of bed Voidages- Physical models: Simple Two phase model; K-L model.

UNIT-V:
High velocity fluidization: Turbulent fluidized bed- Fast fluidization- Pressure drop in turbulent and fast fluidization.

Solids movement, mixing, segregation and staging: Vertical movement of solids- Horizontal movement of solids; Staging of fluidized beds.

UNIT-VI:

Gas dispersion and gas interchange in bubbling beds: Dispersion of gas in beds- Gas interchange between bubble and emulsion- Estimation of gas interchange coefficients.

Particle to gas mass transfer: Experimental Interpolation of mass transfer coefficients- Heat transfer- Experimental heat transfer from the bubbling bed model.

Outcomes:

After completion of the course the students will be able to

1. Identify the appropriate industrial application of a fluidized bed.
2. Determine the flow regimes of fluidization and construct the flow maps.
3. Analyse fluidization behaviour using Davidson model and K-L model
4. Find gas interchange coefficients.
5. Evaluate of heat transfer coefficients and mass transfer coefficients using bubbling bed model.
6. Determine pressure drop in a turbulent and fast fluidized bed.

Text Books:

1. Fluidization Engineering, Kunii Diazo and Octave Levenspiel, 2nd Edition, John Wiley & Sons Inc, 1991.
2. Fluidized Bed Technology: Principles and Applications, J.R. Howard, Taylor and Francis, 1989.

Reference Books:

1. Fluidization Fundamentals and Application, Howard Littman et al., American Institute of Chemical Engineers, 1970.
2. Handbook of Fluidization and Fluid Particle Systems, Wen-Ching Yang, CRC Press, 2003.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

Elective –II
CORROSION & ITS CONTROL

Learning Objectives:

- Basic concepts of material damage/degradation, its scope, and maintenance of chemical equipment will be known.
- To learn a model of electrochemical corrosion cell - this will give the basic concepts on corrosion processes occurring between Metal/Material and environment.
- To know different types of aggressive environments generally one comes across; to give the idea about how the surface of the metal/material interacts with the environments (Liquid, Gas & Solid environments).
- To train the students in the evaluation of corrosion rates, this will give the concepts of quantitative estimation for subsequent applications of remedial measures.
- To make the student conversant with the various corrosion testing methods in practice along with the latest methods developed such as impedance method, linear polarisation technique etc.

UNIT-I:
Introduction: Corrosion and oxidation, Cost of corrosion – Direct and Indirect losses due to chemical corrosion; Definitions – Extractive Metallurgy in reverse – Dry corrosion, wet corrosion – Electro chemical cell as corrosion cell – Electrochemical Mechanism of corrosion – Corrosion cells.
Corrosion Reactions: Metal / Environmental, anode, cathode and the corresponding electrode reactions – Metallurgical aspects of corrosion.
Mixed potential theory of corrosion/ Modern Theories in brief.

UNIT-II:
Corrosion Cell and Electrochemical Polarisation, over-potential/ over-voltage: Potential – current diagrams (EVANS diagrams)–Electrode potentials–EMF series–Galvanic series–Corrosion potential–Corrosion current density–Thermodynamics of corrosion as irreversible electrode process, Tafel equation for over-voltage and evaluation of corrosion rates from current – potential data;,– Corrosion rate expressions: ipy (inches per year penetration), mpy (mils per year), mdd (milligrams per decimetre square per day).

UNIT-III:
Forms of corrosion: Basis on which the corrosion processes have been categorized:
Uniform attack: A hypothetical case for comparison – Pitting factor, Examples for uniform attack
Localised corrosion: Pitting corrosion, crevice and gasket corrosion-Formation of micro climates – Filiform corrosion.

Galvanic corrosion: Electro chemical – Application of EMF in Galvanic series: Dezincification, bimetallic corrosion (two metal corrosion) – Differential concentration, differential temperature and differential stress corrosion cells.
Application of Galvanic corrosion for parting and separation

UNIT-IV:
Forms of Corrosion: Grain–Grain boundary corrosion–Intergranular Corrosion (IGC) in stainless steel (SS)–Weld decay, knife line attack – Remedial measures for IGC.
Stress corrosion cracking (SCC)–Caustic cracking (Boiler corrosion), hydrogen damage, hydrogen embrittlement, season cracking of brasses and other alloys – Remedial measures.
Fatigue Cracking–Fatigue failures in corrosive media–Remedial measures.

