ANNEXURE (VIII)- Syllabus

Part A -Subject Syllabus

1. **MECHANICS**

   Motion of a particle with constant acceleration, acceleration of falling bodies, motion under gravity, motion of a body projected vertically upward, motion of a two particles connected by a string, motion along a smooth inclined plane, constrained motion along a smooth inclined plane. Variable acceleration, Simple harmonic motion, elastic string, simple pendulum.

   Projectile, Work, Power, conservative fields and potential energy, work done against gravity, potential energy of a gravitational field.

   Relative motion, relative displacement, velocity and acceleration, motion relative to a rotating frame of reference. Linear momentum, angular momentum, conservation of angular momentum, impulsive forces, principle of impulse and momentum.

2. **ELECTRICITY AND MAGNETISM-I**

   Coulomb's Law for point charges and continuous distribution of charges. Electric field due to dipole line charge and sheet of charge. Electric flux. Gauss's Law and its applications.

   Work and potential difference. Potential difference as line integral of electric field. Electric potential due to a point charge, a group or point charges, dipole and quadruple moments, long uniformly charged wire, charged disc. Electric field as gradient of scalar potential. Calculation of E due to a point charge and dipole from potential. Potential due to arbitrary charge distribution and multipole moments. Poisson and Laplace's Equation. Calculation of electric potential and field due to a point charge placed near an infinitely conducting sheet.

   Current and current density, equation of continuity. Microscopic form of Ohm's Law.($J=oE$) and conductivity. Failure of Ohm;s Law. Invariance of charge. E in different frames of reference. Field of a point charge moving with constant velocity. Interaction between moving charges and force between parallel currents. Behaviour of various substances in magnetic field. Definition of M and H and their relation to free and boundcurrents. Permeability and susceptibilities and their inter-relationship. Orbital motion of electrons and diamagnetism. Electron spin and paramagnetism. Ferromagnetism. Domain theory of Ferromagnetism. Hysteresis Loss. Magnetisation curve. Ferrites..

   Lorentz's force. Definition of B. Biot Savart's Law and its applications to long straight wire, circular current loop and solenoid. Ampere's Circuital law and its application. Divergence and curl of B. Hall effect expression and co-efficient. Vector potential, Definition and derivation of current density-definition its use in calculation or change in magnetic field at a current sheet. Transformation equation or E and B from one frame to another. Faraday's Law of EM induction. Displacement current . Maxwell's equations. Mutual inductance and reciprocity theorem. Self inductance L for solenoid. Coupling of Electrical circuits. Analysis of LCR series and parallel resonant circuits. Q—factor. Power consumed power factor..

3. **VIBRATIONS AND WAVES**

   Physical interpretation of Maxwell's equations. Electromagnetic waves and wave equation in a medium having finite permeability and permittvity but with conductivity σ=0. Pointing vector. Impedance of a dielectric to EM waves, EM waves in a conducting medium and skin depth. EM waves velocity in a conductor an anomalous dispersion. Response of a conducting medium of EM waves. Reflection and transmission of EM waves at a boundary of two dielectric media for normal incidence. Reflection of EM waves from the surface of a conductor at normal incidence.

4. **OPTICS**

   Interference: Concept of coherence, Spatial and temporal coherence. Coherence time, Coherence length, Area of coherence, Conditions for observing interference fringes, Interference by wave front division and amplitude division, Michelson's interferometer—working, Principle and nature of fringes, Interference in thin films, Role of interference in anti-reflection and high reflection dielectric coatings. Multiple beam interference, Fabry-Perot interferometer, Nature of fringes, Newton Rings.

Diffraction: Huygens-Fresnel theory, half-period zones, Zone plates, Distinction between Fresnel and Fraunhofer diffraction, Fraunhofer diffraction at rectangular and circular apertures, Effects of diffraction in optical imaging, resolving power of telescope. The diffraction grating, its use as a spectroscopic element and its resolving power.

Polarization: Concept and analytical treatment of un-polarized, plane polarized and elliptically polarized light. Double refraction, Nicol prism, Sheet polarizer, Retardation plates, Production and analysis of polarized light (quarter and half wave plates).

