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**Professional Elective II (CHEN 3231 to 3233)**

- CHEN 3231 Nano Technology
- CHEN 3232 Computational Fluid Dynamics
- CHEN 3233 Bioprocess Engineering
# Semester 7

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**LABORATORY**

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### Professional Elective III
- CHEN 4141 Reactor Design
- CHEN 4142 Industrial Safety & Hazard Analysis
- CHEN 4143 Advanced Separation Process

### Free Elective I for Chemical Engineering students
- BIOT 4182 Biopolymer
- AEIE 4181 Instrumentation & Telemetry
- ELEC 4182 Circuit Theory Analysis
- MATH 4182 Linear Algebra
### Semester 8

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#### LABORATORY

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#### SESSIONAL

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<th>CHEN 4241 Catalysis &amp; Catalytic Reactor Design</th>
<th>CHEN 4242 Total Quality Management</th>
<th>CHEN 4243 Environmental Engineering &amp; Pollution Control.</th>
<th>CHEN 4244 Operations Research – Engineering Applications</th>
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<tr>
<td>Free Elective II for Chemical Engineering students</td>
<td>BIOT 4281 Computational Biology</td>
<td>AEIE 4282 Control System and Applications</td>
<td>MATH 4281 Probability and Stochastic Processes</td>
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List of Free Electives offered by Chemical Engineering Department for non-CHE students

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<tr>
<td>CHEN 4181 Safety and Hazard Analysis</td>
<td>CHEN 4281 Catalytic Reactor Design</td>
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<td>CHEN 4182 Project Management</td>
<td>CHEN 4282 Total Quality Management &amp; Assurance</td>
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Semester 1

THEORY
Subject Name: Business English

Paper Code: HMTS1101

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Course Outcome:
1. Analyse the dynamics of business communication and communicate accordingly.
2. Write business letters and reports
3. Learn to articulate opinions and views with clarity
4. Appreciate the use of language to create beautiful expressions
5. Analyse and appreciate literature.
6. Communicate in an official and formal environment.

Module I : 5L
Communication Skill
Definition, nature & attributes of Communication
Process of Communication
Models or Theories of Communication
Types of Communication

Levels or Channels of Communication
Barriers to Communication

Module II : 12L
Business Communication- Scope & Importance
Writing Formal Business Letters.
Writing Reports
Organizational Communication: Agenda & minutes of a meeting, notice, memo, circular
Project Proposal Technical
Report Writing
Organizing e-mail messages E-mail etiquette
Tips for e-mail effectiveness

Module III : 10L
Language through Literature
Modes of literary & non-literary expression
Introduction to Fiction, (An Astrologer's Day by R.K. Narayan and Monkey’s Paw by W.W. Jacobs), Drama (The Two Executioners by Fernando Arrabal) or (Lithuania by Rupert Brooke) & Poetry (Night of the Scorpion by Nissim Ezekiel and Palanquin Bearers by Sarojini Naidu)

Module IV : 3L
Grammar in usage (nouns, verbs, adjectives, adverbs, tense, prepositions, voice change) -to
be dealt with the help of the given texts.

References:

Subject Name: Physics-I

Paper Code: PHYS1001

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Course Outcome
1. Interpret oscillations under different conditions, with the understanding of Resonance phenomena followed by calculation of Q factor.
2. Analyze the Quantum phenomenon like Black body radiation, Compton effect and origin of X-ray spectrum.
3. Understand the wave character of light through the phenomenon of interference, diffraction and polarization.
4. Study of various crystal structures and classification of different crystal planes.
5. Explain the working principle of LASER, and apply the knowledge in different lasing system and their engineering applications in holography.
6. Understand the dual nature of matter, Heisenberg’s uncertainty relation and it’s various application.

Module I: 22 L
Optics
1. Interference:
The principle of superposition of waves, Superposition of waves: Two beam superposition, Multiple-beam superposition, coherent and incoherent superposition.

Two source interference pattern (Young’s double slit), Intensity distribution. Interference in thin films, wedge shaped films and Newton’s rings, applications of interference. Newton’s rings: Determination of wavelength of light, refractive index of liquid.

Diffraction:
Diffraction of light waves at some simple obstacles. Fraunhoffer diffraction through double slit and diffraction grating, grating spectra, resolving power of grating.

Polarisation & Fibre Optics:
Elementary features of polarization of light waves. Production and analysis of linearly, elliptic and Circularly polarized light, polaroids and application of polarizations. fibre optics - principle of operation, numerical aperture, acceptance angle.

Laser
Characteristics of Lasers, Spontaneous and Stimulated Emission of Radiation, Meta-stable State, Population Inversion, Lasing Action, Einstein’s Coefficients and

Module II : 8L
Waves & Oscillation

Module III : 9L
Quantum Mechanics

Module IV: 6L
Introduction of Crystallography

Text Books:
1. Atomic Physics Vol 1 – S.N. Ghoshal
2. Optics – Ajoy Ghak
3. Waves & Oscillation – N.K. Bajaj

Reference Books:
1. Introduction to Special Relativity – Robert Resnick
2. Prespective on Modern Physics - Arthur Beiser
3. Optics – Jenkins and White
5. Introduction to modern Physics – Mani and Meheta
6. Optics – Brijlal and Subrahmanyam
Subject Name: Mathematics I

Paper Code: MATH1101

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Course Outcome:
1. Apply the concept of rank of matrices to find the solution of a system of linear simultaneous equations.
2. Develop the concept of eigen values and eigen vectors.
3. Use Mean Value Theorems for power series expansions of functions of one variable.
4. Analyze the nature of sequence and infinite series.
5. Describe the concept of differentiation and integration for functions of several variables with their applications in vector calculus.
6. Combine the concepts of gradient, curl, divergence, directional derivatives, line integrals, surface integrals and volume integrals.

Module I: 10L
Matrix:

Matrices and their basic attributes, Determinant of a square matrix, Minors and Cofactors, Laplace’s method of expansion of a determinant, Product of two determinants, Adjoint of a determinant, Jacobi’s theorem on adjoint determinant.


Consistency and inconsistency of a system of homogeneous and inhomogeneous linear simultaneous equations, Characteristic Equation and computation of eigenvalues and eigenvectors of a square matrix (of order 2 or 3), Cayley-Hamilton theorem and its applications (with special reference to higher power of matrices, e.g. Idempotent and Nilpotent matrices)

Module II: 10L
Mean Value Theorems & Expansion of Functions:
Rolle’s theorem: its geometrical interpretation and its application, Concavity and Convexity of curves, Mean Value theorems – Lagrange & Cauchy and their application, Taylor’s theorem with Lagrange’s and Cauchy’s form of remainders and its application, Expansions of functions by Taylor’s and Maclaurin’s theorem,

Maclaurin’s infinite series expansion of the functions: \( \sin x, \cos x, e^x, \log(1+x), (a + x)^n \), n being an integer or a fraction (assuming that the
remainder $R_n \to 0$ as $n \to \infty$ in each case).

Infinite Series:
Preliminary ideas of sequence, Infinite series and their convergence/divergence,

Infinite series of positive terms, Tests for convergence: Comparison test, Cauchy’s Root test, D’ Alembert’s Ratio test (statements and related problems on these tests), Raabe’s test, Proof of $e$ being irrational, Alternating series, Leibnitz’s Test

(statement, definition) illustrated by simple examples, Absolute convergence and Conditional convergence,

**Module III : 10 L**
Successive differentiation:
Higher order derivatives of a function of single variable, Leibnitz’s theorem (statement only and its application, problems of the type of recurrence relations in derivatives of different orders and also to find $(y_n)_0$).

Calculus of Functions of Several Variables:
Recapitulation of some basic ideas of limit and continuity of functions of single variable, Introduction to functions of several variables with examples, Knowledge of limit and continuity, Determination of partial derivatives of higher orders with examples, Homogeneous functions and Euler’s theorem and related problems up to three variables, Chain rules, Differentiation of implicit functions, Total differentials and their related problems, Jacobians up to three variables and related problems, Maxima, minima and saddle points of functions and related problems.

**Module-IV : 10 L**
Multiple Integration and Vector Calculus:
Concept of line integrals, Double and triple integrals. Vector function of a scalar variable, Differentiation of a vector function, Scalar and vector point functions, Gradient of a scalar point function, divergence and curl of a vector point function, Directional derivative, Related problems on these topics, Green’s theorem, Gauss Divergence Theorem and Stoke’s theorem (Statements and applications).

Reduction formula:
Reduction formulae both for indefinite and definite integrals of types:

$$\int \sin^n x \cos^m x \, dx, \int \sin^n x \cos^m x \, dx, \int \cos^n x \sin^m x \, dx, \int \frac{dx}{(x^2 + a^2)^n}, m, n \text{ are positive integers.}$$

References:
1. Advanced Engineering Mathematics: Erwin Kreyszig by Wiley India
2. Engineering Mathematics: B.S. Grewal (S. Chand & Co.)
3. Higher Engineering Mathematics: John Bird (Elsevier)
9. Linear Algebra (Schaum’s outline series): Seymour Lipschutz, Marc Lipson
10. (McGraw Hill Education)
11. Vector Analysis (Schaum’s outline series): M.R. Spiegel, Seymour Lipschutz,
12. Dennis Spellman (McGraw Hill Education)
Subject Name: Basic Electronics Engineering

Paper Code: ECEN1001

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Course Outcome:
1) Categorize different semiconductor materials based on their energy bands and analyze the characteristics of those materials for different doping concentrations based on previous knowledge on semiconductors acquired.
2) Describe energy band of P-N Junction devices and solve problems related to P-N Junction Diode both from device and circuit perspectives.
3) Design different application specific circuits associated with diodes operating both in forward and reverse bias.
4) Analyze various biasing configurations of Bipolar Junction Transistor and categorize different biasing circuits based on stability.
5) Categorize different field-effect transistors based on their constructions, physics and working principles and solve problems associated with analog circuits based on operational amplifiers.
6) Design and implement various practical purpose electronic circuits and systems meant for both special purpose and general purpose and analyze their performance depending on the type of required output and subsequently the applied input.

Module I: 10 L
Semiconductors:
Crystalline material, Energy band theory, Fermi levels; Conductors, Semiconductors and Insulators: electrical properties, band diagrams. Semiconductors: intrinsic and extrinsic, energy band diagram, electrical conduction phenomenon, P-type and N-type semiconductors, drift and diffusion carriers.

Diodes and Diode Circuits:
Formation of P-N junction, energy band diagram, built-in-potential forward and reverse biased P-N junction, formation of depletion zone, V-I characteristics, Zener Diode and its Application, Zener and Avalanche breakdown.

Simple diode circuits, load line, piecewise linear model; Rectifier circuits: half wave, full wave, PIV, DC voltage and current, ripple factor, efficiency, idea of regulation.

Module II: 10 L
Bipolar Junction Transistors:
Formation of PNP / NPN junctions, energy band diagram; transistor mechanism and principle of transistors, CE, CB, CC configuration, transistor characteristics: cut-off, active and saturation modes of operation, transistor action, input & output characteristics, load line & amplifier operation and current amplification factors for CB and CE modes. Biasing and Bias stability: calculation of stability factor.
Module III : 9 L
Field Effect Transistors:
Junction field effect transistor (JEET): Principle of operation, JFET parameters, eqv. Circuit, JFET biasing, self bias, design of bias circuits, load line, amplifier characteristics.

MOSFETs:
Construction & principle of operation of p- & n-channel enhancement & depletion mode MOSFETs, drain & transfer characteristics, threshold voltage & its control.

Cathode Ray Oscilloscope:
Construction and working principle of CRO, Lissajous pattern.

Module IV : 9 L
Feed Back Amplifier:
Concept-block diagram, properties, positive and negative feedback, loop gain, open loop gain, feedback factors; topologies of feedback amplifier; effect of feedback on gain, condition of oscillation, Barkhausen criteria.

Operational Amplifier:
Introduction to integrated circuits, operational amplifier and its terminal properties; Application of operational amplifier; Concept of op-amp saturation, inverting and non-inverting mode of operation, Adders, Subtractors, Voltage follower, Integrator, Differentiator, Basic Comparator Circuit.

References:
2. R.A Gayakwad: Op Amps and Linear IC’s, PHI
3. D. Chattopadhyay, P. C Rakshit : Electronics Fundamentals and Applications
4. Adel S. Sedra, Kenneth Carless Smith: Microelectronics Engineering
Subject Name: Engineering Mechanics

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Course Outcome:
1. Understand basic concepts of vector algebra as applied to engineering mechanics.
2. Analyze free body diagram of a system under equilibrium / non equilibrium along with the consideration of frictional forces.
3. Interpret dynamics of members/ links in a mechanism and evaluate inertia force with the help of D’ Alembert’s principle.
4. Know how to evaluate mechanical stability from CG calculations.
5. Apply MI values required for engineering design calculations.
6. Apply the principles of work - energy and impulse- momentum for analysis of dynamic systems.

Module I : 10L
Importance of Mechanics in Engineering ; Definition of Mechanics; Concepts of particles & rigid bodies;
Vector and scalar quantities; Vector algebra –definition and notation; Types of vectors – equal, equivalent, free, bound, sliding ; Addition, subtraction of vectors ; Parallelogram law, triangle law, vector polygon ; Scalar multiplication of vectors ; system ; Unit vector, unit co-ordinate vectors ( , , ) ; Direction cosines ; Addition/ subtraction of vectors in components form.
Definition of force vector ; Dot product , cross product and the application ; Important vector quantities (position vector , displacement vector ) ; Moment of a force about a point and about an axis , moment of a couple ;
Representation of force and moments in items of , . Principle of transmissibility of force (sliding vector); Varignon’s theorem for a system of concurrent forces with proof; Resolution of a force by its equivalent force-couple system; Resultant of forces.

Module II : 10L
Type of forces – collinear, concurrent, parallel, concentrated, distributed; Active and reactive forces, different types of reaction forces; Free body concept and diagram; Concept and equilibrium of forces in two dimensions; Equations of equilibrium; Equilibrium of three concurrent forces -- Lami’s theorem.

Concept of friction: Laws of Coulomb’s friction; Angle of friction, angle of repose, coefficient of friction -- static and kinematic.

Module III : 12L
Distributed force system; Centre of gravity; Centre of mass & centroid; Centroid of an arc; Centroid of plane areas – triangle, circular sector, quadrilateral and composite area consisting of above figures.

Area moment of inertia: Moment of inertia of a plane figure; Polar moment of inertia of a
Concept of simple stress and strain: Normal stress, shear stress, normal strain, shear strain; Hooke’s law; Poisson’s ratio; stress-strain diagram of ductile and brittle material; Proportional limit, elastic limit, yield point, ultimate stress, breaking point; Modulus of elasticity.