UNIT-V:
Corrosion Testing: Testing Panels/specimens –Preparation–Surface preparation of specimens for testing–Testing media–Static and flow of dynamic test–Effect of flow, oxidiser concentration, temperature and medium concentration.
Testing Methods: Weight loss method, corrosion rates evaluation using Faraday's laws, linear polarization techniques from current potential data–Rapid estimation of corrosion rate–Corrosion measurements gadgets–such as pitting gauge–Corrosion rate data representation–Nanographs

UNIT-VI:
Corrosion Control: Organic coatings (paints, varnishes, lacquer, anti–corrosive paints) Inorganic – Chemical conversion coatings such as, Anodizing, Phosphating, Chromating – Metallic coatings; Cladding; Design considerations–Equipment & Layout Design for easy access; Linear polarization for rapid estimation of corrosion rate; Impedance method in brief.
Cathodic protection–Anodic protection–Materials: New materials for corrosion prevention, Alloys – Composite structure – Particulate composites.
Corrosion inhibition using Corrosion inhibitors – Modification of medium.

Outcomes:

- Definitions and economic aspects would give the students a wide scope about this topic.
- Mechanism will give the student basic chemical reactions resulting in oxidation and corrosion.
- Various types of corrosion have been discussed; all these are mostly encountered in the industrial practice. This helps the students to diagnose the type of corrosion, its consequences in the deterioration of the material and its properties.
- Remedial measures and corrosion mitigation techniques, helps the student to apply the principles while designing the equipment.
- The students will be able to choose a suitable material for a given situation and apply the techniques for the protection of the material/equipment/devices.
- Students can apply the inhibition methods to modify the medium or the equipment to increase the life/longevity of the component/structure/equipment/device.

Text Books:

1. Corrosion and Corrosion control, Herbert H. Uhlig & R. Winston Revie, 4th Edition, John Wiley & Sons, 2008.
2. Corrosion Engineering, Mars G. Fontana, 3rd Edition, Tata McGraw-Hill, 2005.
3. Hand book of Corrosion Engineering, H H Uhlig, 3rd Edition, John Wiley & Sons, 2011.

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IV Year B. Tech. Chemical Engineering - II Sem.

Elective –III
COMPUTATIONAL FLUID DYNAMICS

Learning Objectives:

- Understanding the governing equations of fluid dynamics.
- The difference between conservation and non-conservations form of equations.
- Various methods available for solutions of partial differential equations.
- Use of boundary conditions for solutions of these equations.
- Understanding the role of finite elemental methods for solutions of fluid dynamics problems.
- Understanding the concept of stability.
- Understanding various softwares available for solving fluid dynamics problems.

UNIT-I:
Basic Philosophy of CFD: Governing equations of Fluid Dynamics, Incompressible Inviscid flows sources and vortex panel methods.

UNIT-II:
Mathematical properties of fluid dynamic equations – Discretization of partial differential equations

UNIT-III:
Transformations and Grids, Explicit finite Differential methods – Some selected applications to inviscid and viscous flows.

UNIT-IV:
Boundary layer equations and methods of solution

UNIT-V:
Implicit time dependent methods for inviscid and viscous compressible flows, with a discussion of the concept of Numerical dissipation

UNIT-VI:
Introduction to finite element methods in computational fluid dynamics – Weighted residual formulation – Weak formulation – Piece wise defined shape functions – Numerical integration – Partial construction of a weak formulation – Examples.

Outcomes:

- Use of finite difference method and finite volume method for practical applications.
- Use of software tools available for arriving at some problems of interest.
- Distinguishing different flow regimes while performing numerical analysis
- Use of source and vortex panel method of inviscid flow to practical problems

- Arriving at pressure and flow distribution for complicated flow systems.

Text Books:

1. Computational Fluid Dynamics: An Introduction, John F. Wendt, John David Anderson, Springer, 2009.
2. Computational Fluid Dynamics – The Basics with Applications (1-5 Chapters), John D.Anderson, Jr.McGraw – Hill, Inc., New York, 1995.

Reference Books:

1. Numerical Heat Transfer and Fluid flow, S.V. Patankar, Taylor & Francis, 1980.
2. An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Versteeg, H.K., and Malalasekera W., 2nd Edition, Prentice Hall, 2007.
3. Muralidhar, K. Sundarajan, T., Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 1995.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

Elective –III
OPTIMIZATION OF CHEMICAL PROCESSES

Learning Objectives:

- Avenues for optimization in chemical engineering systems. Importance of modeling and parametric analysis of chemical engineering processes.
- Basic mathematical concepts involved in optimization techniques.
- Theoretical knowledge of Single and Multivariable unconstrained optimization.
- Relevance of linear programming for chemical engineering systems. Solution techniques.
- Applications of optimization in chemical engineering processes.

