Chemical Engineering Department

Syllabus of 'Research Methodology'

1. Research Methods:
    a. Qualitative
    b. Quantitative
    c. Case-Studies

2. Research Design & Strategy
    a. Quantitative Design
        I. Experimental Design
            i. Factorial designs
            ii. Time-series designs
        II. Non-Experimental Design
            i. Descriptive designs
            ii. Analytical designs:
                a. Correlational designs
                b. Comparative designs
                c. Predictive study
                d. Case-control
3. Data acquisition:
    a. Research Instruments
    b. Sampling
    c. Validity
    d. Reliability

4. Data Interpretation and analysis: Basic knowledge of Statistics (mean, variance, standard deviation; skewness) ; fundamentals of probability: p-test, t-test; ANOVA
5. Data Fitting: regression analysis

Syllabus: Domain Subject

CH	Chemical Engineering

Section 1: Engineering Mathematics

Linear Algebra*:* Matrix algebra, Systems of linear equations, Eigen values and eigenvectors.

Calculus*:* Functions of single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, Evaluation of definite and improper integrals, Partial derivatives, Total derivative, Maxima and minima, Gradient, Divergence and Curl, Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

Differential equations*:* First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Cauchy's and Euler's equations, Initial and boundary value problems, Laplace transforms, Solutions of one- dimensional heat and wave equations and Laplace equation.

Complex variables*:* Complex number, polar form of complex number, triangle inequality.

Probability and Statistics: Definitions of probability and sampling theorems,Conditional probability, Mean, median, mode and standard deviation, Randomvariables, Poisson, Normal and Binomial distributions, Linear regression analysis.

Numerical Methods*:* Numerical solutions of linear and non- linear algebraic equations. Integration by trapezoidal and Simpson's rule. Single and multi- step methods for numerical solution of differential equations.

Section 2: Process Calculations and Thermodynamics

Steady and unsteady state mass and energy balances including multiphase, multi- component, reacting and non -reacting systems. Use of tie components; recycle,bypass and purge calculations; Gibb's phase rule and degree of freedom analysis.

First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.

Section 3: Fluid Mechanics and Mechanical Operations

Fluid statics, Newtonian and non-Newtonian fluids, shell -balances including differential form of Bernoulli equation and energy balance, Macroscopic friction factors, dimensional analysis and similitude, flow through pipeline systems, flow meters, pumps and compressors, elementary boundary layer theory, flow past immersed bodies including packed and fluidized beds, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop.

Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids.

Section 4: Heat Transfer

Steady and unsteady heat conduction, convection and radiation, thermal boundary layer and heat transfer coefficients, boiling, condensation and evaporation; types of heat exchangers and evaporators and their process calculations. Design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.

Section 5: Mass Transfer

Fick's laws, molecular diffusion in fluids, mass transfer coefficients, film, penetration and surface renewal theories; momentum, heat and mass transfer analogies; stage-wise and continuous contacting and stage efficiencies; HTU & NTU concepts; design and operation of equipment for distillation, absorption, leaching, liquid –liquid extraction, drying, humidification, dehumidification and adsorption.

Section 6: Chemical Reaction Engineering

Theories of reaction rates; kinetics of homogeneous reactions, interpretation of kinetic data, single and multiple reactions in ideal reactors, non-ideal reactors; residence time distribution, single parameter model; non-isothermal reactors; kinetics of heterogeneous catalytic reactions; diffusion effects in catalysis.

Section 7: Instrumentation and Process Control

Measurement of process variables; sensors, transducers and their dynamics, process modeling and linearization, transfer functions and dynamic responses of various systems, systems with inverse response, process reaction curve, controller modes (P, PI, and PID); control valves; analysis of closed loop systems including stability, frequency response, controller tuning, cascade and feed forward control.

Section 8: Plant Design and Economics

Principles of process economics and cost estimation including depreciation and total annualized cost, cost indices, rate of return, payback period, discounted cash flow, optimization in process design and sizing of chemical engineering equipmentsuch as compressors, heat exchangers, multistage contactors.

Section 9: Chemical Technology

Inorganic chemical industries (sulfuric acid, phosphoric acid, chlor-alkali industry),fertilizers (Ammonia, Urea, SSP and TSP); natural products industries (Pulp and Paper, Sugar, Oil, and Fats); petroleum refining and petrochemicals; polymerization industries (polyethylene, polypropylene, PVC and polyester synthetic fibers).

BPE	**Bioprocess Engineering, Biotechnology and Bioenergy**

Kinetics of enzymatic reactions with and without inhibition; Immobilized enzyme kinetics with mass transfer limitation; Luedeking-Piret model for product generation kinetics; Unstructured Microbial growth kinetics (Monod model); Determination of kinetic parameters using batch, CSTR and PFR data; activation energy; packed bed reactor using immobilized enzymes on solid matrices; Fed-batch reactor; Chemostat with recycle; reactor scale-up; Growth kinetics of genetically modified cells; Structured growth models; Mathematical modelling of microbial

interaction (mutualism, competition and Commensalism); Lot ka-Volt erra model for prey-predator interaction; Concept of steady state stability analysis of bioreactors; distillation, Filtration; freeze-drying; Settling and centrifugation; Extraction; Adsorption; Precipitation;; Ultra filtration

Concept of sustainability and climate change; Significance of Bioenergy from the perspective of Clean Development mechanism (CDM); Concept of biorefinery, Processes for generation of biofuels (ethanol, hydrogen, biogas); Concept of generation of ethanol from lignocellulosic wastes through sugar and syngas platforms; microbial fuel cell—Calculation of coulombic efficiency; Bio-capture of CO_2 using algae and cyanobacteria; Strategy of augmentation of algal oil production; Production of biodiesel through chemical and Enzymatic routes; Bioenergetics**.**

OTH	**Renewable Energy, Material Science & Technology, Water treatment and Polymers**

Concept of sustainability and climate change; Concept of Green Energy; role of catalysis for sustainable green energy; Bulk and supported metal, metal oxides/composite catalysts, semiconductor based photocatalysts; nanocomposites; sol-gel and wet-impregnation methods Principle, applications of: Electron microscopy – TEM, SEM, Energy Dispersive Spectroscopy (EDS), BET surface area, Physisorption and Chemisorption; Differential Scanning Calorimetry(DSC), Differential thermal analysis (DTA), Thermogravimetric analysis (TGA) Chromatography; Principles and Applications of High Performance Liquid Chromatograpy and High Performance Thin Layer Chromatography, Gas Chromatography. Significance of Bioenergy from the perspective of Clean Development mechanism (CDM); Concept of biorefinery, Processes for generation of biofuels (ethanol, hydrogen, biogas; biodiesel); microbial fuel cell;

Principles of Conversion of solar energy to thermal and electrical energy; Solar Collectors, Collector efficiency; Solar cells/Photovoltaics; photo-catalysis; Bandgap Energy; Refuse derived fuels—Principles processes like Combustion, Gasification and Pyrolysis; Cogeneration of heat and power (CHP) systems;

Classification of polymer; polymer structure-property relationship; Molecular forces andchemical bonding in polymer; glassy to rubber transition in polymer; molecular weight distribution; principles of radical chain (addition) polymerization; Mechanism of stepwise (condensation) polymerization; Morphology of crystalline polymer.

Water pollution: Sources, sampling. Classification of water pollutants & their effect. BOD, COD, SS, TS, TDS etc. Primary Treatment- Design of Sedimentation tank, Floatation.