5. QUANTUM MECHANICS

Formalism of Wave Mechanics: Brief introduction to need and development of quantum mechanics, Wave-particle duality, de-Broglie hypothesis, Complimentarity and uncertainty principle, Gaussian wave-packet, Schrodinger equation for a free particle, operator correspondence and equation for a particle subject to forces. Normalization and probability
Interpretation of wave function, Super position principle, Expectation value, probability current and conservation of probability, Admissibility conditions on the wave function. Ehrenfest theorem, Fundamental postulates of wave mechanics, Eigen functions and eigen values. Operator formalism, Orthogonal systems, Expansion in eigen functions, Hermitian operators. Simultaneous eigen functions. Equation of motion.
Problems in one and three dimensions: Time dependent Schrodinger equation. Application to stationary states for one dimension, Potential step, Potential barrier, Rectangular potential well, Degeneracy, Orthogonality, Linear harmonic oscillator, Schrodinger equation for spherically symmetric potential, Spherical harmonics. Hydrogen atom energy levels and eigen functions. Degeneracy, Angular momentum.

One Electron Atomic Spectra: Excitation of atom with radiation. Transition probability, Spontaneous transition, Selection rules and life time, Spectrum of hydrogen atom. Frank Hertz Experiment, Line structure, Normal Zeeman effect, Electron spin, Stern Gerlach experiment, Spin orbit coupling (electron magnetic moment, total angular momentum),Hyperfine structure, Examples of one electron systems, Anomalous,Zeeman effect, Lande-g factor (sodium D-lines).

6. ELECTRONICS
Concept of current and voltage sources, p-n junction, Biasing of diode, V-A characteristics. Diode equation, Breakdown diodes: Zener breakdown and avalanche breakdown, Zener diode. Rectification: half wave, full wave rectifiers and bridge rectifiers, Qualitative analysis of Filter circuits (RC LC and π filters) Efficiency, Ripple factor, Voltage regulation. Voltage multiplier circuits.

Junction transistor: structure and working, relation between different currents in transistors, Sign conventions. Amplifying action, Different configurations of a transistor and their comparison, CB and CE characteristics.

Structure, Characteristics, operation of FET, JFET and MOSFET, Pinch off voltage, Enhancement and Depletion mode, Comparison of JFETs and MOSFETs, Difference in field effect transistor and junction type transistor.
Photo-conductive devices: Photo-conductive cell, Photodiode, Solar cell, LED, LCD.

Transistor biasing: Stabilization of operating point, Fixed bias, Collector to base bias, Bias circuit with emitter resistor, Voltage divider biasing circuit.

CE amplifier: Working and analysis using h-parameters, Equivalent circuits, Determination of current gain, Power gain, Input impedance, FET amplifier: Voltage, Current and Power gain

Feed back in amplifiers: Types & advantage of negative feedback. Emitter follower as negative feed back circuit.

7. CALCULUS

Basic properties of limit, continuity of functions and classification of discontinuities of one variable function . Differentiability, Successive differentiation, Asymptotes, Test for concavity and Convexcity and Convexcity. Beta – Gamma Functions.

Limits, continuity and differentiability of two variables. Partial derivatives and its Linearization, Chain rule, Partial derivative with constrained variable. Homogeneous functions, Euler theorem and its applications, Extreme value and saddle point, Lagrange multiplier`, Taylor's theorem and its linear and quadratic approximation.

Improper Integral, Beta and gamma functions, Double integral in Cartesian and polar form, Change of order of integration in double integrals, Triple Integrals in Cartesian polar and spherical co-ordinates. Change of variables. Applications to evaluation of areas, Volume.

8. **VECTOR CALCULUS**
Scalar and vector fields, differentiation of vectors. Vector differential operators: Del, Gradient, Divergence and Curl, Line, surface and volume integrals, Greens Theorem, Stokes Theorem and the Divergence Theorem. Applications of Green's, Stoke's and Divergence theorem.

9. **ANALYSIS**
Sequence: Bounded and Monotonic sequences, Convergent sequence, Cauchy sequences, Subsequence , Sequential continuity.
Series: Comparison tests. Cauchy's integral test, Ratio, Raabe's, Logarithmic, Gauss, Root, Leibnitz's Test. Absolute and conditional convergence.

10. **DIFFERENTIAL EQUATIONS**
Order and degree of a differential equation, separable differential equations, Homogeneous differential equations, Exact differential equations. Linear homogeneous and non-homogeneous differential equations of higher order with constant coefficients and with variable coefficients. Method of Variation of Parameters. Differential operator method. Euler's Cauchy method.

Partial differential equation of first order, Lagrange's solution, , Integral surfaces passing through a given curve, surfaces orthogonal to a given system of surfaces, Partial differential equation of first order but of any degree , Charpit's method. Partial differential equations of the second order and their classification into hyperbolic, elliptic and parabolic types, canonical forms.