UNIT-I:
Nature and organization of Optimization problems: Examples of applications of optimization, The essential features of optimization problems, Formulation of objective functions, General procedure for solving optimization problems, obstacles to optimization. Classification of models, model building procedures, fitting functions to empirical data, the method of least squares, factorial experimental designs, fitting a model to data subject to constraints.

UNIT-II:
Basic concepts of Optimization: Continuity of functions, uni-modal versus Multi-model functions. Convex and Concave functions, Convex region, Necessary and sufficient conditions for an extremum of an unconstrained function, interpretation of the objective function in terms of its quadratic approximation.

UNIT-III:
Optimization of Unconstrained functions: One-dimensional search: Numerical methods for optimizing a function of one variable, scanning and bracketing procedures, Newton's, Quasi-Newton's and Secant methods of uni-dimensional search, region elimination methods, Polynomial approximation methods.

UNIT-IV:
Unconstrained multivariable Optimization: Direct methods, random search, grid search, uni-variate search, simplex method, conjugate search directions, Powell's method, indirect methods-first order, gradient method, conjugate gradient method, second order gradient, Newton method, relation between conjugate gradient methods and Quasi-Newton method.

UNIT-V:
Linear programming and applications: Basic concepts in linear programming, Degenerate LP's – graphical solution, natural occurrence of linear constraints, the simplex method of solving linear programming problems, standard LP form, obtaining a first feasible solution, the revised

simplex method, sensitivity analysis, duality in linear programming, the Karmarkar algorithm, LP applications.

UNIT-VI:

Optimization of Unit operations-1: Recovery of waste heat, shell & tube heat exchangers, evaporator design, liquid-liquid extraction process, optimal design of staged distillation column. Optimal pipe diameter, optimal residence time for maximum yield in an ideal isothermal batch reactor, chemostat, optimization of thermal cracker using linear programming.

Outcomes:

A student proficient in this course shall be able to do the following tasks:

- Ability to formulate a chemical engineering process problem into an optimization problem.
- Ability to formulate a non-linear regression problem as an optimization problem
- Working knowledge of the basic concepts involved in optimization techniques.
- Working knowledge of various optimization techniques such as Newton's method, Quasi-Newton's method, Secant method, conjugate search methods, Powell method, simplex method etc.,
- Ability to solve class room linear and non-linear programming problems using a calculator.
- Apply Optimization techniques for the solution of Chemical and Refinery engineering processes.

Text Books:

1. Optimization of Chemical Processes, T. F. Edgar & Himmelblau D, Mc-Graw. Hill, 2001.
2. Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI-2009.

Reference Books:

1. Engineering Optimization: Theory and Practice, Singaresu S. Rao, 4th Edition, John Wiley & Sons, 2009.
2. Optimization Concepts and Applications in Engineering, Ashok Belegundu, Tirupathi R. Chandrupatla, Cambridge University Press, 2011.
3. Practical Optimization: Algorithms and Engineering Applications, Andreas Antoniou, Wu-Shing Lu, Springer, 2007.

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IV Year B. Tech. Chemical Engineering - II Sem.

Elective –III
COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING

Learning Objectives: The students will be able to learn

- Classification of chemical engineering process simulation models based on mathematical approaches.
- To handle Software Packages such as EXCEL, MATLAB, FEM LAB to solve chemical engineering problems.
- How to analyse and interpret results provided by SOFTWARE modeling approaches.
- Solution dependence and sensitivity on process parameter specifications.

UNIT-I:

Introduction: Algebraic equations-Process simulation- Differential equations.
Review of numerical methods and their application in fluid flow, heat transfer, phase equilibria& mass transfer operations.
Equations of state: Mathematical formulation –Solving equations of state using Excel & Solver- Solving equations of state using MATLAB with a few examples.

UNIT-II:

Vapor liquid equilibrium: Flash and phase separation, Isothermal flash–Development of equations, Example using Excel, Thermodynamic parameters-Example using MATLAB, Non ideal Liquids–Test of thermodynamic model.
Chemical reaction equilibrium: Chemical equilibrium expression- Example of Hydrogen for fuel cells, Solution using Excel & MATLAB; Chemical equilibria with two or more equations- Multiple Equations- Solutions Using MATLAB.

