DETAILED SYLLABUS FOR THE POST OF ASSISTANT PROFESSOR (CHEMICAL ENGINEERING) IN TECHNICAL EDUCATION (ENGINEERING COLLEGES)

(Cat.No.: 721/2021)

(Total Marks- 100)

Module I: (15 Marks)

MATHEMATICS (ENGINEERING)

Matrices- Rank, systems of linear equations, consistency, Eigen values, Eigen vectors, Cayley Hamilton Theorem, diagonalisation, linear dependence and independence of vectors.

Partial Differentiation-Partial derivatives, Euler's theorem on homogeneous functions, total derivatives, Jacobians, Taylor's series (one and two variables), Maxima and minima of functions of two variables – Lagrange' s method.

Vector Differentiation-Scalar and vector functions, differentiation of vector functions – velocity and acceleration – scalar and vector fields – operator, Gradient, Directional derivative, Divergence, Curl, irrotational and solenoidal fields, scalar potential.

Ordinary Differential Equations-First Order ordinary differential equations, systems of linear first order ordinary differential equations, linear ordinary differential equations of higher order with constant coefficients, linear second order ordinary differential equations with variable coefficients (Cauchy and Legendre equations), Method of Laplace transforms for solving ordinary differential equations.

Complex Analysis- Analytic functions, conformal mappings, bilinear transformations, complex integration, Cauchy's integral theorem and formula, Taylor and Laurent's series, residue theorem. Fourier Series- Fourier series of periodic functions of period 2π and 2ℓ, odd and even functions, half range expansions.

Module II: (15 Marks)

a) PROCESS CALCULATIONS

Units and dimensions, conversion of units, dimensional analysis, conversion of empirical equations, concepts of atomic weight, equivalent weight and mole, mole fraction, weight fraction and volume fraction, concentration of liquid solutions – molarity, molality, normality, ppm, density and specific gravity, specific gravity scales, use of mole concept in chemical reaction stoichiometry, ideal gases and gas mixtures, van der Waals, Redlich-Kwong, Soave-Redlich-

Kwong, Peng-Robinson and Virial equations of state, average molecular weight and density of gases, critical properties and compressibility of gases.

Material balances with and without chemical reactions- material balance in unit operations such as evaporation, crystallization, drying, absorption and distillation.

Energy balances- heat capacity, specific heat and enthalpy, Heat capacity of solids, liquids and gaseous mixtures- Kopp's Rule, calculation of enthalpy changes, Estimation of latent heat of vaporization- Kistyakowsky Equation, Trouton's rule, Watson equation, heat balance calculations in processes without chemical reaction, heat of reaction, standard heats of formation, combustion and reaction, heat of solution and heat of mixing, adiabatic and non-adiabatic reactions, theoretical and actual flame temperatures.

Vapour Pressure: vapour pressure of pure liquids and immiscible liquids, ideal solutions and Raoult's law, non-volatile solutes, Humidity and saturation-various terms associated with humidity and saturation.

Material and energy balance problems involving vaporization and condensation, fuels and combustion, heating value of fuels, proximate and ultimate analysis, Orsat analysis of flue gases.

b) CHEMICAL ENGINEERING THERMODYNAMICS:

Fundamental concepts and definitions –system, state and properties, their classification, Zeroth law of thermodynamics, First law of thermodynamics, Second law of thermodynamics, concept of entropy – calculation of entropy changes for various processes, Carnot's principle, Carnot cycle, heat engines and heat pumps, Clausius inequality , statistical explanation of entropy, Third law of thermodynamics, compressors – single-stage and multistage compression, vapour compression and absorption refrigeration cycles, Joule-Thomson expansion and liquefaction processes.

Thermodynamic properties of pure fluids – fundamental property relations, Joule Thomson coefficient, Gibbs-Helmholtz equation, thermodynamic diagrams, fugacity and activity of pure fluids.

Properties of solutions – partial molar properties and their methods of determination, Lewis-Randall rule, Raoult's law, Henry's law, activity and activity coefficients in solutions – effect of temperature and pressure on activity coefficients, Gibbs-Duhem equations, property changes of mixing.

Chemical reaction equilibria – extent of reaction, equilibrium constant, standard free energy change, standard state, feasibility of reaction, effect of temperature on equilibrium constant, evaluation of equilibrium constant, equilibrium conversion in gas-phase reactions – effect of pressure and other parameters on conversion, liquid-phase and heterogeneous reaction, pressures of decomposition in gas-solid reaction, simultaneous reactions, phase-rule for reacting systems.