Module III: 16L
Introduction to dynamics: Kinematics & kinetics; Newton’s laws of motion; Law of gravitation and acceleration due to gravity; Rectilinear motion of particles with uniform & non-uniform acceleration.
Plane curvilinear motion of particles: Rectangular components (projectile motion), normal and tangential components.
Kinetics of particles: D’Alembert’s principle and free body diagram; Principle of work & energy; Principle of conservation of energy.
Impulse momentum theory: Conservation of linear momentum

References:
1. Engineering Mechanics:- Statics and Dynamics by Meriam & Kreige, Wiley India
2. Engineering Mechanics:- Statics and Dynamics by I.H. Shames, PHI
1. Engineering Mechanics by Timoshenko, Young and Rao, TMH
2. Element of strength of materials by Timoshenko & Young, EWP
LABORATORY
**Subject Name: Physics-I lab**

**Paper Code: PHYS1011**

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**Experiments:**

1. Determination of Young’s modulus by Flexure Method and calculation of bending moment and shear force at a point on the beam.
3. Determination of thermal conductivity of a good conductor by Searle’s Method.
4. Determination of thermal conductivity of a bad conductor by Lee’s and Chorlton’s Method.
5. Determination of dielectric constant of a given dielectric material.
6. Use of Carey Foster’s bridge to determine unknown resistance.
8. Determination of wavelength of light by Fresnel’s biprism method.
10. Determination of dispersive power of the material of a given prism.
11. Determination of co-efficient of viscosity of a liquid by Poiseulle’s capillary flow method.
Subject Name: Basic Electronics Engineering Lab

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Experiments:

1. Familiarisation with passive and active electronic components such as Resistors, Inductors, Capacitors, Diodes, Transistors (BJT) and electronic equipment like DC power supplies, multimeters etc.
2. Familiarisation with measuring and testing equipment like CRO, Signal generators etc.
3. Study of I-V characteristics of Junction diodes.
4. Study of I-V characteristics of Zener diodes.
5. Study of Half and Full wave rectifiers with Regulation and Ripple factors.
6. Study of I-V characteristics of BJTs in CB mode
7. Study of I-V characteristics of BJTs in CE mode
8. Study of I-V characteristics of Field Effect Transistors.
9. Determination of input-offset voltage, input bias current and Slew rate of OPAMPs.
10. Determination of Common-mode Rejection ratio, Bandwidth and Off-set null of OPAMPs.
Subject Name: Workshop Practice

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Job 1: General awareness of a typical workshop.
Theory requirements: Workshop definition, various shops in a typical workshop, Carpentry, Fitting, Foundry; Sheet Metal Shop, Welding and Brazing Shop, Machine Shop, Forging & Blacksmithy, Safety precautions to be followed in a workshop, Familiarization of Various safety devices and their uses.

Job 2: Making of a wooden pattern.

Job 3: Making of a matched profile form MS plate.
Theory requirements: Work Bench, Fitting Tools (Bench Vice, Chisel, Hammer, Different types of Files, (Rough, Bastard, Second Cut, Half Round, Triangular File), Saw (Hack saw etc.), Scribe, Punch, Try Square, Angle Plate, caliper (outside & inside), Universal Surface Gauge, Centre Punch, Prick Punch, Drill (Flat, straight fluted, taper shank twist drill).
Fitting Operations, Filing, Marking, Drilling, Tapping (Rougher, Intermediate, Finisher taps), Tap Drill size (D=T-2d), Sawing, Dieing. Safety precautions in Fitting Shop.

Job 4: Making of an internal and external thread.

Job 5: Making of a green sand mould using the pattern made under Job no. 2.
Theory requirements: Mould making, Preparation of sand, (silica, clay, moisture, and misc items and their functions). Properties of a good sand mould, General procedure for making a good sand mould, Different tools used for preparation of a mould, Explanation of various terms, Cope and Drag Box, Runner, Riser, Gating and its utility, Parting sand, Vent holes.

Job 6: Demonstration of metal melting and casting
Theory requirements: Metal melting furnaces: Ladles, Using of Tongs, Molten metal pouring procedure, Safety precautions in pouring molten metal in a mould.

Job 7. Making of a stepped pin in a centre lathe. (2 Classes)

Theory requirements: Machining and common machining operations, Lathe M/c and its specifications, Head stock, Tailstock, Chuck-Self centering chuck, 4 jaw chuck, Bed, Carriage, Feed mechanism, Screw cutting mechanism, various lathe operations like turning, facing, grooving, chamfering, taper turning, Thread cutting, Knurling, Parting, Cutting speed, Feed, Depth of cut, Different types of cutting tools-Safety precautions in a machine shop.

Job 8: Making of square prism from a round shaft by Shaping Machine

Theory requirements: Description of a Shaping machine, Base, Column, Saddle, Clapper box, Quick return mechanism, Feed Mechanism, Table, Rotation of table, Adjustment of stroke length, Adjustment of starting point of cut. Safety Precautions while working in Shaping Machine.

Job 9: Making of square prism from a round shaft by Milling Machine


Job 10: Arc Welding practice and making of a welded joint

Theory requirements: Welding, Weldability, Types of Welding, MMAW, Gas Welding, Electrode, Functions of Flux, Equipment for MMAW, Different types of Flames in Gas Welding and Gas Cutting (Neutral-Oxidising-Reducing Flames), Different types of welding joints, AC Welding, DC Welding; Safety precautions in Welding Shop.

Job 11: Sheet Metal forming & Brazing


References:
SESSIONAL
Subject Name: Language Practice lab (Level 1)

Paper Code: HMTS1111

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**Module I : 3P**
Introduction to Linguistics (Phonology)

Phonetics-Vowel and Consonant Sounds (Identification &articulation)
Word- stress

Intonation (Falling and rising tone)
Voice Modulation

Accent training

**Module II : 3P**
Listening Skills
Principles of Listening
Approaches to listening
Guidelines for Effective Listening
Listening Comprehension
Audio Visual (Reviews)

**Module III : 2P**
Discourse Analysis-
Spoken Discourse

Conversational Skills/Spoken Skills
Analysing Speech dynamics (Political Speeches

Formal Business Speeches)

**Module IV : 9P**
Writing Skill-

Descriptive, narrative and expository writing

Writing with a purpose---Convincing skill, argumentative skill/negotiating Skill (These skills will be repeated in oral skills).

Writing reports/essays/articles—logical organization of thoughts
Book review.
References:

Objective: This course aims at instilling a sense of responsibility. This objective can be achieved by bringing in awareness about the contemporary issues relevant to the GenX and Gen Y through enlightened discussions and active participation. Since the course has 1 credit detailed planning regarding the area of activities and method of evaluation should be charted at the start of the semester.

Module I:
Project Work
Development of projects based on integral and holistic developmental models to be implemented in rural areas or underdeveloped areas in the peripheral areas of cities. This could include a wide area of activity – from taking up a research projects to analyse the need of a particular under-developed area to trying to implement a project already formulated. This could also relate to mobilizing funds for a specific project.

Module II:
Action-oriented schemes
e.g. Organising Blood –donation camps
Conducting child –healthcare services
Helping the old and sick
(in coordination with NGOs and other institutes)

Module III:
Society and Youth
Developing Awareness among the youth about social issues both local and global for e.g. Eradication of social evils like drug abuse, violence against women and others.

Module IV:
Youth and Culture
Generating new ideas and help the participants to be creative and innovative for e.g. Enacting street plays, encouraging creative writing by organizing workshops and competitions. Active participation of the students in the nation building process by making positive changes in the social and individual space.
Semester 2

THEORY
Subject Name: Introduction to Computing

Paper Code: CSEN 1201

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Learning Objective: Introduction to the concept of computer and computation and solving of problems using C as a programming language. Coverage of C will include basic concepts, arithmetic and logic, flow control, and data handling using arrays, structures, pointers and files.

Course Outcome:
1. Understand and remember functions of the different parts of a computer.
2. Understand and remember how a high-level language (C programming language, in this course) works, different stages a program goes through.
3. Understand and remember syntax and semantics of a high-level language (C programming language, in this course).
4. Understand how code can be optimized in high-level languages.
5. Apply high-level language to automate the solution to a problem.
6. Apply high-level language to implement different solutions for the same problem and analyze why one solution is better than the other.

Module I: 13L
Fundamentals of Computer
Basic Anatomy of Computer System, Primary & Secondary Memory, Processing Unit, Input & Output devices. Assembly language, high level language, compiler and assembler (basic concepts).
Binary & Allied number systems (decimal, octal and hexadecimal) with signed and unsigned numbers (using 1’s and 2’s complement) - their representation, conversion and arithmetic operations. Packed and unpacked BCD system, ASCII. IEEE-754 floating point representation (half- 16 bit, full- 32 bit, double- 64 bit). Binary Arithmetic & logic gates. Boolean algebra – expression, simplification, Karnaugh Maps.
Basic concepts of operating systems like MS WINDOW, LINUX. How to write algorithms & draw flow charts.

Module II: 5L
Basic Concepts of C
C Fundamentals:
The C character set identifiers and keywords, data type & sizes, variable names, declaration, statements.
Operators & Expressions:
Arithmetic operators, relational and logical operators, type, conversion, increment and decrement operators, bit wise operators, assignment operators and expressions, precedence and order of evaluation. Standard input and output, formatted output -- printf, formatted input scanf.
Module III: 8L  
Program Structures in C  
Flow of Control:  
Statement and blocks, if-else, switch-case, loops (while, for, do-while), break and continue, go to and labels.  
Basic of functions, function prototypes, functions returning values, functions not returning values. Storage classes - auto, external, static and register variables – comparison between them. Scope, longevity and visibility of variables.  
C preprocessor (macro, header files), command line arguments.

Module IV: 14L  
Data Handling in C  
Arrays and Pointers:  
One dimensional arrays, pointers and functions – call by value and call by reference, array of arrays. Dynamic memory usage – using malloc(), calloc(), free(), realloc(). Array pointer duality.  
String and character arrays; C library string functions and their use.  
User defined data types and files:  
Basic of structures; structures and functions; arrays of structures.  
Files – text files only, modes of operation. File related functions – fopen(), fclose(), fscanf(), fprintf(), fgets(), fputs();

Text Books:  
1. Schaum’s outline of Programming with C – Byron Gottfried  
2. Teach Yourself C- Herbert Schildt  
3. Programming in ANSI C – E Balagurusamy

Reference Books:  
2. C: The Complete Reference – Herbert Schildt  
3. The C Programming Language- D.M.Ritchie, B.W. Kernighan
Subject Name: Chemistry 1

Paper Code: CHEM 1001

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Course Outcome:
1. Knowledge of understanding the operating principles and reaction involved in batteries and fuel cells and their application in automobiles as well as other sectors to reduce environmental pollution.
2. An ability to design and conduct experiments, as well as to organize, analyzes, and interprets data.
3. An ability to identify and formulate polymers and have a knowledge of various polymers like polyethene, PVC, PS, Teflon, Bakelite, Nylon which have engineering applications.
4. Knowledge of synthesizing Nanomaterials and their applications in industry, carbon nano tube technology is used in every industry now-a-days.
5. An ability of synthesizing bio fuels as a renewable and environment friendly alternative source for natural fuel.
6. Elementary knowledge of IR and UV spectroscopy is usable in structure elucidation and characterisation of various molecules.

Module I: 10 L
Thermodynamics & Spectroscopy
Chemical Thermodynamics & Thermochemistry
Concept of Thermodynamic system, Introduction to first law of thermodynamics, Enthalpy, Heat Capacity, Reversible and Irreversible processes, Adiabatic changes, Application of first law of thermodynamics to chemical processes, 2nd law of thermodynamics, Evaluation of entropy, Work function and free energy, Phase Changes, Clausius Clapeyron Equation, Chemical Potential, Gibbs Duhem Relation, Activity and Activity coefficient.
Spectroscopy
Electromagnetic Radiation, Basic idea of UV-visible & IR spectroscopy.

Module II: 10 L
Structure & Bonding
Chemical Bonding
Solid State Chemistry
Introduction to stoichiometric defects (Schottky & Frenkel) and non – stoichiometric defects (Metal excess and metal deficiency). Role of silicon and germanium in the field of semiconductor.
Ionic Equilibria and Redox Equilibria
Acid Base Equilibria in water, Strength of acids and bases, Hydrogen ion exponent, Ionic product of water, Salt Hydrolysis and Henderson Equation, Buffer solutions, pH indicator, Common ion Effect, Solubility product, Fractional Precipitation, Redox Equilibria.
Structure and reactivity of Organic molecule
Inductive effect, resonance, hyperconjugation, electromeric effect, carbocation, carbanion and free radicals.
Brief study of some addition, eliminations and substitution reactions.

Module III : 10 L
Electrochemistry & Reaction Dynamics
Conductance:
Conductance of electrolytic solutions, specific conductance, equivalent conductance, molar conductance, ion conductance, effect of temperature and concentration (Strong and Weak electrolyte). Kohlrausch’s law of independent migration of ions, transport numbers and hydration of ions. Conductometric titrations: SA vs SB & SA vs WB; precipitation titration KCl vs AgNO₃.

Electrochemical Cell:
Cell EMF and thermodynamic derivation of the EMF of a Galvanic cell (Nernst equation), single electrode potentials, hydrogen half-cell and calomel half cell (construction, representation, cell reaction, expression of potential, discussion, application) Storage cell, fuel cell (construction, representation, cell reaction, expression of potential, discussion, application). Application of EMF measurement on a) the change in thermodynamic function (ΔG, ΔH, ΔS) b) the equilibrium constant of a reversible chemical reaction c) the valency of an ion.

Kinetics:

Module IV : 10 L
Industrial Chemistry & Polymerization
Industrial Chemistry
Solid Fuel: Coal, Classification of coal, constituents of coal, carbonization of coal (HTC and LTC), Coal analysis: Proximate and ultimate analysis.
Gaseous fuels: Natural gas, water gas, coal gas, bio gas.
Polymerization:
Concepts, classifications and industrial applications. Polymer molecular weight (number avg. weight avg. viscosity avg.: Theory and mathematical expression only), Poly dispersity index (PDI). Polymerization processes (addition and condensation polymerization), degree of polymerization, Copolymerization, stereo-regularity of polymer, crystallinity (concept of Tₘ) and amorphicity (Concept of Tₑ) of polymer.
Preparation, structure and use of some common polymers: plastic (PE: HDPE, LDPE, PVC, Bakelite, PP), rubber (natural rubber, SBR, NBR) and Vulcanization., fibre(nylon 6.6, Nylon 6, Polyester).
Conducting and semi-conducting polymers.

Text Books:

Reference Books:
2. L. Finar, Organic Chemistry, Addison Wesley Longman, Inc
3. Organic Chemistry, Morrison & Boyd, Prentice Hall of India
4. Physical Chemistry, K. L. Kapoor, McMillan
Subject Name: Mathematics- II

Paper Code: MATH 1201

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Course Outcome:
1. Construct differential equation as a mathematical model of a physical phenomena.
2. Choose proper method for finding solution of a specific differential equation.
3. Discuss the elementary concepts of graph theory, for example, walk, path, cycle, Eulerian graph, Hamiltonian graph and tree.
4. Apply basic graph algorithms for searching and finding minimal spanning tree and shortest path.
5. Solve improper integrals and initial value problems with the help of Laplace transformation.
6. Evaluate distance, angle between planes and shortest distance between two skew lines in three dimension.

Module I: 10 L
Ordinary differential equations (ODE)-
First order and first degree: Exact equations, Necessary and sufficient condition of exactness of a first order and first degree ODE (statement only), Rules for finding Integrating factors, Linear and non-linear differential equation, Bernoulli’s equation.
General solution of ODE of first order and higher degree (different forms with special reference to Clairaut’s equation).
Second order and first degree:

Module II: [10L]
Basics of Graph Theory
Graphs, Digraphs, Weighted graph, Connected and disconnected graphs, Complement of a graph, Regular graph, Complete graph, Subgraph.; Walks, Paths, Circuits, Euler Graph, Cut sets and cut vertices, Matrix representation of a graph, Adjacency and incidence matrices of a graph, Graph isomorphism, Bipartite graph.
Tree:
Definition and properties, Binary tree, Spanning tree of a graph, Minimal spanning tree, properties of trees, Algorithms: Dijkstra’s Algorithm for shortest path problem, Determination of minimal spanning tree using DFS, BFS, Kruskal’s and Prim’s algorithms.

Module III: 10 L
Improper Integral:
Basic ideas of improper integrals, working knowledge of Beta and Gamma functions (convergence to be assumed) and their interrelations.
Laplace Transform:
Introduction to integral transformation, functions of exponential order, Definition and
existence of LT (statement of initial and final value theorem only), LT of elementary functions, Properties of Laplace Transformations, Evaluation of sine, cosine and exponential integrals using LT, LT of periodic and step functions Definition and properties of inverse LT Convolution Theorem (statement only) and its application to the evaluation of inverse LT, Solution of linear ODEs with constant coefficients (initial value problem) using LT.