UNIT-III:

Mass balances with recycle streams: Mathematical formulation-Example without recycle- Example with recycle; Comparison of sequential and simultaneous solution methods- Example of process simulation using Excel for simple mass balances.

UNIT-IV:

Mass transfer operations: Multi component distillation with shortcut methods-Multi component distillation with rigorous plate-to-plate methods- Packed bed absorption & Gas plant production separation.

UNIT-V:

Chemical reactors: Mathematical formulation of reactor problems plug flow reactor and batch reactor, continuous stirred tank reactor-Using MATLAB to solve ordinary differential equations- Isothermal plug flow reactor, Non isothermal plug flow reactor- Using FEM LAB to solve ordinary differential equations- Isothermal plug flow reactor, Non isothermal plug flow reactor- Reactor problems with mole changes and variable density-Chemical reactors with mass transfer limitations- Continuous stirred tank reactors- Transient continuous stirred tank reactors.

UNIT-VI:

Transport Processes in One Dimension: Applications in chemical engineering–Mathematical formulations- Flow of a Newtonian fluid in a pipe- Flow of a non-newtonian fluid in a pipe-Transient heat transfer- Linear adsorption.

Fluid flow in two and three dimensions: Mathematical foundation of fluid flow- Entry flow in a pipe-Entry flow of a non-newtonian fluid-flow in microfluidic devices-Turbulent flow in a pipe-Start Up flow in a pipe-Flow through an orifice-Flow in a serpentine mixer-Boundary conditions-Non dimensionalization.

Outcomes:

The students well trained in the computational methods of chemical engineering shall be able to do the following tasks:

- Identify suitable software package (EXCEL, MATLAB , FEM LAB etc.,) to solve a given chemical engineering modeling problem.
- Attain proficiency to write code and utilize tools available in various softwares to solve the given problem.
- Debug and troubleshoot code for the generation of solution.
- Interpretation of software based simulation results from prior chemical engineering knowledge.
- Parametric analysis and case studies for process system analysis.

Text Book:

1. Introduction to Chemical Engineering Computing, B.A. Finlayson, John Wiley &Sons.,Inc, 2006.

References Books:

1. Applied Mathematical Methods for Chemical Engineers, Norman W. Loney, 2nd Edition, Taylor & Francis, 2007.
2. Mathematical Methods in Chemical Engineering, ArvindVerma, M. Morbidelli, Oxford University Press, 1997.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

Elective – IV
CATALYSIS

Learning Objectives: The students will be able to learn

- Basic concepts of catalyst types and their preparation
- Catalyst surface and material characterization techniques
- Reaction mechanism and its dependence on the chemistry of catalyst surfaces and reacting species
- Modeling of catalytic processes and parameter estimation for catalytic reactors
- Significance of catalysis in chemical process industries

UNIT-I:
Introduction: Homogeneous Catalysis; Bio Catalysis; Heterogeneous Catalysis; Why is Catalysis Important? The Chemical industry; Catalysis as a multidisciplinary Science.
Solid Catalysts: Requirements of a Successful Catalyst; Structure of metals, Oxides and Sulfides and their Surfaces; Characteristics of Small Particles and Porous material; Catalyst Supports; Preparation of Catalyst Supports; Unsupported Catalysts; Zeolites; Catalyst testing.

UNIT-II:
Catalyst Chracterization: X – Ray Diffraction (XRD); X – Ray Photoelectron Spectroscopy (XPS); Extended X – Ray Absorption Fine Structure (EXAFS); Electron Microscopy; Mossbauer Spectroscopy; Ion Spectroscopy: SIMS, LEIS, RBS; Temperature – programmed Reduction, Oxidation and Sulfidation; Infrared Spectroscopy; Surface science techniques.

UNIT-III:
Reaction Kinetics I: The Rate Equation and Power Rate Laws; Reactions and Thermodynamic Equilibrium; Temperature Dependence of the Rate; Integrated Rate Equations: Time Dependence of Concentrations in Reactions of Different Orders; Coupled Reactions in Flow Reactors: The Steady – State Approximation; Coupled Reactions in Batch Reactors; Catalytic Reactions;

UNIT-IV:
Reaction Kinetics II: Langmuir Adsorption Isotherms; Competitive Adsorption; Reaction Mechanisms; Langmuir – Hinshelwood or Eley – Rideal Mechanisms; Langmuir – Hinshelwood Kinetics; The Complete Solution; The Steady State Approximation; The Quasi – equilibrium Approximation; Steps with Similar Rates; Irreversible Step Approximation; Steps with Similar Rates; Irreversible Step Approximation; Nearly Empty Surface; Reaction Order; Apparent Activation Energy; Entropy, Entropy Production, Auto Catalysis and Oscillating Reactions; Kinetics of Enzyme – catalyzed Reactions.