11. **ALGEBRA**

Hermitian, Skew-Hermitian, Orthogonal and Unitary matrices, .Elementary operation on matrices. Gauss Jordan Method. Linear independence-dependence, Row rank, Colum rank and their equivalence. Eigen values, Eigen vectors, Cayley-Hamilton theorem. Consistency of a system of linear equations.

12. **GEOMETRY**

Parabola: Pole and polar, pair of tangents from a point, chord of contact, equation of chord in terms of midpoints and diameter of conic, Subtangent and Subnormal and its geometrical properties.

Ellipse: Properties of ellipse, parametric representation of ellipse, tangents, normals, equation of chord joining two points on ellipse. Director circle of ellipse, chord of contact, conjugate lines and conjugate diameter, Conormal Points and its geometrical properties.

Hyperbola: Properties of hyperbola, fundamental rectangle, parametric representation of hyperbola, asymptotes of hyperbola, Conjugate hyperbola, rectangular hyperbola, tangents and normals.

Plane: General form, Normal form, Intercept form, Reduction of the general form to normal form, Equation of plane through three points, Angle between two planes, Parallel planes, Perpendicular distance of a point from the planes, Pair of the planes, Area of a triangle and Volume of a tetrahedron.

Straight line: Equation of a line in general form, Symmetric form, two point form, Reduction of the general equation to the symmetrical form, Straight line and the planes, Conditions of parallelism and perpendicularity of a line and a plane, Plane through a given line, Perpendicular

distance formula for the line, Projection of a line on a given plane containing them, Condition of intersection of two lines, Shortest distance between two lines, intersection of three planes.

Sphere: General equation of a sphere, Plane section of a sphere, Intersection of two spheres, Sphere through a given circle, Intersection of a straight line and a sphere, Equation of a tangent plane to sphere, Condition of tangency. Plane of contact, Orthogonal Spheres, Angle of intersection of two spheres, Length of tangent, Radical plane, Coaxial system of spheres.

Cone: Equation of a cone whose vertex is at origin, Equation of a cone with a given vertex and a given conic as base, Condition that general equation of second degree represent a cone, Equation of a tangent plane, Condition of tangency of a plane and a cone, Reciprocal cone, Right circular cone.

Cylinder: Enveloping Cylinder, Right circular cylinder

13. **ATOMIC STRUCTURE**
Idea of de Broglie matter waves, Heisenberg uncertainty principle, atomic orbitals, Schrodinger wave equation, quantum numbers, shapes of s, p, d orbitals. Aufbau and Pauli exclusion principles, Hund's multiplicity rule. Electronic configurations of the elements and ions.

14. **PERIODIC PROPERTIES**
Atomic and ionic radii, ionization energy, electronic affinity, electronegativity and their trends in periodic table.
s-block elements: Comparative study, diagonal relationships, salient features of hydrides, solvation and complexation tendencies. Biological significance of elements.
p-block elements: Comparative study (including diagonal relationship) of p-block elements, compounds like hydrides, oxides, oxyacids and halides of p-block elements.
d- & f-block elements: Characteristic properties of d- & f-block elements, their oxidation states, ionic radii, coordination number. lanthanoid and actinoid contraction.

15. **CHEMICAL BONDING**
Valence bond theory and its limitations, various types of hybridization and shapes of simple inorganic molecules and ions: BeF_2, BF_3 , CH_4, PF_5, SF_6, IF_7, $SnCl_2$, XeF_4, BF_4^-, PF_6^-, $SnCl_6^{2-}$. Valence shell electron pair repulsion (VSEPR) theory to NH_3, H_3O^+, SF_4, ClF_3, ICl_2, and H_2O. Molecular Orbital theory of homonuclear and heteronuclear diatomic molecules.

16. **BASIC CONCEPTS OF ORGANIC CHEMISTRY**
Hybridization, Resonance, hyperconjugation, aromaticity, inductive and field effects, hydrogen bonding. Reactive intermediates-carbocations, carbanions, free radicals, carbenes, arynes and nitrenes. Methods of determination of reaction mechanism.