Module IV : 10L
Three Dimensional Geometry

References:
2. Graph Theory: V. K. Balakrishnan, (Schaum’s Outline, TMH)
3. A first course at Graph Theory: J. Clark and D. A. Holton (Allied Publishers LTD)
4. Introduction to Graph Theory: D. B. West (Prentice-Hall of India)
5. Graph Theory: N. Deo (Prentice-Hall of India)
10. Introductory Course in Differential Equations: Daniel A. Murray (Longmans & Green).
12. Analytical Geometry And Vector Algebra- R M Khan
Subject Name: Basic Electrical Engineering

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Course Outcome:
1. Analyze DC circuits using KCL, KVL and network theorems like Superposition Theorem, Thevenin’s Theorem, Norton’s Theorem and Maximum Power Transfer Theorem.
2. Analyze DC Machines; Starters and Speed control of DC motors.
3. Analyze magnetic circuits and apply Gauss’ law for electric field and potential calculation.
4. Analyze single and three phase AC circuits.
5. Analyze the operation of single phase transformers.
6. Analyze the operation of three phase induction motors.

Module I :12L
DC Network Theorem: Kirchhoff’s law, nodal analysis, mesh analysis, Superposition theorem, Thevenin’s theorem, Norton theorem, Maximum power transfer theorem, star-delta conversion.
DC Machines: Construction, EMF equation, Principle of operation of DC generator, open circuit characteristics, external characteristics, Principle of operation of DC motor, Speed-torque characteristics of shunt and series machine, starting of DC motor, speed control of dc motor.

Module II : 8L
Electrostatics: Gauss’s law and its applications to electric field and potential calculation. Capacitor, capacitance of parallel plate capacitor, spherical capacitor and cylindrical capacitor.
Electromagnetism: Amperes law, Biot-savart’s law, Ampere’s circuital law and their applications, Magnetic circuits, analogy between magnetic and electric circuits, Faraday’s law, self and mutual inductance. Energy stored in a magnetic field, Hysteresis and Eddy current losses.

Module III : 10L
AC single phase system: concept of alternating signal, average and RMS values of alternating signal, peak factor, form factor, phase and phase difference, phasor representation of alternating quantities, phasor diagram, AC series, parallel and series parallel circuits, Active power, Reactive power, power factor, Resonance in RLC series and parallel circuit, Q factor, bandwidth.
Three phase system: balanced three phase system, delta and star connection, relationship between line and phase quantities, phasor diagrams. Power measurement by two wattmeter method.

Module IV : 10L
Single phase transformer: Construction, EMF equation, no load and on load operation and their phasor diagrams, Equivalent circuit, Regulation, losses of a transformer, open and short
circuit tests, efficiency.
3-phase induction motor: Concept of rotating magnetic field, principle of operation, Construction, equivalent circuit and phasor diagram, torque-speed/slip characteristics, Starting of Induction Motor.

Text Books:
2. Basic Electrical Engineering, V.N Mittle & Arvind Mittal, TMH, Second Edition
3. Basic Electrical Engineering, Hughes

Reference Books:

1. Electrical Engineering Fundamentals, Vincent Del Toro, Prentice-Hall
2. Advance Electrical Technology, H.Cotton, Reem Publication
3. Basic Electrical Engineering, R.A. Natarajan, P.R. Babu, Sictech Publishers
4. Basic Electrical Engineering, N.K. Mondal, Dhanpat Rai
5. Basic Electrical Engineering, Nath & Chakraborti
Subject Name: Engineering Thermodynamics and Fluid

Paper Code: MECH 1201

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Course Outcome:
1. To analyze a thermodynamic system and calculate work transfer in various quasi-static processes.
2. To understand and apply the first law and 2nd law of thermodynamics.
3. To analyze thermal efficiency of Otto, Diesel cycles.
4. To understand physical properties of fluids.
5. To apply mass, momentum and energy conservation principles to incompressible fluid flow.
6. To describe fluid flow and analyze acceleration of fluid particles.

Module I : 10 L
Basic concepts of Thermodynamics:
Introduction; Macroscopic and microscopic concept; Definition of Thermodynamic systems; Surrounding, universe; Open, closed and isolated systems; Concept of control volume; Thermodynamic properties: intensive, extensive & specific properties; state. Thermodynamic equilibrium; Change of state; Thermodynamic processes and cycles; Quasi-static processes; Reversible processes; Zeroth law of Thermodynamics -concept of temperature.

Heat & Work:
Definition of Thermodynamic work; Work transfer-displacement work for a simple compressible system, path function, PdV work in various quasi-static processes(isothermal, isobaric, adiabatic, polytropic, isochoric); Free expansion; Indicated diagram (P-V diagram).

Module II : 8 L
First law of Thermodynamics:
Statement; 1st law for a closed system executing a cycle; Concept of stored energy; Energy as a property, different forms of stored energy, internal energy, first law for a non-flow process; Flow work: Definition of enthalpy, \( C_p \), \( C_v \); Energy of an isolated system; Flow energy; First law for an open system - steady flow energy equation; Examples of steady flow devices(nozzle and diffuser, turbine, pump, compressor, boiler, condenser and throttling device); PMM-I.

Module III : 10 L
Second law of Thermodynamics:
Qualitative difference between heat and work; Definition of source & sink: cyclic heat.
engine, heat pump and refrigerator, thermal efficiency of heat engine, C.O.P of heat pump and refrigerator; Kelvin-Plank and Clausius statements of second law; Equivalence of the two statements.

Reversible process; Irreversible process; Factors for irreversibility; Carnot cycle and Carnot efficiency; Reversible heat engine and heat pump; PMM-II

Entropy: Mathematical statement of Clausius Inequality: Entropy as a property; Entropy principle; T-s plot for reversible isothermal, adiabatic, isochoric & isobaric processes.

Air standard Cycles:
Otto cycle & Diesel cycle, P-V & T-s plots, Net work done and thermal efficiency.

**Module IV : 10 L**

Properties & Classification of Fluid:
Definition of fluid; Concept of Continuum; Fluid properties- density, specific weight, specific volume, specific gravity; Viscosity: definition, causes of viscosity, Newton’s law of viscosity, dimensional formula and units of viscosity, kinematic viscosity; Variation of viscosity with temperature. Ideal and Real fluids; Newtonian and Non-Newtonian fluids; No-slip condition.
Compressibility and Bulk modulus of elasticity.
Difference between compressible and incompressible fluids.

Fluid Statics:
Introduction; Pascal’s Law--statement and proof; Basic Hydrostatic Law and its proof; Variation of pressure with depth in incompressible fluid, piezometric head, pressure head; Unit and scales of pressure measurement.

**Module V : 10 L**

Fluid Kinematics:
Definition; Flow field and description of fluid motion(Eulerian & Lagrangian method), steady and unsteady flow, uniform and non-uniform flow-examples.
Acceleration of a fluid particle-local acceleration, convective acceleration. Stream line, Stream tube, Path line and Streak line; Laminar and Turbulent flow, Reynolds Number. Equations of streamlines and path lines.
Continuity equation for unidirectional flow and for differential form in 3-D Cartesian coordinate system.
Dynamics of Ideal fluids:
Introduction, Euler’s equation of motion along a streamline; Bernoulli’s equation-assumptions and significance of each term of Bernoulli’s equation.
Application of Bernoulli’s equation-problem on pipe line. Measurement of flow rate: Venturimeter and orificemeter.

Static pressure, Dynamic pressure, Stagnation pressure-measurement of velocity by Pitot tube.

References:
1. Engineering Thermodynamics- Nag, P.K. - T. M.H
2. Fundamentals of Thermodynamics- Sonntag, Borgnakke & Van Wylen, Wiley India
3. Thermodynamics- an Engineering approach - 6e, Cengel & Boles, TM
LABORATORY
Basic Computation & Principles of Computer Programming Lab

Softwares to be used: Cygwin and notepad++, Tiny C

Day 1: LINUX commands and LINUX based editor
Day 2: Basic Problem Solving
Day 3: Control Statements (if, if-else, if-elseif-else, switch-case)

Day 4: Loops - Part I (for, while, do-while)
Day 5: Loops - Part II
Day 6: One Dimensional Array
Day 7: Array of Arrays
Day 8: Character Arrays/ Strings

Day 9: Basics of C Functions
Day 10: Recursive Functions
Day 11: Pointers
Day 12: Structures and Unions
Day 13: File Handling
Subject Name: CHEMISTRY I LAB

Paper Code: CHEM 1011

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1. To determine the alkalinity in a given water sample.
2. Estimation of iron using KMnO₄: self indicator.
3. Estimation of iron using K₂Cr₂O₇: redox sensitive indicator.
4. To determine total hardness and amount of calcium and magnesium separately in a given water sample.
5. To determine the value of the rate constant for the hydrolysis of ethyl acetate catalyzed by hydrochloric acid.
6. Heterogeneous equilibrium (determination of partition coefficient of acetic acid between n-butanol and water).
7. Conductometric titration for determination of the strength of a given HCl solution by titration against a standard NaOH solution.
8. pH-metric titration for determination of strength of a given HCl solution against a standard NaOH solution.
10. To determine chloride ion in a given water sample by Argentometric method (using chromate indicator solution).
**Subject Name: Basic Electrical Engineering Lab**

**Paper Code: ELEC 1011**

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1. Characteristics of Fluorescent lamps  
2. Characteristics of Tungsten and Carbon filament lamps  
3. **Verification of Thevenin’s & Norton’s theorem.**

4. Verification of Superposition theorem  
5. Verification of Maximum Power Transfer theorem  
6. Calibration of ammeter and voltmeter.  
7. Open circuit and Short circuit test of a single phase Transformer.  
8. Study of R-L-C Series / Parallel circuit  
9. Starting and reversing of speed of a D.C. shunt Motor  
10. Speed control of DC shunt motor.  
11. No load characteristics of D.C shunt Generators  
12. Measurement of power in a three phase circuit by two wattmeter method.
Subject Name: Engineering Drawing
Paper Code: MECH 1012

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1. Importance of engineering drawing; Acquaintance with different drafting equipment & accessories;

2. Introduction to lines : Practising different types of lines; Basic concepts in Lettering : Practising vertical & inclined letters (Practice Sheet 1)

3. Different systems of dimensioning with practice.Introduction to the concept of scale of drawing. (Practice Sheet 2)

4. Introduction to concept of orthographic projection: 1\textsuperscript{st} angle and 3\textsuperscript{rd} angle projection method; Symbols; projection of points. (Practice Sheet 3)

5. Projection of straight lines for different orientation including inclined to both the planes. (Practice Sheet 4)

6. Projection of plane surfaces inclined to HP and parallel to VP; Inclined to VP and Parallel to HP (Practice Sheet 5)

7. Projection of solids: Cube, rectangular prism, Hexagonal prism, Cylinder, Pyramid, Cone. (Practice Sheet 6)

8. Section of solids and their projections on principal and auxiliary planes for true shape: Cylinder, hexagonal pyramid. (Practice Sheet 7)

9. Isometric projections: Basic concepts, isometric scale; Isometric projection and view.

10. Practice with simple laminar and solid objects. (Practice Sheet 8)

References:

1. “Elementary Engineering Drawing” by Bhatt, N.D; Charotan Book Stall, Anand


Semester 3

THEORY
Module I : 10 L
Particulate solids : Characterization of solid particles, particle shape, particle size, average particle size of particulate solids in terms of mean diameters like arithmetic mean diameter, mass-mean diameter, volume-mean diameter, volume-surface mean diameter. Mixed particle sizes and size analysis, specific surface of mixture.

Screen analysis : Types and Standards of screens, ideal screen, real screen, screen effectiveness, differential and cumulative analysis, screen capacity, relation of screen capacity to screen effectiveness.

Screening equipment: stationary screens and grizzlies, gyrating screens, vibrating screens and other industrial screens like trammels.

Transportation and storage of solids : Concepts of Conveyor and Elevator, Studies on performance and operation of different conveyor systems like Belt, Screw, Apron, Flight, pneumatic conveyor, pipe conveyor and bucket elevators; Storage of solids and discharge pattern from storage bin, theory and measurement of granular solid flow through orifice.

Module II : 10 L
Comminution of solids (Size Reduction) : Factors affecting comminution, comminution laws :

Kick’s law, Rittinger’s law and Bond’s law and their limitations. Crushing efficiency & power consumption.


Module III : 10 L
Separation based on particle Mechanics through liquids : Free settling and Hindered settling,

Mixing : Principles and utilities of agitation, agitation equipment, flow patterns: prevention of swirling/vortex, draft tubes, Standard turbine design, power consumption, power correlation, significance of dimensionless groups, effect of system geometry, calculation of power consumption in Newtonian liquids. Solid-solid mixing equipment, Mixing effectiveness and Mixing index. Agitator scaleup.

Froth Flotation : Theory, operation, types, Flotation agents, Flotation cells.

Module IV : 10 L

Text books:

References:
1. Introduction to Chemical Engineering - Badger and Bencharo, McGraw Hill.
Module I : 10 L
Fundamental Concepts: Introduction to Fluid mechanics: Definition of Fluid, Continuum concept of fluid, concept of Knudsen number, Fluid properties : density, specific gravity, viscosity, Newtonian fluid; Non-Newtonian fluid

Fluid Statics: Basic equation of fluid statics; pressure variation in a static field; pressure measuring devices–manometer, U-tube, inclined tube, force on submerged bodies (straight, inclined), centre of pressure.

Fluid kinematics: Eulerian and Lagrangian approach, Streamline, pathline, streak line, concept of velocity and acceleration, material, temporal derivatives

Fluid dynamics: Concept of velocity –local, average, maximum, flow rate – mass, volumetric, velocity field; dimensionality of flow; flow visualization – stress field; Reynold’s number—its significance, laminar, transition and turbulent flows, steady, unsteady and uniform, non-uniform flows.

Basic equations in integral form: Basic laws for a system; relation of system derivatives to the control volume formulation; conservation of mass; continuity equation.

Module II : 10L
Momentum balance equation: Derivation of momentum balance equation-Introduction to Navier Stoke’s equation in rectangular, cylindrical coordinates, Introduction to rotational and irrotational flow, momentum correction factor.

Internal incompressible viscous flow: Navier Stokes equation and its applications in fluid flow through various geometries.

External incompressible viscous flow: Boundary layer, Basic concepts of hydrodynamic boundary layer

Introduction to Euler’s Equation, Bernoulli’s equation- applications of Bernoulli’s equation, kinetic energy correction factor; head loss; friction factor-Fanning and Darcy, Moody diagram; major and minor losses.
Module III : 10 L
Flow measurement: Introduction; general equation for internal flow meters; Orifice meter; Venturimeter; concept of area meters rotameter; Local velocity measurement: Pitot tube. Hot wire anemometer, mass flowmeter.

Open channel flow: Introduction, Flow classification, importance of Froude number, Chezy formula, Manning roughness correction, flow measurement by weirs.

Fluid moving machines: Introduction; Basic classification of pumps: Non-Mechanical Pumps—acid egg, steam jet ejector, air lift pump, Mechanical pump: Centrifugal pumps cavitation, NPSH, Positive displacement pumps (rotary, piston, plunger, diaphragm pumps); pump specification; basic characteristics curves for centrifugal pumps; fan, blower and compressor. Valves and fittings: Pipe fittings and valves, schedule no, equivalent diameter.

Module IV: 10L
Fluidization: Introduction; different types of fluidization; minimum fluidization velocity; governing equation; pneumatic conveying and other industrial uses.

Fluid flow about immersed bodies: Introduction; concept of drag and lift; variation of drag coefficient with Reynolds number; stream-lined body and bluff body. Packed bed: concept of sphericity; Ergun equation, modified friction factor.

Introduction to compressible flow: concept of speed of sound, Mach number, subsonic, supersonic flow, isentropic flow, applications.

Introduction to turbulent flow: Basic concepts, Prandtl mixing length, concept of shear velocity, Reynold’s stresses.