UNIT-V:
Reaction Rate Theory: Introduction; The Boltzmann Distribution and the Partition Function; Partition Functions of Atoms and Molecules; Maxwell – Boltzmann Distribution of Velocities;

Total Partition Function of System; Translational Partition Function; Vibrational Partition Function; Molecules in Equilibrium; Collision Theory; Activation of Reacting Molecules by Collisions: The Lindemann Theory; Transition State Theory; Thermodynamic Form of the Rate Transition State Expression; Transition State Theory of Surface Reactions.

UNIT-VI:

Heterogeneous Catalysis in Industrial Practice: Steam Reforming Process; Reactions of Synthesis Gas; Water Gas Shift Reaction; Synthesis of Ammonia; Crude Oil; Hydro treating; Gasoline Production; Petrochemistry: Reactions of Small Olefins; Automotive Exhaust Catalysis.

Outcomes:

The students proficient in catalysis must

- Know various techniques for catalyst preparation including zeolites, monoliths etc.,
- Know various characterization properties a catalyst must possess for its functionality
- Know various catalyst surface and materials characterization techniques and analysis of associated results
- Be able to identify pertinent adsorption based kinetic models for existing laboratory data
- Be able to apply various reaction rate theories for industrial catalysis problems
- Have a sound knowledge with respect to the catalysis practiced in chemical industry for hydrogenation/dehydrogenation reactions, petroleum refinery processes, petrochemical processes and environmental processes.

Text Books:

1. Chorkendorff I., Niemantsverdriet J. W., (2005). Concepts of modern catalysis and kinetics, Wiley-VCH, Weinhem.
2. Viswanathan B., Sivasanker S., Ramaswamy A. V. , (2002). Catalysis: Principles and Applications, Narosa Publishing House, New Delhi.
3. Julian R. H. Ross (2011). Heterogeneous Catalysis: Fundamentals and Applications, Elseveir.

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Elective – IV
PIPELINE ENGINEERING

Learning Objectives: The students will be able to learn

- Basic concepts in design, operation and maintenance of liquid and gas pipe lines.
- Basic concepts related to the behavior of well fluids for proper designing of flow lines/trunk pipe lines.
- Procedures to obtain permissions to install pipe lines as per the State/DGMS regulations.
- Operation and maintenance of gas compressors and compressor stations.
- HSE issues of handling and transport of oil and gas.
- Pipeline integrity management techniques.

UNIT-I:

Elements of pipeline design: Fluid properties – Environment - Effects of pressure and temperature - Supply / Demand scenario - Route selection - Codes and standards - Environmental and hydrological considerations – Economics - Materials / Construction – Operation - Pipeline protection - Pipeline integrity monitoring.

Pipeline route selection, survey and geotechnical guidelines: Introduction - Preliminary route selection - Key factors for route selection - Engineering survey - Legal survey - Construction / As-built survey - Geotechnical design.

UNIT-II:

Natural gas transmission: General flow equation – Steady state - Impact of gas molecular weight and compressibility factor on flow capacity - Flow regimes - Widely used steady-state flow equations – Summary of the impact of different gas and pipeline parameters on the gas flow efficiency – Pressure drop calculation for pipeline in series and parallel – Pipeline gas velocity – Erosional velocity – Optimum pressure drop for design purposes – Pipeline packing – Determining gas leakage using pressure drop method – Wall thickness / pipe grade – Temperature profile – Optimization process – Gas transmission solved problems.

UNIT-III:

Gas compression: Types of compressors – Compressor drivers – Compressor station configuration – Thermodynamics of isothermal and adiabatic gas compression – Temperature change in adiabatic gas compression – Thermodynamics of polytropic gas compression – Gas compressors in series – Centrifugal compressor horsepower – Enthalpy / Entropy charts (Mollier diagram) – Centrifugal compressor performance curve- Reciprocation compressors.

Coolers : Gas coolers – Air-cooled heat exchangers –Heat transfer equations for coolers – Fan air mass flow rate – Required fan power – Gas pressure drop in coolers – Iterative procedure for calculations based on unknown T_2.

UNIT-IV:

Liquid flow and pumps: Fully developed laminar flow in a pipe – Turbulent flow – Centrifugal pumps – Retrofitting for centrifugal pumps (Radial-flow) – Pump station control – Pump station piping design.