17. **ALKANES ALKENES AND ALKYNES**
Alkanes: Isomerism in alkanes, methods of preparation: Wurtz reaction, Kolbe reaction, Corey-House reaction.
Nomenclature, structure, methods of formation of alkenes and alkynes, dehydration of alcohols and dehydrohalogenation of alkyl halides regioselectivity in alcohol dehydration. The Saytzeff rule, Hofmann elimination. Chemical reactions of alkenes. Markownikoff's rule, hydroboration-oxidation, oxymercuration reduction. Epoxidation, ozonolysis, hydration, hydroxylation and oxidation with $KMnO_4$. Chemical reactions of alkynes, acidity of alkynes. electrophilic and nucleophilic addition reactions, hydroboration-oxidation.

18. **ALCOHOLS AND PHENOLS**
Nomenclature, Structure and methods of preparation of alcohols and phenols.
Alcohols: Hydrogen bonding, Acidic nature, Chemical reactions of alcohols and Pinacol-Pinacolone rearrangement.
Phenols: physical properties and acidic character. Reactions of phenols - electrophilic aromatic substitution, acylation and carboxylation. Fries rearrangement. Gatterman synthesis, Hauben-Hoesch reaction, and Reimer-Tiemann reaction.

19. ALDEHYDES, KETONES AND CARBOXYLIC ACIDS DERIVATIVES

Aldehydes and Ketones: Nomenclature, methods of preparation of aldehydes and ketones, Nucleophillic addition to carbonyl group, Wittig reaction, and Mannich reaction. Oxidation of aldehydes, Baeyer-Villiger oxidation of ketones, Cannizzaro reaction, MPV (Meerwein Pondoroff Vorley) reaction, Clemmensen, Wolff-Kishner, $LiAlH_4$ and $NaBH_4$ reductions. Michael addition.

Carboxylic Acids: Nomenclature, Acidity of carboxylic acids, Preparation of carboxylic acids, Chemical reactions of carboxylic acid.

Structure and nomenclature of acid chlorides, Esters, Amides and Acid anhydrides. General methods of preparations and their chemical reactions.

20. SPECTROSCOPY

Ultraviolet (UV) absorption spectroscopy: absorption laws- Beer-Lambert's law, Types of electronic transitions, Effect of conjugation. Chromophore and auxochrome. Bathochromic, hypsochromic, hyperchromic and hypochromic shifts.

Infrared (IR): Infrared (IR) absorption spectroscopy-molecular vibrations, Hooke's law, Characteristic absorption of various functional groups.

Nuclear magnetic resonance (NMR) spectroscopy: Proton magnetic resonance (^{1}H NMR) spectroscopy, nuclear shielding and deshielding, chemical shift, spin-spin splitting and coupling constants.

21. SOLUTIONS

Molarity, molality, mole fraction, percentage. Vapour pressure of solution and Raoult's law for ideal and non-ideal solutions, plots for ideal and non-ideal solutions, Colligative properties-relative lowering of vapous pressure, depression of freezing point, elevation of boiling point and osmotic pressure.

22. STATES OF MATTER

Gaseous state; Gas Laws- Boyle's law, Charle's law, Gay Lussac's law, Graham's law of diffusion, Avogadro's law, Dalton's law of partial pressure.

Solid state; Amorphous and crystalline solids, Bragg's law and its applications; Unit cell and lattices, packing efficiency, calculation of density of unit cell. Imperfection in solids.

23. THERMODYNAMICS AND CHEMICAL KINETICS

Types of systems, intensive and extensive properties. Laws of Thermodynamics. Rate of chemical reactions, factors affecting rates of reaction, order and molecularity of reactions, Rate law, Rate constant, Half-life, Arrhenius theory, activation energy and its calculations.

Part B
General Knowledge, Logical Reasoning & Mental Ability

(1) General Knowledge and Current affairs of National and International importance including:

(i)   Economic issues.

(ii)   Polity issues.

(iii)   Environment issues

(iv)   Geography

(v)   Science and Technology.

(vi)   Any other current issues.

(vii)   (a) History of India with special reference to Indian freedom struggle movement

        (b) History of Punjab- 14th century onwards

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(2) General Mental Abilitiy , Logical Reasoning & Quantitative Aptitude

(i)   Analytical Reasoning, Logical Reasoning and Mental Ability

(ii)   Basic numerical skills, numbers, magnitudes, percentage, numerical relation appreciation.

(iii)   Data analysis, Graphic presentation charts, tables, spreadsheets.

General Information regarding 04 posts of Research Officer (Group-A) and 16 posts of Assistant Research Officer (Group-A) in the Department of Water Resources, Government of Punjab in the year of 2022