Text book:


References:

Subject Name: Energy Engineering

Paper Code: CHEN 2103

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Module I: 10L
Introduction: Conventional (fossil energy) and non-conventional (alternative energy) resources & reserves. Global Energy production & consumption pattern. Production & consumption pattern in India.
Coal Reserves in India
Physical Properties of coal, Proximate & Ultimate Analysis of Coal, Cleaning, washing & Storage of coal.
Theory of coal pyrolysis and Carbonization: Low Temperature Carbonization (LTC), High Temperature Carbonization (HTC), Horizontal & Vertical Gas Retorts, Coke Ovens-Beehive & Byproduct Slot type. Recovery of byproducts. Details of Structural configuration and Operating principles of Coke ovens including Charging and Discharging Mechanism.

Module II: 10L
Liquid Fuels: Constitution of petroleum, theory of formation of crude petroleum oil. Characterization of crude oil & petroleum fuels, on shore and off-shore oil exploration. Parameters and testing logistics of petroleum products—Octane no., Cetane no., Pour point, Smoke point, Cloud point, Flash point, Fire point, Aniline point and Diesel index.
Processes of a typical Indian refinery involving Operation and flow-sheet of crude distillation plant; Thermal & catalytic cracking and reforming processes; coking, visbreaking, Fluid catalytic cracking and Hydrocracking.
Concept of Modern Refinery integrated with downstream petrochemicals units which manufacture naphtha-based aromatics as well as propylene-based polymers.
Liquid fuel from coal: Fischer Tropsch process.

Module III: 10L
Gaseous Fuels: Classification of gaseous fuel; Physico-chemical principles, Calorific Value, Wobbes index, and flame speed.
Module IV: 10 L
Nuclear energy: Sources of Nuclear fuels, Indian scenario; Nuclear reactions and power generation by Nuclear reactors- Breeder reactor- reaction & operation.
Fuels from Renewable Sources – Bio Fuels 1
Preliminary concepts of Illumination Engineering—CFL and LED lights.

Text Books:
2. Elements of Fuels, Furnaces and Refractories – Prof. O.P. Gupta, Khanna publishers
3. Understanding Renewable Energy Systems - Volker Quaschning - Earthscan Ltd

Reference Books:
2. Fuel Cells: From Fundamentals to Applications - Supramaniam Srinivasan - Springer
Subject Name: Industrial Stoichiometry

Paper Code: CHEN 2104

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Module I: 10L
Units and Dimensions:, Conversion of Equations, Systems of Units, Dimensional Homogeneity and Dimensionless Quantities, Buckingham Pi-theorem for Dimensional Analysis, Concentration of different forms, Conversion from one form to another, Raoult’s Law, Henry’s law, Antoine’s Equation. Clausius Clapeyron Equation.
Mathematical Requisites: Use of log-log and semi-log graph paper, Triangular Diagram, Graphical Differentiation and Graphical Integration, Least Square Method, Curve Fitting, Method of Regression.

Module II: 10L
Introduction to Chemical Engineering Calculations: Basis, Mole Fraction and Mole Percent, Mass Fraction and Mass Percent, Material Balance without Chemical Reaction: Material Balance during Mixing, Humidity and Application of Psychrometric Chart, Material balance calculation of the following unit operations: Crystallization, Evaporator, Distillation Column, Absorption Column, Drier, Liquid - Liquid and Solid - Liquid Extraction Units

Module III: 10L
Material Balance with Chemical Reaction: Single Reaction, Multiple Reactions, Reactions with Recycle, Purge and By pass, Combustion Reaction, Calculation of Excess Air, Material Balance of Unsteady State Reaction systems.

Module IV: 10L
Text Books:
2. Basic Principles and Calculations in Chemical Engineering, 6th. Ed., D.M. Himmelblau: Prentice Hall,

References:
Module I : 9L
General idea of ecology, ecosystem – components, types and function.
Structure and function of the following ecosystem: Forest ecosystem, Grassland ecosystem, Desert ecosystem, Aquatic ecosystems, Mangrove ecosystem (special reference to Sundarban); Food chain (definition and one example of each food chain), Food web.
Biogeochemical Cycle- definition, significance, flow chart of different cycles with only elementary reaction (Oxygen, carbon, Nitrogen, Phosphorus, Sulphur).
Biodiversity- types, importance, Endemic species, Biodiversity Hot-spot, Threats to biodiversity, Conservation of biodiversity.

Module II : 9L
Air pollution and control
Atmospheric Composition: Troposphere, Stratosphere, Mesosphere, Thermosphere, Tropopause and Mesopause.
Definition of pollutants and contaminants, Primary and secondary pollutants: emission standard, criteria pollutant. Sources and effect of different air pollutants- Suspended particulate matter, oxides of carbon, oxides of nitrogen, oxides of sulphur, particulate, PAN.
Module III : 9L
Water Pollution and Control: Hydrosphere, Hydrological cycle and Natural water. Pollutants of water, their origin and effects: Oxygen demanding wastes, pathogens, nutrients, Salts, thermal application, heavy metals, pesticides.
River/Lake/ground water pollution: River: DO, 5 day BOD test, Unseeded and Seeded BOD test, BOD reaction rate constants, COD.
Lake: Eutrophication (Definition, source and effect). Ground water: Aquifers, hydraulic gradient, ground water flow (definition only).
Water Treatment system (coagulation and flocculation, sedimentation and filtration, disinfection, hardness and alkalinity, softening) Waste water treatment system, primary and secondary treatments (Trickling filters, rotating biological contractor, Activated sludge, sludge treatment, oxidation ponds)
Water pollution due to the toxic chemicals effects: Lead, Mercury, Cadmium, Arsenic.
Noise Pollution, Definition of noise, effect of noise pollution, noise classification (Transport noise, occupational noise, neighbourhood noise). Definition of noise frequency, noise pressure, noise intensity, noise threshold limit value, equivalent noise level, L10 (18hr Index), effective perceived noise level.
Noise pollution control.

Module IV : 9L
Land Pollution Solid Waste: Municipal, industrial, commercial, agricultural, domestic, pathological and hazardous solid wastes, electronic waste.
Environmental impact assessment, Environmental audit, Environmental laws and protection act of India.
Energy audit, Green building, Green sources of energy, Concept of Green Chemistry, Green catalyst, Green solvents (replacement of VOC).

References/Textbooks :
5. Basic Environmental Engineering and Elementary Biology - GourKrishna Das Mahapatra, Vikas Publishing House P. Ltd.
Subject Name: Indian Culture and Heritage

Paper Code: HMTS 2002

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**Module I : 8L**
Indian Religion & Philosophy: Orthodox Indian Philosophy, Unorthodox Indian philosophy, Essentials of Hinduism, An overview of Jainism, Buddhism, Sikhism, Islam, Christianity religions.

**Module II : 8L**
Values and Personality: Aspects of Indian Values, Essentials of Personality Building, Ethics at work place, Aspects of Leadership qualities.

**Module III : 8L**
Indian Scriptures: Selections from the Vedas, Select verses from Upanishad, An overview of Gita, XVIth chapter of Gita.

**Module IV : 8L**
Indian Psychology: Aspects of Yoga Philosophy, Mind and its workings according to Yoga, Law of Karma, Selections from Manusmriti.

References / Text Books:
1. Indian Philosophy - S.C. Chatter and D. M. Dutta, Calcutta University Press.
2. Spiritual Heritage of India - Swami Prabhavananda, Sri Ramakrishna Math, Chennai.
3. Raja Yoga - Swami Vivekananda, Advaita Ashrama, Mayavati.
5. Gita - Swami Swarupananda, Advaita Ashrama, Kolkata.
7. Carving a Sky (MSS) - Samarpan.
8. Essentials of Hinduism (MSS) - Samarpan.
LABORATORY
Subject Name: Energy Laboratory

Paper Code: CHEN 2111

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At least eight experiments are to be performed

1. Proximate analysis of Coal.
2. Determination of carbon residue of fuel oil.
3. Determination of aniline point of a fuel oil.
4. Determination of moisture content of fuel oil by Dean & Stark apparatus.
5. Atmospheric Distillation of a petroleum product.
6. Determination of Flash Point & Fire Point of an oil by Abel apparatus.
8. Determination of kinematic viscosity of oil by Redwood Viscometer.
10. Determination of calorific value of solid and liquid fuel by Bomb Calorimeter.
11. Determination of vapour pressure of petroleum product using Reid apparatus.
12. Experiments on Non-conventional Energy Source using Solar Cooker/Flat Plate
13. Analysis of a gaseous mixture by Orsat apparatus.
Subject Name: Fluid Mechanics Lab

Paper Code: CHEN 2112

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At least eight experiments are to be performed

1. Determination of coefficient of discharge at various Reynold’s number during fully developed fluid flow through orificemeter.

2. Determination of coefficient of discharge at various Reynold’s number during fully developed fluid flow through venturimeter.

3. Determination of loss coefficient of pitot tube and construction of fully developed velocity profile through pipe in laminar and turbulent flow regime.


5. Determination of pressure drop for flow through packed bed and verification of Ergun equation.

6. Determination of characteristic curve of a centrifugal pump.

7. Experiments on Reynold’s apparatus for determination of flow regime and construction of fanning’s friction factor vs Reynold’s number plot.

8. Determination of pressure drop and bed height profile with varying modified Reynold’s number during flow through a fluidized bed. Determination of incipient fluidization.


11. Assembling of pipe line and fitting according to a given layout.
Subject Name: Mechanical Operations Laboratory

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At least eight experiments are to be performed

1. Sieve Analysis: To analyze a given powder for its particle size distribution. / Cumulative and Differential methods of particle size distributions.

2. Overall Screen Effectiveness: To find out screen efficiency through a suitable material balance with respect to a single screen.

3. Jaw Crusher: To find out the reduction ratio and capacity and to verify Rittinger’s Law.

4. Ball Mill: To determine the reduction ratio, capacity and the critical speed of the ball mill.

5. Rod Mill: To determine the reduction ratio and capacity and compare the reduction ratio for the same feed sample to that in a ball mill.

6. Hammer Mill: To find out the reduction ratio and capacity.

7. Batch sedimentation: To determine the settling and sedimentation characteristics of given slurry.

8. Elutriator: To study the sorting of a given mixture in an elutriator.

9. Filtration: To determine the specific cake resistance and filter medium resistance in the given plate and frame filtration.

10. Mixing: To determine the power number and power consumption for a given liquid in an agitated vessel.

11. Cyclone Separator: Demonstration of the operation of a cyclone separator and determination of its overall collection efficiency.

12. Hard Grooved Instrument: To determine the work index of a given brick sample.
**Subject Name: Chemical Engineering Drawing Lab**

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1. Introduction to AUTOCAD software for drawing in 2D: Drawing and editing commands. Knowledge of setting up layers, dimensioning, hatching, making block, plotting and printing, working with external reference file.

2. Drawing any three of the following item using AUTOCAD software.
   a) Flange coupling for shaft and vessel or pipe.
   b) Pipe joints and fittings, single line and double line pipe line assembly
   c) Stuffing box.
   d) Detailed cut section drawing of Globe valve and Stop valve.
   e) Piping and instrumentation diagram of any given chemical process.

3. Assembly drawing of a single stirred jacketed pressure vessel with all its accessories using AUTOCAD software.

4. Introduction to AUTOCAD software for drawing in 3D: Working in 3-dimensions, Drawing and editing commands, viewing 3D objects, basic solid and wireframe models, extruding, simple revolved objects. Generation of orthographic projections from 3D drawing.
Semester 4

THEORY
Module I : 8L

Human society and the Value System:

Values, definition, importance and application. Formation of Values: The process of Socialization, Self and the integrated personality Morality, courage, integrity.

Types of Values: Social Values, Justice, Rule of Law, Democracy, Indian Constitution, Secularism Aesthetic Values: Perception and appreciation of beauty.


Spiritual Values &their role in our everyday life.

Value Spectrum for a Good Life, meaning of Good Life .

Value Crisis in Contemporary Society: Value crisis at Individual Level, Societal Level, Cultural Level.

Value Crisis management - Strategies and Case Studies.

Module II : 8L

Ethics and Ethical Values.
Principles and theories of ethics.

Consequential and non-consequential ethics.

Egotism, Utilitarianism, Kant's theory and other non-consequential perspectives.
Ethics of care, justice and fairness, rights and duties.

Ethics: Standardization, Codification, Acceptance, Application.
Types of Ethics: Ethics of rights and Duties, Ethics of Responsibility, Ethics and Moral judgment, Ethics of care, Ethics of justice and fairness, Work ethics and quality of life at work.

Professional Ethics:
Ethics in Engineering Profession; moral issues and dilemmas, moral autonomy (types of inquiry).
Kohlberg's theory, Giligan's theory (consensus and controversy).
Violation of Code of Ethics: conflict, causes and consequences
Engineering as social experimentation, engineers as responsible experimenters (computer ethics, weapons development); Engineers as managers, consulting engineers, engineers as experts, witnesses and advisors, moral leadership; Conflict between business demands and professional ideals, social and ethical responsibilities of technologies.
Whistle Blowing: Facts, contexts, justifications and case studies
Ethics and Industrial Law.
Institutionalizing Ethics: Relevance, Application, Digression and Consequences.

Module III: 8L
Science, Technology and Engineering as knowledge and profession; Definition, Nature, Social Function and Practical application of science.
Rapid Industrial Growth and its Consequences.
Renewable and Non-renewable Resources: Definition and varieties.
Energy Crisis.
Industry and Industrialization.
Man and Machine interaction.
Impact of assembly line and automation.
Technology assessment and Impact analysis.
Industrial hazards and safety.
Safety regulations and safety engineering.
Safety responsibilities and rights.
Safety and risk, risk benefit analysis and reducing risk.
Technology Transfer: Definition and Types, The Indian Context.

Module IV: 8L
Environment and Eco-friendly Technology: Human Development and Environment; Ecological Ethics/Environment ethics; Depletion of Natural Resources: Environmental degradation Pollution and Pollution Control
Eco-friendly Technology: Implementation, impact and assessment
Sustainable Development: Definition and Concept
Strategies for sustainable development
Sustainable Development--- The Modern Trends
Appropriate technology movement by Schumacher and later development Reports of Club of Rome.
Textbook/References :
Subject Name: Chemistry II

Paper Code: CHEM 2201

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Module I : 9L
Colloids: Introduction; Classification of colloids; Size and shape; preparation of sols; Origin of charge in Colloidal particles; Stability of Colloids; Kinetic, Optical & electrical properties; Electrokinetic phenomena; Electrical Double Layer; Ultracentrifuge and Molecular weight determination of Macromolecules.
Kinetic theory of gases, Van der Waals Equation of state, Maxwell distribution law, vapour-liquid equilibrium
Adsorption: Introduction; Gibb’s adsorption equation; Surface Excess; Adsorption isotherms: Freundlich, Langmuir, BET adsorption equations; Surface Films; Langmuir Balance; two dimensional equation of state.

Module II : 9L
Solution thermodynamics: Duhem Margulas equation and its application, concept of fugacity, activity and activity coefficients and their measurements.
Colligative properties of dilute solutions: vapour pressure lowering and osmotic pressure, thermodynamic derivation of their relationship, semipermeability, reverse osmosis, elevation of boiling point and depression of freezing point, van’t Hoff factor, molar mass and colligative properties, experimental determination of colligative properties.

Module III : 9L
Preparation and synthetic application Grignard’s reagent.
Common organic reactions i.e. Friedel-Crafts, Cannizaro, Aldol condensation, Beckmann, Schmidt, Lossen, Curtius Rearrangements.
Industrial Preparation: Synthesis of commercially important compounds (e.g. industrial reactions of phthalic anhydride from xylene and naphthalene, DDT from chlorobenzene, aspirin and methyl salicylate from phenol).

Module IV : 9L
Aminoacids: Classification; General methods of preparation and properties of amino acids, polypeptide synthesis.
Carbohydrate: Classification, Glucose and fructose, Disaccharides: Sucrose & maltose.

Text Books:
1. Physical Chemistry - G.W.Castellan, Narosa.

Reference Books:
Subject Name: Data Structure & Database Concept

Paper Code: CSEN 2206

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DATA STRUCTURE

Module I : 10L
Linear Data structures:
Implementation of Stack, Queue and their variations using linked list
Recursion: Design of Recursive algorithm, Tail Recursion.