Transient flow in liquid and gas pipelines: Purpose of transient analysis – Theoretical fundamentals and transient solution technique – Applications – Computer applications.

UNIT-V:

Pipeline mechanical design: Codes and standards – Location classification – Pipeline design formula – Expansion and flexibility – Joint design for pipes of unequal wall thickness – Value assemblies – Scraper traps – Buoyancy control – Crossings – Depth of cover – Aerial markings – Warning signs.

Pipeline construction: Construction – Commissioning.

UNIT-VI:

Materials selection: Elements of design – Materials designation standards

Pipeline protection, Instrumentation and Pigging: Pipeline coating – Cathodic protection – Cathodic protection calculations for land pipelines – Internal corrosion – Flow meters and their calibration – Sensors – Pigs.

Outcomes: The students will be able to

- Become pipeline engineers to supervise pipeline industry.
- Provide guidance and supervision in the repair and maintenance of pipelines.
  Plan and execute corrosion protection methods to improve the life of the pipeline.
- Become a good public relations officer in dealing public and media at the time of land acquisition & during emergency operations.

Text Books:

1. Pipeline Design and Construction: A Practical Approach, M. Mahitpour, H. Golshan and M.A. Murray, 2nd Edition, ASME Press, 2007.
2. Pipeline Engineering, Henry Liu, Lewis Publishers (CRC Press), 2003.

Reference Books:

1. Piping Calculation Manual, E. ShashiMenon, McGraw-Hill, 2004.
2. Piping and Pipeline Engineering: Design, Construction, Maintenance Integrity and Repair, George A. Antaki, CRC Press, 2003.
3. Pipeline Planning and Construction Field Manual, E. ShashiMenon, Gulf Professional Publishing, 2011.
4. Pipeline Rules of Thumb Handbook, E. W. McAllister, 7th Edition, 2009.
5. Liquid Pipeline Hydraulics, E. ShashiMenon, Mareel Dekker, Inc., 2004.
6. Gas Pipeline Hydraulics, E. ShashiMenon, Taylor & Francis, 2005.

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Elective – IV
PROCESS TROUBLESHOOTING

Learning Objectives:

- To have working knowledge of various process equipment and range of operating parameters and variables. The equipment refer to pumps, heaters, refrigeration systems, process heaters, water coolers, distillation and vacuum towers and reactors.
- To have basic knowledge of various reasons for equipment malfunctioning.
- To have working knowledge of various petroleum refinery processes such as Crude Distillation Unit, Delayed Coking Unit, Fluid Catalytic Cracking, Sulfur Recovery and Alkylation Units
- To have basic knowledge of various reasons for process malfunctioning
- To have basic philosophy of integrating, analyzing and retrospection of time dependent process data.

UNIT-I:
Introduction to Process Troubleshooting and guidelines for process troubleshooting

Centrifugal pumps: What can go wrong?; How pumps work: Rattling Equals Cavitation; Why pumps cavitate on start- up; Origins of cavitation; Starting troublesome pumps and ensuring minimum recirculation flow; Consequences of cavitation : Oversized pumps surge, When not to pull a pump, Internal recirculation; Worn- out impeller; Blowing seal : Rough running, check spare pumps, Avoiding motor failures, Expanding pump capacity.

Process Heaters: Draft; Reduced draft; Combustion air supply; Trimming burner operation; Optimizing excess air; Optimizing heater draft; Excessive draft; Plugged draft gauges; Insufficient Air; Optimizing excess air; Flue gas oxygen; Flame appearance; Fin tube damage; Sealing skin leaks; Convection and radiation; Draft measurements; Leak prevention; Air preheaters; Preheater vibration; Other Ideas to save energy; Measuring heater temperatures; Spotting hot tubes; Cooling overheated tubes; Coke deposition; Oil burning; Heater huffing and puffing; Expanding heater capacity; Draft limited; Heat absorption limited.

UNIT-II:
Process Heat exchangers: Process heat transfer, fouling, high pressure drop and chemical cleaning.

Water Coolers: Plugged tubes; Back flushing; Air bumping; Acid cleaning; Calculating water flow rate; Hydrocarbons leaking into cooling towers; Which exchanger is leaking?; Warm cooling tower; High exchanger outlet temperature; Water side fouling; Biological growth; pH control; Cycles of condensation; Monitoring exchanger fouling.