Module III: (15 Marks)

a) FLUID AND PARTICLE MECHANICS

Physical properties of fluid – Pascal's law – Hydrostatic equilibrium in gravity and centrifugal field – Barometric equation – Lapse rate – principle of manometer, types, principles of continuous gravity and centrifugal decanter. Fluid flow phenomenon – Reynolds number , classification of flow, turbulence – different types , Reynolds stress, concept of boundary layer, flow in boundary layer , Boundary layer separation and wake formation, potential flow, rotational and irrotational flows.

Basic equations of fluid flow – Eulerain and Lagrangian approach, continuity, Bernoulli's and momentum equation, Torricelli equation, Navier Stoke's equation, dimensionless parameters and their significance, laminar flow of incompressible fluids in pipes and conduits, shear stress and velocity distribution in internal and external flows, concept of friction factor, turbulent flow of incompressible fluids in pipes and conduits – universal velocity distribution equation, friction factor and Reynolds number correlations, Nikuradse and Karman equation-Blasius equation, Prandtl one seventh power law, losses in sudden expansion and contraction, fittings and valves, flow through non circular cross section – concept of equivalent length.

Concept of drag and drag coefficient for typical shapes, streamlining, stagnation point, friction in flow through packed bed, motion of particle through fluids in gravity and centrifugal field, terminal settling velocity, different regimes of settling, Ergun equation, Kozney-Carman equation, Blake Plummer equation, free and hindered settling, Fluidization - type of fluidization, regimes of fluidization, pressure drop calculation, minimum fluidizing velocity, effect of pressure and temperature on fluidized bed behaviour..

Flow of compressible fluids – sonic velocity and Mach number , basic equations for compressible fluid flow – Isothermal and adiabatic, stagnation properties, flow processes- total energy balance, mechanical energy balance, Bernoulli equation, flow in pipes and maximum velocity – flow through nozzles and ejectors – critical pressure ratio in nozzles. Flow measuring devices: venturi meter, orifice meter, flow nozzle, pitot tube. Rectangular, Triangular & Trapezoidal weir; Rotameter. Fluid moving machineries: Fans, pumps, compressors, blowers and their characteristics, mixing and agitation.

b) HEAT TRANSFER OPERATIONS:

Modes of heat transfer, conduction- basic laws, thermal conductivity of solids, liquids and gases, steady state heat conduction in systems of constant and varying thermal conductivity with and without uniform generation of heat, steady-state conduction through single resistance and composite resistances in series, thermal insulation-industrial insulating materials, refractories,

critical thickness of insulation, concept of optimum thickness of insulation, transient heat conduction in semi-infinite solids, lumped heat transfer analysis, heat transfer in extended surfaces.

Convection- mechanism, overview of continuity, momentum and energy balance equation, boundary layer concepts – thermal and velocity boundary layers, boundary layer thickness, relationship between hydrodynamic and thermal boundary layer thickness, dimensional analysis – Rayleigh and Buckingham's pi theorem, its limitations, principle of similarity, application of dimensional analysis, forced convection-general methods for estimation of convection heat transfer coefficient, flow in a circular tube (both developing and developed flows with constant wall temperature – its analysis and constant heat flux conditions) and noncircular tubes, flow over flat plates, flow over cylinder, spheres and tube banks. Heat transfer in liquid metals – empirical correlations, analogy between momentum and heat transfer, development of Reynold's and Prandtl analogy, comparison of different analogy expressions, natural convection- from vertical and horizontal surfaces, under laminar and turbulent conditions for plates, cylinders under constant heat flux and wall temperature conditions.

Heat transfer by Radiation- Theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission – total emissive power, emissivity, radiative properties, concept of black and grey body, radiation intensity, laws of black body radiation, non-black surfaces, Lambert's cosine law, radiation between black surfaces and gray surfaces, radiation shape factor, reciprocity theorem, radiation between large parallel gray planes – concentric cylinders and spheres (no derivation required), radiation between a small gray body and a large gray enclosure, radiation shields, electrical network analogy – radiation heat transfer between black surfaces.

Heat Transfer with Phase Change- Boiling and condensation, dimensionless parameters in boiling and condensation, pool boiling – modes of pool boiling, nucleate pool-boiling, correlations, parametric effects on pool boiling.

Boilers- Different types of boilers and their classification terms associated with boiler operation, heat transfer characteristics in boiler operation and determination of heat transfer rate, parameters to be considered in boiler design.