Module II : 13L
Non-Linear Data Structures: Trees : Binary Trees, Traversals, Binary Search Trees- Insertion and Deletion algorithms, AVL Tree, Heap(Definition and basic concepts)
Graphs: Breadth First Search (BFS) and Depth First Search (DFS). Sorting Algorithms: Bubble sort, Insertion sort, Selection sort, Quick sort.
Searching Algorithms: Linear search, Binary search.

DATABASE CONCEPT

Module III : 10L
Introduction to relational algebra & SQL: Operators like select, project, rename, artesian product, join, union, intersect, minus, DDL, DML.

Module IV : 12L
Relational Database Design: Functional Dependencies, Normalization: Different anomalies in database designing 1NF, 2NF, 3NF and BCNF, Lossless-Join Decomposition and Dependency Preservation,
Introduction to Transaction Processing Concepts: ACID properties, Serializability and Recoverability
Text Books:
Data Structures:
1. Data Structures - Seymour Lipschutz, Publication: Tata McGraw-Hill (India)

Database Concept:

Reference Books:
Data Structure:
2. The Art of Computer Programming - Donald E. Knuth, Addison-Wesley Professional.

Database Concept:
Module I : 10L
Introduction to basic modes of heat transfer and their application in chemical process, heat transfer by conduction: Fourier law, thermal conductivity, thermal resistance; general heat conduction equation, thermal diffusivity; steady state heat conduction with heat generation for plane wall, cylindrical body and spherical body; conduction-convection system: critical insulation thickness of curved surface, steady state heat conduction through fin, fin efficiency, unsteady state heat conduction in solid with large thermal conductivity, significance of Biot no and Fourier no, transient heat conduction in solid.

Module II : 10L
Convective heat transfer without phase change: Newton-Rikhman law, local and average heat transfer coefficient, Reynold-Colburn analogy, concept of individual heat transfer coefficient and overall heat transfer coefficient, LMTD, empirical correlation for heat transfer coefficient in forced convection; elementary concept of thermal boundary layer, temperature distribution in laminar flow, analysis of free convection and correlation of free convection, Grashof number.

Module III : 10L
Heat transfer with phase change: filmwise and dropwise condensation, laminar film condensation on vertical plate, Nusselt equation; analysis of heat transfer during boiling, different boiling regimes during pool boiling.
Characteristics of radiation, properties of radiating surface, black body radiation: Plank’s distribution law, Total emissive power: Stefan-Boltzman law, use of radiation function table; Wien’s displacement law; Kirchoff’s law; emissivity of black body, gray body and real body; radiation between surfaces: view factor, Electrical network approach for radiation heat exchange, radiation shields and their application, radiation heat exchange for three radiating surfaces; radiation heat transfer through absorbing emitting medium.

Module IV : 10L

Evaporators and their classification, capacity and steam economy, BPE, material and energy balance of single effect evaporator, classification of multiple effect evaporator, design of single
effect and multiple effect evaporator.

Text Books:

1. Process Heat Transfer - D. Q. Kern, MGH.
2. Heat Transfer Principles and Application - B. K. Dutta, PHI.
3. Units Operations of Chemical Engineering - McCabe & Smith and Harriot, MGH.

References:

**Subject Name: Separation Processes I**

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**Module I : 10L**
Principles of molecular diffusion and diffusion between phases, Fick’s Law, Diffusivity, Equation of continuity, Diffusion in solids, Knudsen diffusion. A definition of Mass transfer coefficient, other definitions of mass transfer coefficient, Correlation involving mass transfer coefficients, Theories of mass transfer, Mass transfer across interfaces, Two-resistance theory, Analogy between momentum, heat and mass transfer.

**Module II :10L**
Introduction to distillation, Vapor -liquid equilibria, Relative volatility, Ideal and non-ideal solutions, Batch Distillation, Rayleigh equation, Flash distillation, Steam distillation, Rectification of binary systems, Reflux ratio, Boil-up ratio, Fenske’s Equation, Flooding, Dumping, Coning in a plate column, Calculation of number of plates in a distillation column by McCabe-Thiele method, Enthalpy-concentration diagram, Calculation of number of plates in a distillation column by Ponchon-Savarit method, Optimum reflux ratio, Plate efficiency.

**Module III : 10L**
Introduction to absorption, The mechanism of absorption, Absorption equipment, Limiting gas-liquid ratio, Flooding, loading in packed column, Diameter and height calculations for packed columns, H. E. T. P., H. T. U. and N. T. U. concepts, Packed tower design, Gas film coefficient, Liquid film coefficient, Height of column based on overall coefficients, Number of plates and Diameter of Plate type towers, Absorption factor, Number of plates by use of absorption factor, Kremser equation.


**Module IV : 10L**
a. Distillation Column internals and sizing, Azeotropic & Extractive distillation, Multi-component distillation.

b. Adsorption: Introduction, Nature of adsorbents, Batch adsorption, Adsorption isotherms, Adsorption equipment, Breakthrough curves, Scale up, Length of unused bed, Design of fixed bed adsorption column.
Text Books:


References:

1. Transport process and Unit Operations: Geankoplis. 3rd Edn., PHI.
2. The Elements of Fractional Distillation: Robinson, C. S. and Gilliland, E. R. MGH.
3. Separation Processes: King, C. J. MGH.
6. Distillation Design, Henry Kister, MGH.
Module I : 10L
Introduction-Macroscopic and microscopic approaches; Units; Basic concepts of system, property, force, temperature, pressure, work, energy, heat and equilibrium from thermodynamic aspect.

Application of 1st law of thermodynamics to chemical process: open and closed system energy balance equations, SFEE, compressible flow through a nozzle, working principle of single stage and multistage compressor.

P-V-T behaviour of pure substances, equation of state: virial equation of state, cubic equation of state, law of corresponding states, generalised correlations for gases and liquids, acentric factor, compressibility factor.

Module II : 10L
Application of second law of thermodynamics to chemical process, entropy generation and irreversibility, clausius inequality.

Ideal power cycle, Rankine cycle, reheat cycle, regenerative cycle, and working principle of IC engine: Otto cycle, diesel cycle, brayton cycle.

Ideal refrigeration cycle, vapour compression cycle, Bell-Coleman cycle, absorption refrigeration cycle, isenthalpic expansion: Linde and Claude liquefaction cycle.

Module III : 10L
Thermodynamic property relations of pure fluid: Maxwell relations. The Jacobian Method, residual property, physical significance of Gibb’s free energy and work function, concept of fugacity.

Solution thermodynamics: partial molar properties, chemical potential, Gibbs-Duhem equation, effect of temperature and pressure on chemical potential, fugacity in solution, Lewis-Randall rule and Henry’s law, Raoult’s law, excess property, activity and activity coefficient, property change on mixing, Excess Gibbs free energy models – Margules, Redlick – Kister, Whol’s, Van Laar, Wilson & NRTL, UNIQUAC, Group Contribution methods, modified Raoult’s law, P-x-y and T-x-y diagram of binary liquid solution, azeotrope calculation, thermodynamic consistency checking of data.
Module IV : 10L
Chemical reaction equilibria: Reaction Stoichiometry, reaction coordinate, criteria of reaction equilibrium, equilibrium constant, standard Gibbs energy change and equilibrium constant, effect of temperature on equilibrium constant, effect of pressure on equilibrium constant, effect of inert material, excess reactant and product on equilibrium constant, heterogeneous reaction equilibria, phase rule and Duhem theorem for reacting syst

Text Books:

2. A Text Book of Chemical Engineering Thermodynamics, Narayanan, PHI

References:

3. Chemical and Process Thermodynamics: Kyle PHI.
LABORATORY
Subject Name: DBMS Laboratory

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Experiments on Database on RDBMS Platform (Oracle):

1. DDL Commands: Creating Tables along with constraints like: Primary Key, Foreign Key, unique, Not Null, Check. Altering Table Structure like adding and modifying constraints, adding and modifying column data types, etc..

2. DML: Inserting rows, Updating rows, Deleting rows

3. SQL Query: Cartesian Product, Join, Union, Intersect, Minus, Single Row functions, multiple row functions using GROUP BY clause, ORDER BY Clause, Nested Sub-Queries

4 Introduction to PL/SQL: Programming Language Constructs in PL SQL like variable declaration, Conditional Statements, different types of loop structures, functions, etc. Programming using Cursors, Creating different types of Triggers.

Reference Books:

1. SQL, PL/SQL: The Programming Language Of Oracle (With CD-ROM) (English) 4th Revised Edition: Ivan Bayross, Publisher: BPB Publications.
Subject Name: Heat Transfer lab

Paper Code: CHEN 2211

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At least eight experiments are to be performed

1. Determination of thermal conductivity of a metal bar using Fourier's heat conduction equation.
2. Estimation of heat loss through a lagged pipe and determination of thermal conductivity of insulating material.
3. Determination of thermal conductivity of insulating powder during heat transfer in a spherical vessel.
4. Determination of heat transfer coefficient of air during forced convection heat transfer and to study the effect of air velocities on heat transfer coefficient.
5. Determination of overall heat transfer coefficient in a Counter current & Parallel flow double pipe heat exchanger and to study the effect of fluid flow rate on overall heat transfer coefficient.
6. Determination of overall heat transfer coefficient and efficiency of a Shell and Tube heat exchanger and to study the effect of fluid flow rate on overall heat transfer coefficient.
8. Determination of Stefan’s Boltzman constant experimentally.
10. Determination of Biot number for a conductive convective system and validation of lumped system assumption.
Subject Name: Language Practice Lab Level II

Paper Code: HMTS 2011

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Module I: 8L

Conversational skills in the business scenario: One-to-one and Group communication, Gender and Culture Sensitivity, Etiquette, Sample Business Conversation, Telephonic Conversation.

Module II: 8L
Presentation skills:
Speech Purposes: General Informative Speeches, Persuasive Speeches, Entertaining Speeches, Methods of Speaking: Speaking from a Manuscript, Speaking from Memory, Impromptu Delivery, Extemporaneous Delivery, Analyzing the Audience, Nonverbal Dimensions of Presentation.


Module III: 8L
Group Discussion
Introduction to Group Communication

Module IV: 8L

Resume and CV: Difference, Content of the Resume – Formulating Career Plans: Self Analysis,


References:

Semester 5

THEORY
Subject Name: Economics for Engineers
Paper Code: HMTS-3101

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Module 1: 6L
Market: Meaning of Market, Types of Market, Perfect Competition, Monopoly, Monopolistic and Oligopoly market.
The basic concept of economics – needs, wants, utility.
Inflation: meaning, reasons, etc.

Module 2: 4L
Business: Types of business, Proprietorship, Partnership, Joint-stock company, and cooperative society – their characteristics.
Banking: role of commercial banks; credit and its importance in industrial functioning. Role of central bank: Reserve Bank of India.
International Business or Trade Environment.

Module 3: 8L
Cost Accounting- Terminology, Fixed, Variable and Semi-variable costs.
Marginal Cost based decisions. (6L)

Module 4: 12L
Equity and Debt, Cost of Capital. (4L)
Capital Budgeting: Methods of project appraisal - average rate of return - payback period - discounted cash flow method: net present value, benefit cost ratio, internal rate of return.
Depreciation and its types, Replacement Analysis, Sensitivity Analysis. (8L)

Evaluation: Max marks-100
Internal Test-30
Semester Test-70
Suggested Readings:

Module I: 10 L
Water treatment: Water for the chemical process industry, Boiler feed-water, Cooling tower water, Demineralised water, Drinking water; Treatment methodology: Conventional water-treatment procedures, Ion-exchange, Membrane technology etc.


Soda-ash: Production and consumption pattern, Raw materials, Solvay process Physico-chemical principles of manufacture, carbonation and ammonia recovery step, flow-sheet and sequence of operation, other processes, advancement of process technology and modified Solvay process, major engineering problems, uses.

Module II: 10 L
Industrial Acids:
Hydrochloric Acid: Manufacturing methods: By product Recovery from other production processes, conventional raw materials and principles of manufacture, flow-sheet and sequence of operation, major engineering problems, uses.
Sulfuric acid: Raw materials resources, sulfuric acid production processes, Contact process, Physico-chemical principles and general theory of contact reaction with thermodynamic and reaction engineering aspects, different types of catalyst – preparation methodology and relative merits, flow-sheet and sequence of operation, details of major equipments, advancement of process technology and major engineering problems, DCDA process, uses.
Nitric Acid: Raw materials resources, Ostwald Process–physico-chemical principles, catalyst, process flow sheet and sequence of operation, details of major equipments, uses.
Phosphoric Acid: Raw materials, manufacturing process with process flow sheet, details of major equipments, uses.

Module III: 10 L
Fertilizer Industries:
Nitrogenous fertilizers: Ammonia-Source of hydrogen; methods of obtaining hydrogen from
different sources, source of nitrogen-liquefaction of air and distillation of liquid air;  
Synthesis of ammonia- physico chemical principles, catalyst for synthesis of ammonia, process  
flow sheet and sequence of operation, details of major equipments.

Urea - Raw materials, manufacturing process with flow sheet, sequence of operation, major  
equipments details.

Ammonium sulphate: Raw materials, manufacturing process with flow sheet, major equipments  
details.
Phosphatic fertilizers: Manufacturing process of super phosphate of lime, single and triple super  
phosphate, Diammonium phosphate.
Mixed fertilizers: NPK –manufacturing process, details of major equipments;

**Module IV: 10 L**

Ceramic and ceramic materials:

Cement: Chemical composition of Portland cement, raw materials, dry and wet process for  
making cement clinker, setting and hardening of cement.

Glass: Composition of glass, raw materials, manufacturing method of glass- pot furnace and tank  
furnace, annealing of glass.

Ceramic: Basic raw materials, white-wares, manufacturing process of porcelain and their  
forming operations.
Refractories: Properties of Refractories, raw materials, manufacturing techniques of acid  
refactories, basic Refractories, sintered and fused refractories, insulating refractories.

**Text Books :**

1. Dryden, C. E., and Rao, M.G. (Ed.), Outlines of Chemical Technology Affiliated East  
   West Press

**References:**

1. Venkateswarlu, S. (Ed.) Chemtech (II) Chemical Engineering Development Centre,  
   Indian Institute of Technology, Madras
Subject Name: Chemical Reaction Engineering

Paper Code: CHEN 3102

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Module I: 10L
Introduction; Definition of reaction rate; Kinetics of homogeneous reaction: Concentration-dependent term of a rate equation, single and multiple reactions, rate equation from given mechanisms.


Interpretation of batch reactor data: Constant-volume batch reactor, Integral method of analysis of data: General Procedure, Irreversible unimolecular-type first-order reaction, Irreversible bimolecular-type second-order reactions, rate equation for enzymatic reaction, Zero-order reactions, Over-all order of irreversible reactions from the Half-life method, Initial rate method of analysis.

Irreversible Reactions in parallel, Autocatalytic reactions, Irreversible reactions in series, First-order Reversible Reactions, Differential method of Analysis of data: Analysis of the Complete Rate Equation, Partial analysis of rate equation,

Variable-Volume reaction system: Its Integral method of analysis for Zero-order reactions, First order reaction, Second-order reactions;

Module II: 10L
Single ideal Reactors: Introduction; Basic division of ideal reactors, Ideal Batch Reactor, Concept of flow reactors, Space-time and Space-velocity,

Steady-state Mixed Flow Reactor: Design Equation, Graphical Representation of Design Equation, related problem;


Multiple-Reactor Systems: PFRs in Series and/or in Parallel, Equal-size MFRs in Series, MFRs of different sizes in Series, Determining the best size combination of reactor size for a given
combination, Reactors of Different Types in Series,

Recycle Reactor: Definition of Recycle Ratio, Design Equation, and Optimum Recycle ratio.

**Module III: 10L**

Design for Multiple Reactions: Introduction, Reactions in Parallel, Qualitative aspects of Product Distribution,

Quantitative Treatment of Product Distribution and of Reactor Size: Definition of Instantaneous and Overall fractional yield, graphical representation; Reactions in Series: Successive First-Order Reactions, Product Distribution, Quantitative Treatment of PFR, MFR and Batch Reactor.