Refrigeration Systems – Is refrigeration efficiency falling?; Diagnosing refrigeration compressor problems; Short of horsepower; Cooling the motor; Steam drivers; Valves a problem on reciprocating compressors; Refrigerant composition; Speed limited; Horse power limited; Accumulator relief valve; Minimum suction pressure problems; Importance of the throttle valve; Missing accumulation drum; Evaporating problems; Drown tubes in refrigerant; Increasing plant throughput; Evaporator Fouling; Refrigerant condenser difficulties.

UNIT-III:

Distillation Towers: Confusing Incidents; High liquid level induces flooding; Vertical temperature survey; Two phase bottom level problem; Foaming; Expanding tray capacity; Damaged trays; Liquid filled towers; reflux changes; Level control; Reboiler problems; Trapout pans; Plugged reboilers; Repair of trapout pans; steam side problems; Blown condensate seal; Reflux problems.

Vacuum Towers: Loss of bottoms pump suction pressure: Insufficient quench, TGO pan overflows, Grand oil, Suction screen, Air leak; High flash zone pressure; Thermal cracking; Ejector problems: Air leaks, Motive steam quality, Condensers, Plugged seal legs, Ejector internals; Black gas oil; Excessive production of trim gas oil; Low pumparound draw temperatures; Light resid; Steam to heater passes; Projects to improve gas oil recovery; Transfer line failures: Furnace tube failures.

UNIT-IV:

Crude Distillation - Interpreting process drop data; The solution is an aspect of the problem; Eliminating the gas oil; A tray construction error; Correcting the tray problem; Typical troubleshooting problems: Decreased fractionation, upset tray decks; Improper heat balance, Raise pumparound to save energy, Light naphtha end point, Dirty naphtha; Steam stripping cat cracker feed;Causes of inadequate stripping; Steam stripping summary; Defining the project scope; Stripping steam rates; Gathering the artificial intelligence; Diesel oil stripping; Jet fuel stripper; Bottom’s stripper; The wrap up meeting; Leaking Drawoff trays; Welded trapout pans; Overhead Condenser corrosion; Exchanger train fouling; Preflash towers save energy; Energy saving; Preflash tower foaming; Rising energy index.

Delayed Coking processes – Coking heater; Mass velocity and heat flux; Feed interruptions; Velocity steam; Sodium; Light resid; Foamovers; Parallel Passes; Steam air decoking; On-line spalling; Wet gas compressor; A fouled overhead condenser; Vapor line restrictions; Wet gas compressor rotor fouling; Combination tower; Explosion proof trays; Energy savings; Coke drum cycles affect combination tower operation; Minimizing coke yields.

UNIT-V:

Reactors – Low conversion, deviations in feed ratios, deviations in operating parameters, catalyst damage, balance life assessment of catalyst.

Fluid Catalytic Cracking Units – Catalyst steam stripping; Riser temperature control with stripping stream; Observing optimum stripping steam rates with high concentration of CO in regenerator flue gas; Catalyst poisoning affects wet gas compressor performance; Compressor surge affects regen slide valve; Causes of increased hydrogen production; Resin entrainment into FCCU feed; Catalyst regeneration problems: Air grid troubles, Insufficient air, Regeneration size and spent catalyst distribution, Identifying air grid damage; Catalyst deactivation; Catalyst deactivation Vs. refactory feed; Reducing regenerator temperature; Troubleshooting cyclone malfunctions: Dipleg unsealed, plugged dipleg, Dipleg failure; Air blower problems; Catalyst feed mixing; Cracking catalyst data.

Amine Regeneration and Scrubbing – Dirty amine; The seeds of destruction; Dirty amine ruins operation; Cleaning up amine: Corrosion inhibitors; reboiler corrosion; Regenerator feed temperature; Reclaimer operation: Washing the reclaimer, How much soda ash to use; Extending reclaimer tube life, Using a reclaimer instead of a filter; Foaming: Early warning system, Causes and cures of foaming; Liquid – liquid amine scrubbers; Declining amine strength; Retrofitting tips; Cut reboiler steam usage; Minimizing CO_2 recovery.

UNIT-VI:

Alkylation – The alkylation process; Process flow; Acid carry over; Physical carry over; Low isobutene concentration; Reduced acid circulation; Poor mixing.