Condensation- Physical mechanisms, types of condensation, factors affecting condensation, laminar film condensation on a vertical plate – condensation on spheres, horizontal tubes and for a vertical tier of horizontal tubes, condensation inside a horizontal tube – correlations, film condensation inside horizontal tubes, dropwise condensation, promoters and inhibitors used in condensation, effect of noncondensables on condensation, turbulent film condensation.

Evaporation – equipment and types, single effect and multiple effect evaporators, methods of feeding, evaporator accessories, vapour recompression evaporators, scale formation and its effect.

Heat Exchangers-Types, constructional details and internal components and their functions, condensers, logarithmic mean temperature difference and LMTD correction factors – overall heat transfer coefficient – fouling factors – heat exchanger effectiveness – effectiveness- NTU approach, heat transfer augmentation, compact heat exchangers.

Module IV: (15 Marks)

a) MASS TRANSFER OPERATIONS

Molecular diffusion – Fick's law, diffusivity and estimation, Mass transfer coefficients, dimensionless groups and dimensional analysis, elementary treatment of theories of mass transfer-film, penetration and surface renewal theories, interphase mass transfer , two-film theory , individual and overall mass transfer coefficients.

Gas absorption, multistage absorption, tray towers, venturi scrubbers, packed columns, general constructional details of tray towers and packed columns, choice of solvent, material balance in counter current and cocurrent absorption and stripping, multistage operation, tray efficiency, design of packed columns, dilute solutions and simplified design methods.

Humidification and dehumidification, wet-bulb temperature and adiabatic saturation temperature, types of cooling towers, enthalpy transfer unit, general design procedure, crystallization – principles, purity, yield, energy requirements, supersaturation, nucleation, rate of nucleation, growth of crystals, crystallisation equipment, MSMPR crystallizer.

Drying, equilibrium moisture content, batch drying, rate of drying, cross-circulation drying, mechanism of moisture movement, continuous drying, parallel and counter current, material and enthalpy balances, industrial dryers for batch and continuous drying.

Distillation – types of distillation, fractionation, plate columns for distillation, condensers, reboilers, principles of rectification, material and energy balance, reflux ratio and its importance, enthalpy-composition diagrams – difference points, L/G ratio, number of plates, feed plate location, minimum reflux conditions.

Extraction – applications, mixer rule, distribution curve, choice of solvent, single-stage and multistage operations, extraction with reflux, construction and working of mixer – settler cascades, sieve-tray columns and baffle towers for extraction, continuous contact extraction, design for insoluble liquids, construction and working of agitated towers, pulse columns and centrifugal extractors.

Leaching – factors affecting rate of leaching, stage efficiency, working principles of leaching equipment, thickeners, classifiers and moving bed leaching equipment, membrane separation processes, types of membranes, dialysis, pervaporation, reverse osmosis – effects of operating variables, concentration polarization, ultrafiltration.

Adsorption- agitated vessels for solid liquid adsorption, multistage fluidised bed adsorber for recovery of vapour, continuous contact adsorption- steady state moving bed adsorber, counter current adsorption of one component, adsorption of two components, unsteady state fixed bed adsorber, adsorption wave – break through curves and rates of adsorption.

Ion Exchange-principles of ion exchange techniques and application, modern separation techniques, concept of dialysis and electrodialysis, continuous dialyser, concept of diffusion and permeation – concept of osmosis and reverse osmosis, industrial application and design aspects.

b) MECHANICAL OPERATIONS

Particle diameter and shape factor, particle size analysis, sieve analysis, particle size distribution, cumulative and differential methods of analysis, mean diameters, specific surface area and number of particles, sub-sieve analysis, pipette analysis, beaker decantation, sedimentation, elutriation, microscopic counting, permeability and adsorption, screening – effectiveness and capacity of screens and factors affecting them, types of industrial screens.

Principles of free and hindered settling, equal settling particles, classifiers, types of classifiers, principles of mineral beneficiation- Ore sorting, electronic sorting, assay sampling, recovery, liberation, locked particles, Jigging, Wilfley table, heavy media separation, magnetic and high-tension separation, high voltage separation, types of equipment, batch and continuous thickening, kynch theory, design of continuous thickener.

Filtration – theory of constant pressure and constant rate filtration, cake porosity and compressibility, filter aids, types of batch and continuous filters, washing of filter cakes, centrifugal methods of separation including centrifugal filtration, continuous centrifuge, gas cleaning methods, gravity settling, cyclone separation, electrostatic, precipitation, scrubbing, storage of solids, liquids and gases.

Laws of comminution – mechanism and efficiency of size reduction, principles of important size reduction equipments, closed circuit and open circuit grinding, free crushing and choke feeding – wet and dry grinding – mixing of granular solids and pastes – degree of mixing – type and selection of equipment – storage and conveying of solids – silos, bins, and hoppers – different types of conveyors – selection of conveyors.

Module V: (15 Marks)

a) CHEMICAL REACTION ENGINEERING

Overview of chemical reaction engineering, classification of chemical reactions, variables affecting the rate of reaction, definition of reaction rate, kinetics of homogeneous reaction, pseudo steady state hypothesis (PSSH), searching for a mechanism, General considerations, hydrogen bromide reaction, polymerisation –steps in free radical polymerisation, evaluation of rate equation by integral and differential analysis for constant volume and variable volume system, classification of reactors, design of single and multiple reactions – size comparison of single and multiple reactors, auto catalytic reactions, design of evaluation of laboratory reactors, Integral (fixed bed) reactor, stirred batch reactor, stirred contained solid reactor (SCSR), differential reactors-continuous stirred tank reactor (CSTR), Laminar flow reactor, stirred through transport reactor, re-calculating transport reactor.

Heterogeneous Reactions- Catalysis and catalytic reactors, Catalysts, types of catalysts, catalyst properties, steps in a catalytic reaction, Heterogeneous data analysis for reactor design, catalyst deactivation, deactivation mechanisms, diffusion and reaction in porous catalysts, Thiele Modulus, internal effectiveness factor, overall effectiveness factor, estimation of diffusion and reaction limited regimes, Weisz –Prater criterion for internal diffusion, Mears criterion for external diffusion.

Fluid-Fluid reactions-Rate equations, kinetic regimes for mass transfer and reactions, rate equation for instantaneous and fast and slow reactions, two film theory, film conversion parameters, pressure drop in reactors, accounting the pressure drop in the rate law, flow through a packed bed, pressure drop in pipes, simultaneous reactions and separations.

b) PROCESS INSTRUMENTATION AND CONTROL

Introduction – definition of instrumentation – concept of an instrument – functional elements and functions of an instrument – classification of instruments, performance characteristics of an instrument like static and dynamic type, temperature measurement – electrical, non-electrical, contact and non-contact methods. Pressure measurement – manometers of U-tube type, well type and inclined type, Prandtl and air type micro-manometers, Barometer method for atmospheric pressure measurement, low pressure measurement by Pirani gauge, McLeod gauge, thermal conductivity gauge, Transducers of electrical mechanical type, density measurement using constant volume hydrometer and, air pressure balance method, gas density detector and gas specific gravity measuring system.

Flow measurements – Liquid and gas flow measurements, ways of measuring liquids and gas flow, direct volume measurements, open channel flow measurements, turbine type flow meters strain

gauge flow meters mass flow meter, measuring flow of dry materials, Thermal analysis – differential thermal analysis, thermogravimetric, conductimetric analysis Chromatography and application, PH control temp control, heat exchangers, distillation column, reaction system etc.

Moisture content and humidity -moisture content determination by thermal drying, Instruments for measuring humidity like hygrometer, psychrometer, dew point apparatus, pH measurement using calomel electrode, composition analysis using spectroscopic methods like absorption, emission and mass spectrometers, analysis of solids by X-ray diffraction, Gas analysis by thermal conductivity, polarography & chromatography.

Introduction to process dynamics and control - definition of terms - Linear open loop systems, mercury thermometer, liquid level process: single tank, two tank interacting and non-interacting systems, manometer- response of these towards step and sinusoidal functions, Linear open loop second order systems - mercury thermometer in a well and manometer - impulse and step response of under damped, critically damped and over damped systems, Transient response of simple control systems- step response and offset , stability of linear systems - Routh-Hurwitz criterion for stability, root locus technique, transportation lag and its effect on root locus diagram. Introduction to frequency response - substitution rule, Nyquist diagram, Nyquist stability criteria, Bode diagram for first order systems, first order systems in series, second order systems, bode stability criterion, gain margin and phase margin, Controller tuning- Ziegler-Nichols method, reaction curve method, comparison of closed loop responses for different controller settings. Supervisory control and data acquisition (SCADA), distributed control system (DCS).

“Special Control Technicques : Advanced congrol techniques, cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control.”

Module VI: (15 Marks)

a) PROCESS DESIGN

Design of heat transfer equipments- Double pipe heat exchangers, shell and tube heat exchangers, condensers, tubular horizontal and tubular vertical, evaporators, single effect and multiple effect evaporators, crystallizers.

Design of mass transfer equipments- distillation columns, absorption and stripping column columns, their accessories, driers and cooling towers.

b) ENVIRONMENTAL ENGINEERING

Impact of man on the environment-an overview, the biosphere, the hydrologic cycle and measurement of precipitation, the nutrient cycle, mathematics for growth, consequence of population growth, energy problem, importance of environment for mankind, pollution of air, water and soil, dangers of pollution and its solution.

Legislation- Legislative aspects including water (Prevention and control of pollution) Act 1974, Air (prevention and control of pollution) Act 1981, Environmental protection act 1986 and effluent standards.

Air pollution- Sources and effects – Nature of air pollution classification, properties and sources of pollutants, acid rain, Greenhouse effect, Ozone depletion, Effects of man, animal, vegetation and material dangers, atmospheric stability, lapse rates, inversions, plume behaviour and theory of pollutant dispersion, Air quality criteria and standards, methods of pollutant sampling and measurement. Control methods for particulate emulsions and pollutants – design aspects of Cyclone separator, Electrostatic precipitator, Bag house filter, Scrubbers, Different types, Indoor Air pollution control, Water pollution: Sources and classification of water pollutants and their effects. Sampling and analysis.

Waste water treatment- Design aspects of Preliminary, primary, secondary and tertiary treatment of waste water, recovery of materials from process effluents – anaerobic and aerobic sludge treatment and disposal – cake filtration and composting – methods of physiochemical and biological treatment of industrial effluents from fertilizer, petrochemical, pulp and paper, caustic soda, tanning and sugar industries. Alternate routes of manufacture and sequencing of operations as a means of pollution control, alternate use for by-product as means of pollution control, advanced treatment methods reverse osmosis and carbon adsorption.

Solid waste management: Sources, classification and microbiology of solid waste, solid waste characteristics – health aspects, methods of collection and disposal, solid waste processing and recovery – composting, sanitary land filling, thermal processes, regeneration and recycling, city waste and industrial wastes management – biological methods.

Nuclear waste- Sources and nature of nuclear waste, treatment, storage technology for liquid, solid and gaseous (radioactive) wastes.

Noise control- Noise control programme, noise control criteria, administrative and engineering controls acoustical absorptive materials.

Environmental Management- ISO standards, Ecomark, Green production, Kyoto protocol, Montreal Protocol, Euro norms, Environmental Impact assessment – Environmental agencies, standards and legal, aspects in Environmental management.

Module VII (10 Marks)

CHEMICAL PROCESS INDUSTRIES

Fuel gases- natural gas, coke oven gas, producer gas, water gas, LPG. Industrial gases-carbon dioxide, hydrogen, nitrogen, oxygen, manufacturing of sulphur and sulphuric acid, phosphorus and

phosphoric acid- wet process phosphoric acid, electric furnace phosphorus and phosphoric acid, single super phosphate and triple super phosphate.

Chlor-alkali industries- salt, soda ash, baking soda, caustic soda, chlorine, hydrochloric acid, Nitrogen industries-ammonia, nitric acid, urea, fertilizer industries, ammonium sulphate, ammonium nitrate, nitrolime, MAP, DAP and nitrophosphates, mixed and complex fertilizers, Carbon chemicals- carbon black, activated carbon, synthetic graphite, calcium carbide, Surface coating industries- pigments, paints, varnishes, lacquers, industrial coatings, Cement-portland cement, constituents, types, raw materials and manufacturing processes, Glass - classes of glass, raw materials, methods of manufacture. Ceramics and refractories (general study), Pesticides-DDT, Nicotine, Parathrins, Heptachlor, endosulfan, Natural products industries- soaps and detergents, glycerine, pulp and paper, wood chemicals, Coal chemicals, Food processing, food by-products, leather, gelatine, adhesives, vegetable oils, animal fats and oils, waxes, sugar, starches and related products, industrial alcohol by fermentation, absolute alcohol, beers, wines and liquors. Pharmaceuticals, biotechnology.

Petroleum: Classification of crude, characteristics of crude, chemical composition of crude, processing of crude – sweetening, atmospheric and vacuum distillation of crude, cracking and coking, refining, reforming, hydro-cracking and isomerisation, Production of lubricating oils, lube additives, Motor gasoline, kerosene, aviation turbine fuel and aviation gasoline, Petrochemicals: Primary processes for olefins, acetylenes, higher homologues, aromatics and their derivatives, propylene, acetylene, methanol and its derivatives.

NOTE: - It may be noted that apart from the topics detailed above, questions from other topics prescribed for the educational qualification of the post may also appear in the question paper. There is no undertaking that all the topics above may be covered in the question paper.