Solid-Catalyzed Reaction: Introduction; Basic idea of catalysis, Catalyst properties, Steps in catalytic reaction:

Qualitative discussion on Pore Diffusion, Adsorption, Surface reaction and Desorption, Concept of Rate limiting step;

Design of reactors for gas-solid reactions: Design equation and data analysis of heterogeneous system; Quantitative aspects of Pore diffusion controlled reactions (single cylindrical pore, first-order reaction): Material balance for the elementary slice of catalyst pore, Definition of Thiele Modulus and Effectiveness Factor.

Different methods of catalyst preparation. Catalyst surface area and pore volume measurement

Fluid-Particle Reactions: Introduction; Different behavior of reacting solid particles; Selection of a Model; Qualitative discussion on Progressive Conversion Model & Unreacted Core Model;

Introduction to non isothermal reactions: adiabatic and temperature programmed reactions.

**Module IV: 10L**

Distribution of Residence Times for Chemical Reactors: General Characteristics; Residence-Time Distribution (RTD) Function;

Measurement of the RTD: Pulse Input; Related problems; Characteristics of RTD: Integral Relationships, Mean Residence Time, Different Moments of RTD; RTD in Ideal Reactor: RTD in Batch and PFR, Single CSTR, PFR/CSTR series RTD; Concept of Macromixing & Micromixing, Zero Parameter Model: Segregation Model & Maximum Mixedness Model.

Text Books:


References:

Subject Name: Separation Process – II

Paper Code: CHEN 3103

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**Module I : 10L**
Humidification & Dehumidification Processes:
Introduction to Humidification and dehumidification operations, Characteristics of saturated and unsaturated vapor gas mixtures, Dry and wet bulb thermometry, Psychrometric chart, Adiabatic saturation curves, Psychrometric ratio, Gas liquid contact, Design of humidifiers, Dehumidification operation, Principle and design of cooling towers - Natural draft, forced draft and induced draft cooling towers.

**MODULE II : 10L**
Liquid-Liquid Extraction & Leaching:

Introduction to Extraction, Liquid- liquid equilibria, Triangular diagram, Selectivity and choice of solvents, Stage-wise contact, Co- current & counter-current extractor, Stage type extractors and differential extractors, Determination of number of equilibrium stages by graphical method for multistage extraction, Supercritical Fluid Extraction.

Introduction to leaching, General principle, Factors affecting the rate of extraction, Calculation of number of stages, Batch processes, Counter-current washing, Stage calculation methods.

**MODULE III : 10L**
Drying & Crystallization:

Introduction to drying, Rate of drying, Batch drying mechanism, Time of drying, the mechanism of moisture movement during drying, Classification and selection of dryer, Batch dryer and continuous dryer.

Introduction to crystallization, Theory of Crystallization, Formation and growth of crystals, Crystal yield, Rate of crystallization, Crystallizers.

**MODULE IV: 10L**
Membrane Separation Processes:
Introduction to membrane separation processes, Classification of membranes and membrane processes, Dialysis, Ultra filtration- Concentration Polarization, Application of Ultrafiltration Process, Reverse Osmosis, Reverse osmosis in water treatment plant, Pervaporation, Electrodialysis, Membrane fouling, Liquid membrane.

Text Books:


References:

Module I: 10L
Approximation in numerical computation: Truncation and rounding errors, Fixed and floating-point arithmetic, Propagation of errors.
Interpolation: Newton forward/backward interpolation, Lagrange’s and Newton’s divided difference Interpolation.

Numerical integration: Trapezoidal rule, Simpson’s 1/3 rule, Expression for corresponding error terms.

Module II: 10L

Bisection method, Secant method, Newton-Raphson method.

Module III: 10L

Module IV: 10L

Textbook:

Reference:
Professional Elective-I

Subject Name: Polymer Science & Engineering

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Module I: 10 L
Definitions and concepts of terms used in polymer engineering; Classification of polymers; Polymer structures, functionality; polymerization reactions – mechanism of polymerization; stereospecific polymerization, copolymerization. Introduction to nano-polymers: Characterisation techniques: XRD, FESEM and AFM

Module II: 10 L
Polymerization reactors, polymerization processes, characterization of polymers: DSC, DTGA, DMA, Creep Test analysis of polymerization reactions, polymer degradation.

Module III: 10 L
Molecular weight and molecular weight distribution in polymers, properties of polymers – physical, chemical, mechanical and electrical properties of polymers, elementary idea on polymer rheology, polymer blends.

Module IV: 10 L
Polymer processing: modeling – compression & transfer, injection & jet; casting; extrusion, calendaring, lamination, spinning & finishing.

Text Books:

References:
Professional Elective-I

Subject Name: Petrochemical Technology

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**Module I : 10L**
Evolution of petrochemical industry in India, recent trend of petrochemical industry in India, Petrochemical industry feedstock: overview of petroleum refinery industry and its product, natural gas processing; impurities in feedstock for petrochemical industry and the process of their removal.
Synthesis gas production and its use: Steam reforming operation of Naphtha and natural gas, fuel oil partial oxidation method, Methanol production, synthetic liquid fuel production by Fischer-Tropsch process, aldehyde and alcohol production from synthesis gas, ammonia production and its application.

**Module II : 10L**
Steam cracking operation of naphtha and C₂ to C₄ saturates, downstream separation scheme of naphtha cracking. Manufacture of Petrochemicals based on Ethylene: EDC, VCM, VAM, Ethylene oxide, Ethanol amine Manufacture of Petrochemicals based on Propylene: Acrylonitrile, Acrolein, Propylene oxide, glycerine (acrolein route, allyl chloride route, propylene oxide route), Isopropanol
Production of Butadiene from C₄ cut.

**Module III : 10L**
Catalytic reforming of naphtha, catalyst and process variable of BTX reformer, separation of Benzene, Toluene and Xylene from BTX reformate, pyrolysis gasoline hydrogenation and separation of aromatics, separation of meta xylene from mixed xylenes, alkylation of benzene, production of styrene, cumene and phenol, production of Phthalic anhydride. Synthetic detergent and its classification, production of linear alkyl benzene and keryl benzene sulfonate from kerosene cut, additives for detergent.

**Module IV : 10L**
Overview of plastic industry: Production of LDPE, LLDPE, HDPE, PP, PVC, Polystyrene and their application.

Comparative study of Plastic, fibre and elastomer; production of SBR, Butadiene rubber, production of ABS plastic, polyamide, polyester, acrylic fibre, polycarbonates, production of phenol-formaldehyde resin; overview of polymer processing.
Text Books:


References:

Professional Elective-I

Subject Name: Material Science & Engineering

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Module I: 10L
Structure of materials-Various types of bonds; Crystalline Structure of Solids- concepts of unit cell and space lattice, packing factor;

X-ray diffraction for determining crystal structure; Mechanical properties: Strength, hardness, toughness, ductility, brittleness of Engineering Materials; Elastic, Anelastic and visco-elastic behaviour of materials; Electrical, Electronic, Optical & Optoelectronic properties of material; Inorganic & organic amorphous materials and their structural & property characteristics; Optical fibers.

Module II: 10 L
Mechanism of plastic deformation, slip and twinning, structural imperfections: elementary concepts of point, line, surface & volume imperfections; Influence of dislocations/Line imperfections on the mechanical properties of materials; Strain hardening and recrystallisation; Elementary aspects of creep, fatigue, fracture; Phase Diagrams- Solidification and structure of metals, Grain boundaries; Phase equilibrium and phase diagrams of binary alloys; Phase diagram of ternary systems; Iron-Carbon diagram; Heat Treatment –Introduction and purposes of heat treatment; T-T-T diagram; Corrosion-Concepts and forms of corrosion; Corrosion Mechanism and prevention; Protective materials and coating.

Module III: 10 L
Basic principles of metal extraction: Pyrometallurgy: Smelting, calcinations, roasting—oxidizing, predominance area diagrams, multiple hearth, flash and fluo-solid, sintering, smelting, slag and its classification.

Steelmaking process flow diagram: Iron making (Operation involved in Blast furnace)– Steel making (oxygen blown converter –LD) – Secondary steel making / refining (ladle processing, vacuum degassing, ladle furnace processing) – Continuous casting – with emphasis on application of the concepts of physicochemical principles involved, moving/packed bed reactor, gas-liquid two-phase flow, heat transfer with phase change (solidification).

Module IV: 10 L
Principles of Hydrometallurgy and Electrometallurgy, Extraction of Aluminum: Hall-Heroult
process, Electrolytic refining; Sources of Zinc & Copper: Pyro & Hydro metallurgical extraction of copper & Zinc; Extraction of Lead, Recent development in Lead smelting.

Text Books:


References:

1. Elements of Material Science and Engineering, by Lawrence, H. Vanvlack; Published by Pearson Education, 1980.
2. Engineering Physical metallurgy; Lakhtin, Y. Published by MIR Publishers, Moscow, 1975.
LABORATORY
At least eight experiments are to be performed

1. Study of simple batch distillation to verify Rayleigh’s equation.

2. Experiment on wetted wall column to determine mass transfer co-efficient.

3. To study the performance of a distillation (sieve tray/ bubble cap) column.

4. To study gas absorption in a packed tower to determine volumetric mass transfer coefficient and is variation with change in liquid rate.

5. To study the drying rate characteristics curve under constant drying condition in a tray dryer.

6. Experiment on batch adsorption and verification of adsorption isotherms.

7. Experiment on liquid-liquid extraction (to determine the overall mass transfer coefficient for counter current operation)

8. To study drying characteristics in a Rotary Dryer.

9. Determination of psychrometric properties air-water vapour system.

10. To determine the diffusivity of a volatile solid in gas.

Subject Name: PEDD- I

Paper Code: CHEN 3112

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1. Design and Drawing Pressure Vessel - thin and thick cylinder design, design of cylinder head, cover plate, selection of gasket, design of bolt and flange.

2. Design and Drawing of Reactor.

Each student shall be allotted design problems on sl. no 1& 2 at the beginning of the 5th semester and the student shall carryout complete process and mechanical design under supervision of a faculty. The student shall also prepare engineering drawing of the equipment and submit two copies of the design report in tight and bound form 7 days before commencement of 5th semester examination. Assessment would be made on the basis of the submitted report and the viva voce examination conducted by a board of examiners constituted by the Departmental Academic Committee consisting of two faculty members and class teachers with Head of the Department as Chairman during 5th. Semester examination.

Text Book / References:

1. Process Equipment Design – Brownell and Young, John Wiley and sons.
**Subject Name: Chemical Reaction Engineering Laboratory**

**Paper Code: CHEN 3113**

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At least eight experiments are to be performed

1. Experimental studies on kinetics of a non-catalytic homogeneous liquid phase reaction in an isothermal batch reactor
2. Experimental studies on kinetics of a homogeneous liquid phase reaction in an isothermal semi-batch reactor
3. Experimental studies on kinetics of a non-catalytic homogeneous liquid phase reaction in a Spiral plug flow reactor.
4. Experimental studies on kinetics of a non-catalytic homogeneous liquid phase reaction in an isothermal CSTR.
5. Experimental studies on kinetics of a non-catalytic homogeneous liquid phase reaction in a packed bed reactor.
6. Experimental studies on RTD in a tubular PFR using pulse input of tracer and measurement of axial dispersion coefficient.
7. Experimental studies on kinetics of a heterogeneous catalytic reaction in a UV photoreactor.
8. Experimental studies on RTD in a packed bed reactor using pulse input of tracer and measurement of axial dispersion coefficient.
9. Experimental studies on kinetics of hydrolysis of ethyl acetate in presence of acid catalyst in an adiabatic batch reactor.
10. Experimental studies on kinetics of sulfonation of toluene in an isothermal batch reactor.
Semester 6

THEORY
Subject Name: Process Dynamics, Instrumentation and Control

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Module I: 10 L
Introduction: Principles of measurement. Error Analysis, Static and dynamic characteristics of instruments.
Temperature measurement: Filled system Thermometer, Thermocouples, Resistance Thermometers, radiation and optical pyrometers;
Pressure: Manometers: U tube manometer, inclined limb manometer, Ring balance manometer, Elastic deformation: bourdon, bellows, diaphragm and electrical type gauges: strain gauge, piezoelectric, pressure transducers.
Vacuum gauges: mechanical, electrical and ionization types;
Flow: Head flow meters, area flow meters, positive displacement flow meters, mass and magnetic flow meters;
Level: Direct and inferential type; composition.

Module II: 10L
Introduction to process control, Use of Laplace transforms in process control, Different forcing functions: Step, Pulse, Impulse, Ramp, Sinusoidal and frequency inputs & their graphical representation.
First order system; Transfer function; Examples of First Order Systems, Pure capacitive system, Response of different forcing functions; First order systems in series- non-interacting & interacting. Second order system- Under- damped, critically damped & over damped, Second order system examples - Damped vibrator, Control valve, U-tube manometer, terms related to under damped system, Transportation lag.

Module III: 10 L
Feedback control loop and its components, advantages and disadvantages of feedback control system Simple process models and their transfer functions: stirred tank heater, continuous stirred tank reactor, heat exchanger, distillation column, U-tube manometer
State-space representation of linear systems
Different types of controllers and their applications: P, PI, PD, PID & their transfer function, servo and regulatory control, transient responses of feedback control systems
Block diagram: Block diagram of different chemical process units, block diagram reduction,
Module IV: 10L
Definition of stability, concept of bound and unbound function

Adaptive & digital control, concept of PLC & DCS.

Text books:

References:
Subject Name: Project Engineering

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**Module I: 10L**
Role of a Project Engineer, Development of Laboratory bench scale experiment to pilot & semi-commercial plant operation, scale up and scale down techniques, pre-design cost estimations, fixed capital and working capital, manufacturing cost, plant location and plant lay out, plant utilities, safety measures.
Time value of money, simple interest, nominal and effective interest rates, compound and continuous interest, present worth and discount, annuity, perpetuity and capitalized costs, Pay out period.

**Module II: 10L**
Depreciation: Types of depreciation, Depletion, concepts of service life, salvage value, and book value, straight-line method, Declining balance method, sum of the years digit method and sinking fund method for determination of depreciation, modified accelerated cost recovery system (MACRS),
Alternative investment, Choices among various alternatives, Replacements, Methods of profitability evaluation for replacements, Return on investment, Net present worth (NPW), Discounted cash flow rate of return (DCFR), Effect of inflation on profitability, income taxes, GDP and national growth.

**Module III: 10L**
Basic concepts of process integration, Pinch analysis.

**Module IV: 10L**
Project scheduling: Bar chart, Milestone chart, Concept of network analysis: Numbering network, PERT, CPM, statistical distribution associated with PERT network, Earliest expected time and latest allowable occurrence time calculation, Slack, determination of critical path, concept of float.
Text Book:

2. PERT and CPM – Principles and Applications, Affiliated East West, 3rd Ed., 1989

References:

Module I: 10 L
Oils and Fats: Elementary idea, Composition (Fatty acid profile), Methods of extracting vegetable oils; Hydrogenation of oils, Major engineering problems and improved technology; Transesterification and Interesterification through enzymatic route; their applications.

Soaps, Detergents & Glycerin: Classification of cleansing compounds, uses; Methods of soap production, Methods of detergent manufacture, Methods of production of Glycerin (Process description and flow sheet of each process).

Module II: 10 L
Sugar and starch industries: Manufacturing process of sugar with flow diagram, Sugar refining, Manufacturing process of starch and their different by-products; Glucose, Sorbitol and Polyols. Fermentation industries: Industrial alcohol, Absolute alcohol, their production processes with flow diagram.


Module III: 10 L
Organic synthesis: nitration, sulfonation, amination, halogenation, hydrolysis with examples. Petrochemicals: Methanol, Vinyl chloride, Ethylene oxide, Isopropanol, Butadiene, Phenol and Pthalic anhydride – their manufacturing process with flow diagram and engineering problems

Paints & pigments: Domestic and industrial paints- their compositions including ingredients and additives in relation to their applications – Paint manufacturing processes.