Sulfur Recovery – Sulfur recovery chemistry; Process flow; What can go wrong : Finding lost conversion, measuring sulfur losses, Wrong air ratio, Plenty of catalyst, Reactor problems, COS and CS_2, Leaking reheat exchanger, Sulfur fog, Cold reheat gas, When to change catalyst; Pressure drop; Carbon deposits; Leaks cause pressure drop; Preventing boiler leaks; Condenser leaks; Routine pressure surveys; Plugged seal legs; Shortened seal legs; Catalyst support screens; Start- up tips; Avoid deficient oxygen; Start up atmospheric vent; Maximizing plant capacity; Oxygen enrichment; Fail safe with O_2; Bypass reheat exchanger; increased front end pressure; Hydrocarbon in acid gas ; Water vapor and carbon dioxide; Reactor inlet baskets; Pyrophoric iron; Tail gas clean up.

Outcomes:

After the course, the students will become adept in Process Troubleshooting Course and must be able to do the following:

- For each equipment, prepare a summary document that provides the operating range of parameters and variables of all important sections of the equipment. The equipments refer to pumps, heaters, refrigeration systems, process heaters, water coolers, distillation and vacuum towers. The graduate engineer will be able to identify process upsets in advance and take necessary corrective actions proactively.
- Monitoring of reactors/converters - root cause analysis for low conversion – optimizing feed ratios and operating parameters.
- Classify and identify all important parameters associated with safety regulations of the process equipment.
- Be able to analyze the impact of variations in operating parameters on the performance of process /equipment.
- Identify possible reasons for malfunctioning of an equipment.
- Suggest possible remedial mesures for process startup and regular operation of the equipment and overall process.
- For a process, identify all possible reasons for its process deviation/upset. The processes may refer to Crude Distillation Unit, Delayed Coking Unit, Fluid Catalytic Cracking, Sulfur Recovery and Alkylation Units.

Text books:

1. Troubleshooting Process Operations, Lieberman N. P., 3rd Edition, PenWell Books, Oklahoma, 1991.
2. Successful Troubleshooting for Process Engineers – A Complete Course in Case studies, Woods D., Wiley, 2006.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
IV Year B. Tech. Chemical Engineering - II Sem.

PROJECT WORK

Learning Objectives: The students are guided to learn the following aspects:

- Understanding & evaluating the usage / commercial /environmental aspect of a Petroleum Product / process from a demand / supply or regulation point of view.
- Understanding & evaluating the technology aspects of various alternatives available, called "Best Available Technologies (BAT)", through literature & references and select a suitable process with optimum capacity.
- Carrying-out the basic design of the process using steady state simulation and generate PFD heat & material balance and utility consumption summary.
- Preparing Material Selection drawing based on 20 year equipment life. Carrying-out preliminary equipment design, with mechanical details, of all major equipment and preparing equipment data sheets.
- Preparation of Equipment Layout & Plot Plan drawing.
- Preliminary cost estimation of the plant (CAPEX) and OPEX via utility / chemical / catalyst consumption.
- Presentation & Project management skills.

The project work may consist of any one of the following:

a) The project work should consist of a comprehensive design project of one of the Petroleum Refinery Units/ a Petrochemical plant in the form of a report with the following chapters:
   1. Introduction
   2. Physical and chemical properties and uses
   3. Literature survey for different processes
   4. Selection of the process
   5. Material and energy balances
   6. Specific equipment design, (Process as well as mechanical design with drawing), including computer programs wherever possible, of heat transfer equipments or separation equipments or reactors
   7. General equipment specifications
   8. Plant location and layout
   9. Materials of construction
   10. Health and safety factors
   11. Preliminary cost estimation
   12. Bibliography.

b) Modeling & Simulation of any petroleum refining unit/petrochemical process.

c) Any experimental work with physical interpretations.

Outcomes: The student shall be able to independently carryout the following tasks:

- Preparation of Project Feasibility Reports for Petroleum /Petrochemical Plants.
- Gather & use various sources such as market data, literature, customer feed-backs etc. to evaluate the Best Available Technologies in the market and select suitable process meeting the site conditions, environmental regulations, product quality etc.
- Simulation of Overall Plant including estimation utility consumptions.
- Generation of PFD (Process Flow Diagrams), MSD (Material Selection Diagrams) and Heat & material balance reports.

- Sizing of all plant equipment and preliminary cost estimation using cost indexes, charts& literature.
- Preliminary cost estimation of piping, instrumentation, electrical equipment, civil works & construction as % of Equipment cost, to determine Installation cost of the plant.
- Preliminary utility, catalyst & chemical consumption estimation and using this data estimating the operating cost.
- Manage a comprehensive project in a planned manner, within specified time and present the salient features of the result to the audience with confidence and clarity.