Module IV: 10L

Polymer forming processes- their suitability for the type of polymer feedstock and the size and shape of the products.
Text books:


References:

Subject Name: Mathematical Methods in Chemical Engineering

Paper Code: CHEN 3204

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Module I : 10L
Solution of linear algebraic equations; Matrix series; Differentiation & Integration of matrix; Lambda matrix; Characteristics equation; Eigenvalue Problem; Solution of systems of linear differential equations by matrix. Representation of the problems: Solvent extraction in two stages, Solvent extraction in N stages, Simple water still with preheated feed, unsteady state operations; Dependent and Independent variables and parameters; boundary conditions.

Linear & simultaneous differential equations, related problems. Series and parallel reactions in CSTR.

Module II : 10L
Solution by series: Introduction; Infinite series; Power series; Method of Frobenius and Related problems: Temperature distribution in a transverse fin, Tubular gas preheater; Bessel’s Equation, Problem of heat loss through pipe flanges, properties of Bessel function.

Module III : 10L
Partial differentiation & Partial Differential Equations: Introduction; Interpretation of partial derivatives, Formulation of partial differential equations; Boundary conditions; Particular solutions of partial differential equations; Orthogonal functions; Method of separation of variables; Laplace transform method.

Module IV: 10L
Boundary layer theory; Applications in Laminar Flow along a flat plate; Forced Convection heat transfer in a sphere in creeping flow. Diffusion and Chemical reaction in isothermal laminar flow along a flat plate.

Textbook:

Professional  Elective II

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**Module I : 10 L**
Introduction to the physics of solid state; Structure & Bonding.
Elements of nanoscience & nanotechnology.

**Module II : 10 L**
Synthesis of nanomaterials: General approaches, Physical Methods, Chemical Methods & Biological Methods;

Properties of nanomaterials: Mechanical, Structural, Thermal, Electrical & Optical properties.

**Module III : 10 L**
Characterization techniques of nanomaterials: Microscopy; Spectroscopy; & Diffraction techniques; Some special nanomaterials: Carbon nanotubes, Porous silicon, Zeolites, Aerogels, Core-shell nanoparticles.

**Module IV : 10 L**
Application: Nanolithography, Nanocomposites, Nanoparticles as catalyst, conducting polymers; nanotechnology: DNA Nanowires, Nanomedicines.

Text book:

Module I : 10 L
Conservation Principles – Conversation of Mass, Momentum, Energy in dimensional and non-dimensional forms – Lagrangian and Eulerian forms ; Conservative and Non-conservative forms of transport equations ; Equations – Elliptic, Parabolic and Hyperbolic Understanding the convection and diffusion terms ; Generalized Advection-Diffusion Equation with source term Initial condition and Boundary conditions (three kinds).

Module II : 10 L

Module III : 10 L

Module IV: 10 L
Evaluation of pressure from Equation of Continuity ; Velocity correction ;SIMPLE Algorithm – Residues in solution – Relaxation Iterative scheme – Over and under relaxation - quick updation ; Discussion on SIMPLER, SIMPLE-C .
Other methods – Artificial Compressibility method.

Test Books/ References:

Professional Elective II

Subject Name: Bioprocess Engineering

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Module I: 10 L
Principles of enzyme catalysis Proteins as enzymes; Michaelis-Menten kinetics; Briggs Halden theory Kinetics and Statistics; Inhibition; Effect of pH and temperature; Enzymology; methods of immobilization, diffusional limitations in immobilized enzyme systems.

Module II: 10 L
Microbial growth Introduction to metabolism; Nutrient transport; Glycolysis; TCA cycle and other pathways; Control of metabolism; Factors affecting microbial growth; Stoichiometry: mass balances; Stoichiometry: energy balances; Growth kinetics; Measurement of growth. Agitation and aeration: types of impellors and sparger, oxygen transfer rate, oxygen uptake rate, volumetric oxygen transfer rate (kLa), measurement of kLa, power requirement for agitation in gaseous and non gaseous systems.

Module III: 10L
Bioreactors Introduction to bioreactors; Batch and Fed-batch bioreactors, Continuous bioreactors; Immobilized cells; Bioreactor operation; Sterilization; Aeration; Sensors; Instrumentation; Culture-specific design aspects: plant/mammalian cell culture reactors. Scale up, operation and control of bioreactors: Concepts of various bioreactor configurations, scale-up, various criteria for scale-up, scale-down, bioreactor instrumentation and control.

Module IV: 10 L
Bioseparations Biomass removal; Biomass disruption; Membrane-based techniques; Extraction; Adsorption and Chromatography. Industrial Processes and Process economics Description of industrial processes; Process flow sheeting; Process economics.

Texts/References:

### Subject Name: Principles of Management

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#### Module I: 4L
Management: Definition, nature, purpose and scope of management, Skills and roles of a Manager, functions, principles; Evolution of Management Thought: Taylor Scientific Management, Behavioral Management, Administrative Management, Fayol’s Principles of Management, Hawthorne Studies.

#### Module II: 8L
a) Planning: Types of plans, planning process, Characteristics of planning, Traditional objective setting, Strategic Management, premising and forecasting.
b) Organizing: Organizational design and structure, Coordination, differentiation and integration.
e) Coordinating: Concepts, issues and techniques.
f) Controlling: Concept, planning-control relationship, process of control, Types of Control, Control Techniques.

#### Module III: 4L
Span of management, centralization and de-centralization Delegation, Authority & power - concept & distinction, Line and staff organizations.

#### Module IV: 8L
Organization Behaviour: Motivation, Leadership, Communication, Teams and Team Work.
Management by Objectives (MBO): Management by exception; Styles of management: (American, Japanese and Indian), McKinsey’s 7-S Approach, Self Management.

### Evaluation:
Max. Marks-100
Internal Test-30
Semester End Test-70
Suggested Readings:
2. Stoner, Freeman, Gilbert Jr., Management, PHI.
3. Bhatt & Kumar, Principles of Management, OUP.
LABORATORY
Subject Name: PEDD II

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1. Design and Drawing of Heat Exchanger.

2. Design and Drawing of Orifice meter / Venturi meter/ Rotameter (Anyone).

Text Book / References:

1. Process Equipment Design – Brownell and Young, John Wiely and sons.

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Module- I: Numerical Methods (Programming language: Matlab)

1. Solution of Linear System by Gauss Elimination method and Gauss-Seidel iterative method: Steady-state solution of isothermal CSTR in Series in which a first-order reaction is taking place.
2. Solution of a non-linear equation by Newton-Raphson method.
3. Solution of a set of non-linear equations by Newton method: steady-state solution of a non-isothermal CSTR in which a first-order reaction is taking place.
SESSIONAL
Subject Name: Personality Development

Paper Code: HMTS 3221

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Module I: 1L/week
Self-Growth
i) Self Growth- Maslow’s Hierarchy of Needs Theory
ii) Anger, Stress & Time Management- Theories and application
iii) SWOT Analysis

Module II: 1L/week
Stepping Up
i) Growth & Environment
ii) Competitive Spirit
iii) Responsibility Factor

Module III: 1L/week
Professional Communication
i) Impression Management- theory on social psychology
ii) Employability Quotient
iii) Cross-cultural communication

Module IV: 1L/week
Leadership & Team Playing
i) Leadership & Team Playing: Theories, Styles, Stages
ii) Motivation, Negotiation Skills, Conflict Management
iii) Planning & Envisioning: Initiative and Innovation in the Work Environment- De Bono’s Six Thinking Hats

Methodology: Assignment and project

Suggested Reading:

1. Personality Development and Soft Skills by Barun K. Mitra, Oxford University, 2011
A Seminar topic will be allotted to individual student according to his/her subject of interest. A thorough report should be prepared based on which seminar presentation and question-answer session will be conducted. Assessment of the student would be done by the faculty members on the basis of presentation, performance in the question-answer session and the report submitted, giving equal weightage on each component.
Semester 7

THEORY
Subject Name: Transport Phenomena

Paper Code: CHEN 4101

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Module I : 10L
Concept of unified approach to Momentum, Heat and Mass Transport through Transport Phenomena - Assumptions of Transport phenomena; Similarity of Mass, Momentum and Energy transfer, momentum, heat and mass diffusivities, momentum, heat and mass transport theorem

Review of vectors & Tensors: Vector operation from geometrical view point, Dot and Cross product of vectors, multiple product of vectors, unit vectors, Tensor operation in terms of components, the unit dyads, dyadic product, scalar product of tensors, tensor product of tensors, vector product of tensor, vector tensor differential operation.

Module II : 10L
Newton’s law of viscosity, pressure and temperature dependence of viscosity, shell momentum balance and boundary condition, Equations of Continuity and Motion in rectangular (Cartesian) coordinate system, Expression of stress tensor for Newtonian and non-Newtonian fluids; Special forms of equation of Motion – Euler equation, Navier-Stokes equation, Concept of hydrodynamic boundary layer and boundary layer equation. Concept of turbulence, velocity distribution in vertical falling film, velocity distribution in laminar and turbulent flow through a tube, concept of friction factor and drag coefficient.

Module III : 10L
Fourier law of heat conduction, temperature and pressure dependence of thermal conductivity, shell energy balance and boundary condition, energy equation in rectangular (Cartesian) coordinate system, Use of the Energy equation – Unsteady state heat conduction in finite and semi-infinite slabs, concepts of thermal boundary layer and thermal boundary layer equation, temperature distribution during film condensation on vertical surface, temperature distribution in laminar and turbulent flow through a tube, concept of heat transfer coefficient.

Module IV : 10L
Fick’s law of molecular diffusion, temperature and pressure dependence of diffusivity, shell mass balance and boundary condition, equation of continuity for a multicomponent mixture in rectangular (Cartesian) coordinate system, unsteady state diffusion through finite and semi-infinite slab, concepts of concentration boundary layer and boundary layer equation, concentration distribution during mass transfer through falling film, use of equation of...
change for mixtures- simultaneous heat and mass transport, concentration profile in tubular reactor, catalytic gas phase reactive system, concept of mass transfer coefficient.

Text Book:

References:
Module 1 : 10 L

Module II : 10L

Module III : 10 L
Synthesis of separation trains: Criterion for selection of separation methods; selection of separation equipment for absorption, stripping and distillation, liquid-liquid extraction, membrane separation, adsorption, leaching, crystallization and drying; Sequencing of distillation column for the separation of nearly ideal fluid mixture; separation of systems for gas mixtures.

Module IV: 10 L
Optimization of Process flow sheet - General formulation of the optimization problem; Linear programming, Non-linear programming with a single variable ; Conditions for NLP with gradient method for two or more decision variables; Optimization algorithm ; Flowsheet optimization – case studies.

Text Books:

References:
Module I: 10L

Reactors: Types of reactors, Advantages and Disadvantages, Reactor Selection, Applications
Homogeneous Reactor Design: Formulation of ideal reactor design equations for simple models of batch, mixed flow and plug flow reactors.

Module II: 10L
Combination of reactors of various types in either series or parallel operation Selection of proper contacting patterns for multiple reactions occurring in either series or parallel

Description of heterogeneous catalytic reactors, e.g. packed bed reactor, tubular reactor, mixed flow reactor, slurry reactor, trickle bed reactor.


Module III: 10L

Design of bioreactors with emphasis on Cell growth kinetics, Substrate limited growth, the logistic equation, rate loss, stoichiometry, mass balances, design equations, numerical problems, wash out, oxygen limited fermentation, scale up concepts of bio-reactors, chemostat and its applications.

Module IV: 10L
Reactor Internals: component and use.
Evaluation of conversion in non ideal reactors from RTD study using experimental data and model equations. Introduction to non isothermal reactor design, Energy balance equations for batch and flow reactors, Evaluation of batch and flow reactor volumes for adiabatic reaction.
Reactor Safety and Runway Reaction

Text Books:

References:
1. O. Levenspiel, Chemical Reaction Engineering, Wiley Eastern Ltd., 2nd & 3rd Editions
Professional Elective III

Subject Name: Industrial Safety and Hazard Analysis

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**Module I : 10L**
Definition of safety, Hazard and Risk, Safety program, Engineering ethics, Inherent safety, Safety regulations, OSHA, Process safety management, Hazards due to fire, explosions and toxic chemicals, Distinction between fire and explosion, Upper Flammability limit and Lower Flammability Limit, Fire Triangle, BLEVE, Runaway reaction.

**Module II : 10L**
Tools for hazards identification: HAZOP, Fault Tree, Event Tree, FMEA, Dow Fire and Explosion Index, Mond Index.

**Module III : 10L**
Risk analysis concept and methodology: Risk concept and measure of risk, Risk acceptance criteria, Quantitative risk analysis, Probit number.

**Module IV: 10L**
Control of chemical plant hazards, Intensification and attenuation of hazardous materials, Industrial plant layout, Ventilation, Fire prevention, Personnel protection devices, Laboratory safety, Emergency safety, Safety systems and disaster management. Case studies, Flixborough (England), Bhopal (India), Seveso (Italy), Pasadena (Texas)

Text Book:

References:
1. O.P. Kharbanda, E. A. Stallworthy, Safety in Chemical Process Industries: Heinmann
2. Professional Publishing LTD, 1988
4. S.L Cutter, Environmental Risks & Hazards, Prentice Hall, 1994
Professional Elective III

Subject Name: Advanced Separation Process

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**Module I : 10 L**
Basic membrane separation process: Size exclusion based membrane separation process (Microfiltration, ultrafiltration, nanofiltration, reverse osmosis); transport equations (concept of knudsen diffusivity and molecular diffusion); Type of membrane and fabrication of membrane (Inorganic and organic); overview on phase inversion technique; Difference, between symmetric membrane and composite membrane in view of the mechanical properties of the membrane; Membrane characterization techniques; Applications of different membrane modules and a concept of shear enhanced membrane modules like VSEP.

**Module II : 10L**
Advanced membrane separation processes: Concept of dialysis and fabrication of dialysis membrane; Understanding VLE and its application in pervaporation and membrane distillation; difference with gas separation technique; Concept of chromatographic separation techniques like gel filtration model; Overview on membrane chromatography process.

**Module III : 10 L**
Advanced membrane separation process based on liquid membrane: Role of surfactants and types of surfactants, emulsion preparation, concept of HLB; Preparation of emulsion liquid membrane – Emulsion membrane, Bulk liquid membrane, and supported liquid membrane; Development of transport equation; Concept of micelle; Overview of micelle enhanced ultrafiltration process and its application overview.

**Module IV: 10 L**
Concept of isoelectric point and its importance in protein separation; Basics of electrophoresis – Detailed elaboration on vertical and horizontal electrophoresis side-by-side; Basic overview on isoelectric point focusing (IEF) techniques and its application in protein separation; Basic difference between ion-exchange chromatography and IEF techniques.
Text Books:

References:
LABORATORY
At least any six of the following experiments are to be performed

1. Determination of Turbidity of Water using Nephelo Turbidity Meter.
2. Construction of standard curve (Absorbance vs. concentration) of a pure protein by Folin’s Method using Spectrophotometer.
3. Determination of Fe$^{3+}$ by Colorimeter Method.
4. Determination of Dissolved Oxygen from water by DO Meter.
5. Kinetic study of a Biochemical Reaction by UV Spectrophotometer.
7. Determination of concentration of any optically active substance in presence of non-active species by a Polarimeter.
8. Determination of TDS of water sample by Conductivity Meter.
10. Demonstration of analysis of liquid mixture using HPLC.
11. Determination of functional groups in the solid/liquid using FTIR.
At least any eight of the following experiments are to be performed

1. Study on the dynamic characteristics of first order liquid level system.
2. Study on the dynamic characteristics of U-tube manometer (second order system).
3. Study on the dynamic characteristics of compound (interacting) second order system.
4. Study on the dynamic characteristics of compound (non-interacting) second order system.
5. Study on the response of controlled variable for a feedback control system with P, PI & PID controller.
6. Study on the flow characteristics and determination of discharge coefficient for different type pneumatic control valves.
7. Experiment on calibration of a load cell.
8. Liquid level measurement using air-purge method.
9. Determination of time constant of thermocouple during temperature measurement.
10. Experiment on calibration of pressure gauge using Dead-weight tester.
11. Experiment on flow measurement using wet gas meter.
Each student shall be required under the supervision of a faculty to carry out a project work or investigation on an industrial research problem. The project/research work has to be carried out by the student himself occasionally consulting his supervisor. The project/research problem will be allotted to the student at the beginning of the seventh semester indicating the jobs to be done by the student. The report in duplicate has to be submitted in typed and bound form one week before the commencement of the VIIth semester examination. The examination shall include oral presentation of the research work and a viva-voce before a committee of at least two members of faculty appointed by the HOD including the Supervisor. Equal weightage shall be given on oral presentation and viva voce.
### Subject Name: Industrial Training

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Students sent for Industrial Training during Summer Recess after 6th Semester for a minimum duration of four weeks will submit two copies of Training Report (only Hard/Spiral bound is allowed) on or before a notified date, to the Faculty In-charge, In-plant Training. The Viva voce would be held before commencement of Practical Examination. Report should consist of:

1. Copy of Training Certificate & allotment order (if any)
2. A general overview of the Plant.
3. The products and raw material sources of the Plant.
4. Process description/flow diagram of individual units
5. Environment & Safety Aspects, Techno-economics /Corporate Social Responsibility work of the organization if any.
6. For Training in R & D organizations/project Work, overview of work with sketches, Objectives, Materials & Methods, Result & Discussions are to be included instead of items mentioned in points 2-5.
Subject Name: Seminar II

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A Seminar topic will be allotted to individual student according to his/her subject of interest. A thorough report should be prepared based on which seminar presentation and question-answer session will be conducted. Assessment of the student would be done by the faculty members on the basis of presentation, performance in the question-answer session and the report submitted, giving equal weightage on each component.
Subject Name: Professional Development

Paper Code: HMTS 4121

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**Module I: Professional Growth**
Goal Setting- Characteristic of goals, Short-term and long-term goals, Goal-achievement timeline
Skill identification and Skill up gradation- Washington Accord and Skills for engineers (generic and specific), Local and global skills, Knowledge sources such as MOOC, NPTEL
Career Planning- Vision and mission, Skill mapping to job profile, Basic and add-on qualifications, Career growth, Self-appraisal, Lifelong learning
Assessment - Activity

**Module II: Entrepreneurship**
The start-up ecosystem in India- Why entrepreneurship?, Indian tech start-up landscape, Stand-up India policies, funding agencies, market development, trends and best practices
E-Commerce- India as a growing E-commerce market, Possibilities of growth, funding, niche retailers
Make in India- New processes, Investments, Focus sectors, Makers of Make In India, Opportunities, Policies
Assessment-Project (30 marks)

**Module III: Industry specific opportunities**
Industry prospects in India and Beyond
Industry-specific job opportunities
Research & Development
Other opportunities
Assessment---Presentation

**Module IV: Working and living happily**
Managing crisis- Organisational and personal crisis, Analysing crisis, Turnaround strategies, Learning from crisis as opportunity
Work-life balance- Performance-expectation management, Personal and professional goal-mapping
Understanding happiness- Components, Conflicts, Happiness Index
Assessment: Activity/case

Suggested Reading:
THEORY
Semester 8
### Professional Elective IV

**Subject Name: Catalysis & Catalytic Reactor Design**

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**Module I : 10L**

Introduction to homogeneous and heterogeneous catalysis, Factors affecting heterogeneous catalytic reaction; Methods for finding rates- Integral Analysis, Differential Analysis
Types of catalytic Reactor- Differential Reactor, Integral Reactor and their performance equations.
Pore diffusion resistance combined with surface Kinetics. Concept of Thiele modulus and Weisz modulus, Concept of effectiveness factor.

**Module II : 10L**

External mass and heat transfer in catalyst particles. Design of Packed bed reactor, fluidized bed reactor, Basket type reactor. Description of slurry reactor; Trickle bed reactor.
Different steps in a catalytic reaction, Langmuir adsorption isotherm
Catalysis mechanism: Langmuir-Hinshelwood mechanisms, Eley –Rideal mechanisms
Enzyme kinetics: Michaelis and Menten equation, Briggs Halden equation, numerical problems on enzymatic reactions

**Module III : 10L**

General methods for preparation of catalysts: precipitation, sol-gel, mixing components with water milling, impregnation, Concept of Promoter & Inhibitor;

**Module IV: 10L**

Catalyst Deactivation: Fouling and poisoning; Mechanisms of Catalyst Deactivation, Rate equation, activity of catalyst, Parallel deactivation, Series deactivation, Side by side deactivation, independent deactivation.
Biocatalyst and Bioreactor Design:
Cell growth kinetics, Substrate limited growth, the logistic equation, rate loss, stoichiometry, mass balances, design equations, numerical problems, oxygen limited fermentation, scale up concepts of bio-reactors, chemostat and its applications, Wash Out, continuous culture devices, case studies on penicillin production.
Text Books

References:
1. James J Carberry, Chemical and catalytic reaction engineering, McGraw Hill.2001


### Professional Elective IV

**Subject Name: Total Quality Management**

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**Module I: 10L**

Basic concepts—Three paradigms of management and evolution of concept of quality management, Organization: its basic objectives and goal, Mission and Vision, customer and secondary customer, Deming’s wheel, bottom line: profit vs quality, historical defilements: Juran, Deming, Ischikawa and Taguchi, Kaizen, JIT. Basic statistical concepts associated with quality management, measurement of central tendency and dispersion, range versus variance, quality and process capability, probability distributions, concept of statistical quality control.

**Module II: 10L**

Use of control charts and process engineering techniques for implementing the quality plan: X—R chart, moving average chart, p-chart, c-chart and control chart for continuous production Acceptance sampling: single–double and multiple sampling, AOQ, AQL, LTPD, Chain sampling plan, Dodge-Romig plan.

**Module III: 10L**

Tools and techniques for improvement in TQM: type A techniques with a special reference to FPC & FD, QFD, SWOT analysis; type B techniques with a special reference to brainstorming, stratification, Ischikawa diagram, check sheet, Pareto diagram Philosophy and concept of quality circle: formation, steering committee, power and functions of leader, dy. Leader, coordinator, facilitator, case studies.

**Module IV: 10L**

Different standards: ISO, BS and Bureau of Indian Standards, details of ISO 9000 series, ISO 14000 series and SA 8000 and the certification authorities, productivity control management.
Text Books:

References:
2. S R Udpa, Quality Circle 1981.
Module I : 10 L

Air pollution : Sources and effects of different air pollutants, Sampling and analysis of air pollutants, Air pollution control methods and equipment, Cyclone Separator, Baghouse, ESP, Venturi Scrubber

Module II : 10 L
Water pollution: Sources, sampling and classification of water pollutants, determination of basic parameters and computations associated with: BOD, COD, TS, TDS, SS;

Waste water treatment: primary, secondary, tertiary and advanced; aerobic treatment with special reference to activated sludge, trickling filter, RBDC and RBRC, EA; non conventional: WSP, anaerobic treatment with special reference to AFFR, UASB

Module III : 10 L

Module IV: 10 L
Pollution control in selected process industries – fertilizer industries, petroleum refineries and petrochemical units, pulp and paper industries, Tanning industries, Sugar industries, Dairy, Alcohol industries, Electroplating and metal finishing industries, Radioactive wastes, Root Zone and Reed Bed Treatment for Effluents of small scale industries, Ranking of wastewater treatment alternatives. Case Studies.
Text Books:
1. C.S. Rao, Environmental Pollution Control Engineering, New Age International, 2nd Edition,
3. S.J. Arceivala, Wastewater treatment for pollution control, TMH, 2nd Edition

References:
Professional Elective IV

Subject Name: Operations Research – Engineering Applications

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**Module I: 8L**
Introduction to Linear Programming Problem (LPP), Mathematical Requisites, Formulation of the problem related to Chemical Engineering. Graphical solution of Two and Three Variables of LPP, Different types of Solution, Canonical and standard Forms of LPP, Development of Simplex Method with examples, The Charnes’ Big M Method with examples.

**Module II: 8L**
Introduction to Transportation Problems, Balanced and unbalanced Transportation Problems, Formation of Basic Feasible Solutions with NW Corner rule, Optical Solution of Transportation Problems with examples, Assignment Problems – Introduction, Formulation and solution with numerical examples. Theories on Duality with numerical problems.

**Module III: 8L**
Dynamic Programming, its need, Formulation, problems and solution methodologies, Game Theory with problems and solution methodologies. Correlation and Regression. ANOVA – One way model; Response Surface Methodologies with numerical problems.

**Module IV: 8L**
Queuing Models – Development of Models (Model I, II and III only), Numerical Problems and their solution. l PERT & CPM: Development of Network Theory from Gantt/ Milestone Chart, Numbering the network, Calculation of Earliest Expected Time, Latest Allowable Occurrence time, Critical Path computation with problems.

Text Books:

References:
**Subject Name: Organizational Behaviour**

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**Module I : 5L**
Introduction to Organizational Behaviour-Concept, Importance, Challenges and Opportunities (1L)
Personality-Meaning of Personality, Personality Determinants and Traits, Psychoanalytic Theory, Argyris Immaturity to Maturity Continuum Impact on organization. (2L)
Attitude-Concept, Components, Cognitive Dissonance Theory, Attitude Surveys. (2L)

**Module II : 6L**

**Module III : 8L**
Leadership-Concept, Leadership Styles, Theories-Behavioural Theory: Ohio Studies, Michigan Studies, Blake & Mouton Managerial Grid; Contingency Theory: Fielder Theory. (4L)

**Module IV : 5L**
Organizational Design-Various organizational structures and their pros and cons.
Concepts of organizational climate and culture, Organizational Politics-Concept, Factors influencing degree of Politics (2L)
Conflict management- Concept, Sources of conflict, Stages of conflict process, Conflict resolution techniques, Tools-Johari Window to analyse and reduce interpersonal conflict, Impact on organization. (3L)

**Suggested Readings:**
1. Organization Behaviour by Stephen Robbins
2. Organization Behaviour by Luthans
3. Organization Behaviour by L.M. Prasad
4. Organization Behaviour: Text, Cases &Games by Aswathappa K.
SESSIONAL
Each student shall continue to work on the project work/research problem allotted to him at the beginning of the seventh semester under supervision of a faculty member. After completion of all assigned jobs, the report in duplicate has to be submitted by the student in typed and bound form one week before the commencement of the eight semester (final) examination. The examination shall include oral presentation and viva voce giving equal weightage to both. The examination shall be conducted in presence of external expert and the student’s supervisor.
Each student shall be required to prepare a report on a topic of design under the supervision of a faculty. The design problem has to be solved by the student himself occasionally consulting his supervisor. The design problem shall be allotted to the student at the beginning of the eighth semester. The report in duplicate has to be submitted in typed and bound form one week before the commencement of the 8th (final) semester examination. The examination shall include oral presentation of the design report and a viva-voce. Equal weightage shall be given on oral presentation and viva-voce.
Viva – Voce examination shall be conducted to ascertain the students’ overall grasp of the principles of Chemical Engineering and allied subjects. Evaluation of students would be conducted by a panel consisting of at least four Faculty members.
Free Elective – 7th Semester  
(For non-CHEStudents)

Subject Name: Safety and Hazard Analysis

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Module I : 10 L  
Definition of safety, Hazard and Risk, Safety program, Engineering ethics, Inherent safety, Safety regulations, OSHA, Process safety management, Hazards due to fire, explosions and toxic chemicals, Distinction between fire and explosion, Upper Flammability limit and Lower Flammability Limit, Fire Triangle, BLEVE, Runaway reaction.

Module II : 10 L  
Tools for hazards identification: HAZOP, Fault Tree, Event Tree, FMEA, Dow Fire and Explosion Index, Mond Index.

Module III : 10 L  
Risk analysis concept and methodology: Risk concept and measure of risk, Risk acceptance criteria, Quantitative risk analysis, Probit number.

Module IV: 10L  
Control of chemical plant hazards, Intensification and attenuation of hazardous materials, Industrial plant layout, Ventilation, Fire prevention, Personnel protection devices, Laboratory safety, Emergency safety, Safety systems and disaster management. Case studies, Flixborough (England), Bhopal (India), Seveso (Italy), Pasadena (Texas)

Text Books: 

References:  
1. O.P. Kharbanda and Stallworthy E. A, Safety in Chemical Process Industries:, Heinmann  
2. Professional Publishing LTD.,1988  
Subject Name: Project Management

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Module I : 10L
Project Management Fundamentals: Definition of a Project, Project Management, Scope Management, Program Management, Portfolio Management, Stakeholder Management: Identify Stakeholders, Plan Stakeholder Management; Manage Stakeholder Engagement, Control Stakeholder Engagement, Organization Structure; Project Lifecycle vs. Product Lifecycle; Feasibility Analysis; Project Evaluation Techniques; Summary Illustrative Review Problems / Incidents.

Module II : 10L

Module III : 10L

Module IV: 10L
Text Books:

Reference:
**Subject Name: Catalytic Reactor Design**

**Paper Code: CHEN 4281**

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**Module I : 10L**
Introduction to homogeneous and heterogeneous catalysis, Factors affecting heterogeneous catalytic reaction; Methods for finding rates- Integral Analysis, Differential Analysis
Types of catalytic Reactor- Differential Reactor, Integral Reactor and their performance equations.
Pore diffusion resistance combined with surface Kinetics. Concept of Thiele modulus and Weisz modulus, Concept of effectiveness factor.

**Module II : 10L**
External mass and heat transfer in catalyst particles. Design of Packed bed reactor, fluidized bed reactor, Basket type reactor. Description of slurry reactor; Trickle bed reactor.
Different steps in a catalytic reaction, Langmuir adsorption isotherm.
Catalysis mechanism; Langmuir-Hiselwood mechanisms, Eley –Rideal mechanisms
Enzyme kinetics: Michaelis and Menten equation, Briggs Halden equation, numerical problems on enzymatic reactions

**Module III : 10L**
Determination of Catalyst surface area and particle size; Brunauer, Emmett, Teller (BET) equation, Concept of void volume and solid density-Helium mercury method, Pore volume Distribution-mercury penetration method, Nitrogen desorption method.
General methods for preparation of catalysts: precipitation, sol-gel, mixing components with water milling, impregnation, Concept of Promoter & Inhibitor;

**Module IV: 10L**
Catalyst Deactivation: Fouling and poisoning; Mechanisms of Catalyst Deactivation, Rate equation, activity of catalyst, Parallel deactivation, Series deactivation, Side by side deactivation independent deactivation.
Biocatalyst and Bioreactor Design: Cell growth kinetics, Substrate limited growth, the logistic equation, rate loss, stoichiometry, mass balances, design equations, numerical problems, oxygen limited fermentation, scale up concepts of bio-reactors, chemostat and its applications, Wash Out, continuous culture devices, case studies on penicillin production.
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References:
1. James J Carberry, Chemical and catalytic reaction engineering, McGraw Hill.2001
# Free Elective – 8th Semester
(For non-CHE Students)

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**Module I : 10L**
Basic concepts—Organization: its basic objectives and goal, Mission and Vision, customer and secondary customer, Bottom line: profit vs quality, Basic statistical concepts associated with quality management, measurement of central tendency and dispersion, range versus variance, quality and process capability, probability distributions, concept of statistical quality control.

**Module II : 10L**

**Module III : 10L**
Tools and techniques for improvement in TQM: type A techniques with a special reference to FPC & FD, QFD, SWOT analysis; type B techniques with a special reference to brainstorming, stratification, Ishikawa diagram, check sheet, Pareto diagram Philosophy and concept of quality circle: formation, steering committee, power and functions of leader, dy. Leader, coordinator, facilitator, case studies.

**Module IV: 10L**
Text Books:

References: