Himachal Pradesh
Public Service Commission

No.03-16/2024-PSC (R-II) **Dated: 21-08-2025**

Syllabus of Paper-II i.e. Descriptive Type Subject Aptitude Test (SAT) for recruitment to the post of Assistant Director (Physics & Ballistics), Class-I (Gazetted) in the Directorate of Forensic Services, Home Department, Himachal Pradesh. The SAT paper shall be of 03 hours duration having 120 Marks. The SAT paper shall have two parts i.e. Part-I and Part-II and cover the following topics of:-

{Master of Science (Physics) level}

PART-I (60 MARKS)

1. **MATHEMATICAL PHYSICS:-**

Matrices and Vector Analysis: Linear algebra, matrices, Cayley-Hamilton Theorem, Eigenvalues and eigenvectors, Vector algebra and vector calculus, Vector differential operators: gradient, curl, Divergence and Laplacian, Vector operators in curvilinear coordinates, Gauss's theorem, Green's theorem and Stoke's theorem, Differential Equations: Linear ordinary differential equations of first & second order, Partial differential equations separation of variables, singular points, series solutions-Frobenius method, second solution. Probability distribution, Binomial distribution, Poisson distribution, Normal distribution, Applications of Binomial, Poisson and Normal distributions, Central limit theorem; Complex Analysis: Elements of complex analysis, analytic functions, Analyticity and Cauchy-Reimann Conditions, Cauchy's integral theorem and formula,Taylor, Laurent and Maclaurine series expansion, zeros and singular points, poles, residues and residue theorem, Cauchy's residue theorem, contour integration, Jordan's Lemma, evaluation of definite integrals;Delta and Gamma Functions Dirac delta function, Delta sequences for one dimensional function, properties of delta function, Orthogonal function and Integral representation of Delta function, Gamma function, factorial notation and applications, Beta function, Relation with gamma function; Special Differential Equations and Their Solutions (Legendre's differential equation: Legendre polynomials, Generating functions, Recurrence Formulae, Rodrigue's formula, Orthogonality of Legendre's polynomial; Bessel's differential equation: Bessel's polynomial, generating functions, Recurrence Formulae, orthogonal properties of Bessel's polynomials; Hermite differential equation, Hermite polynomials, generating functions, recurrence relation; Laguerre's differential equation: Laguerre's polynomial, generating function, Recurrence Formulae, orthogonal properties of Laguerre's polynomials; Laplace Transforms Laplace transforms: Linearity property, first and second translation property of LT, Derivatives of Laplace transforms, Laplace transform of integrals, Initial and Final value theorems; Methods for finding Laplace's Transform (LT) of a function: direct and series expansion method, Method of differential equation; Inverse Laplace Transforms: Linearity property, first and second translation property, Convolution property – Application of LT to differential equations and boundary value problems;Fourier Series andFourier Transform: Fourier series expansion of a function–Dirichlet's conditions, Complex representation of Fourier series, problems related to periodic functions, Fourier integrals, convergence of

Fourier series, solving simple partial differential equations using Fourier's series- Fourier transforms: sin, cosine & complex transforms- solving simple partial differential equations using Fourier transform, Tensors: Tensor and their ranks, contravariant and covariant tensors, symmetric and asymmetric tensors, Scalars or invariants, The Kronecker delta, Algebraic operations of tensors – sum and difference of tensors, direct product of tensors, Contraction, Extension of the rank, quotient law. Group Theory: Definition of a group, The multiplication table, conjugate elements and classes of groups, directs product of groups, Isomorphism, homeomorphism, permutation group, Definitions of the three dimensional rotation group and SU(2).

2. CLASSICALMECHANICS:-

Lagrangian Formulation Mechanics of a system of particles, Constraints of motion, Generalized coordinates, D'Alembert's Principle and Lagrange's velocity – dependent force and the dissipation function, Application of Lagrangian formulation; Hamilton Principle: Calculus of variations, Lagrange's equation from Hamilton's principle, Extension to non-holonomic systems, advantages of variational principle formulation, symmetry properties of space and time and conservation theorems; Rigid Body Motion Independent co-ordinates of rigid body, orthogonal transformation, Eulerian Angles and Euler's theorems, infinitesimal rotation, Rate of change of vector, Coriolis force, angular momentum and kinetic energy of a rigid body, the inertia tensor, principal axis transformation, Euler equations of motion, Torque free motion of rigid body, motion of a symmetrical top; Small Oscillations Eigenvalue equation, Free vibrations, Normal Coordinates,Vibrations of a triatomic molecule; Hamilton's Equations: Legendre Transformations, Hamilton's equations of motion, Cyclic-coordinates, Hamilton's equations from variational principle, principle of least action; Canonical Transformation and Hamilton- Jacobi Theory: Canonical transformation and its example, Poisson brackets. Equations of motion, Angular momentum, Poisson's Bracket relations, infinitesimal canonical transformation, Conservation Theorems, Hamilton–Jacobi equations for principal and characteristic functions, Harmonic oscillator problem, Action angle variables for system with one degree of freedom. Special Theory of Relativity: Preliminaries of special theory of relativity, four vector notation, energy, momentum four-vector for a particle, relativistic invariance of physical laws.

3. QUANTUM MECHANICS:

General Formalism of Quantum Mechanics: Linear Vector Space-Linear Operator, Eigen functions and Eigenvalues, Hermitian Operator, Postulates of Quantum Mechanics, Simultaneous Measurability of Observables, Uncertainty Relation, Dirac's Notation, Equations of Motion; Schrodinger, Heisenberg and Dirac representation, momentum representation, Density Matrix and its properties; Energy Eigenvalue Problems: Particle in a box, Linear Harmonic oscillator, Tunneling through a barrier, Hydrogen atom; Angular Momentum: Orbital Angular Momentum, Spin Angular Momentum, Total Angular Momentum Operators, Commutation Relations of Total Angular Momentum with Components, Ladder operators, Commutation Relation of Jz with J+ and J-, Eigen values of J^2, Jz, Matrix representation of J^2 , Jz, J+ and J-, Addition of angular momenta-Clebsch - Gordon Coefficients, selection rules – recursion relations-computation of Clebsch-Gordon Coefficients, Approximate Methods Time Independent Perturbation Theory: Non-Degenerate

Case and Degenerate Case, Stark Effect in Hydrogen atom, Spin-orbit interaction, Variation Method, Born-Oppenheimer approximation, WKB Approximation and its validity: Time Dependent Perturbation Theory: First and Second Order Transitions, Transition to Continuum of States, Fermi Golden Rule-Constant and Harmonic Perturbation; A Charged Particle in an Electromagnetic Field, Scattering Theory Scattering Amplitude, Expression in terms of Green's Function, Born Approximation and its validity, Partial wave analysis, Phase Shifts, Asymptotic behavior of Partial Waves, The Scattering Amplitude in Terms of Phase Shift, Scattering by Coulomb Potential and Yukawa Potential, Identical Particles: Brief introduction to identical particles in quantum mechanics, The Schrodinger equation for a system consisting of identical particles, symmetric and antisymmetric wave functions, Elementary theory of the ground state of two electron atoms, ortho-and parahelium, spin and statistics connection, scattering of identical particles, Relativistic Wave Equation, Klein-Gordon Equation-Plane Wave Equation-Charge and Current Density, Application to the Study of Hydrogen Like Atom.

4. CLASSICAL ELECTRODYNAMICS:-

Electrostatics Introduction, Work and Energy in electrostatics, Polarization, Laws of electrostatic field in the presence of dielectrics, Energy of the field in the presence of a dielectric, Boundary condition, Poisson and Laplace equations, Earnshaw's theorem, Boundary conditions and Uniqueness theorem, Multipole expansion, Method of electrostatic images. Magnetostatics: Introduction, Laws of magnetostatics, Magnetic scalar and vector potentials, Magnetic media, magnetization, magnetic field vector, Boundary conditions, Time Varying Fields Maxwell's equations, Displacement current, Electromagnetic potential, vector and scalar potential, Gauge transformations; Lorentz and Coulomb Gauge, Poynting theorem, conservation laws for a system of charged particles and electromagnetic field, continuity equation, Electromagnetic Waves Plane waves in Non-conducting and conducting media Polarization-linear and circular polarization. Skin effect, Reflection and refraction of electromagnetic waves across a dielectrics interface at a plane surface between dielectrics. Total internal reflection, Polarization by reflection, Reflection from the surface of a metal, Electromagnetic Radiation Retarded Potentials, Radiation from an oscillating Dipole, Lienard-Wiechert Potentials, Potentials for a charge in uniform motion-Lorentz Formula, Fields of an accelerated charge. Transmission lines and wave guides- TE, TM and TEM modes, rectangular and cylindrical wave guides, resonant cavities, Energy dissipation, Q of a cavity.

5. ELECTRONICS:-

Operational Amplifier Differential amplifier, inverting and non-inverting inputs, analysis of inverting and non-inverting amplifier, Effect of negative feedback on input resistance, output resistance, Band width; closed loop gain and offset voltage, Voltage follower, Input bias current, input off-set current, total output offset voltage, CMRR. DC and AC amplifier, summing, scaling, instrumentation amplifier, integrator and differentiator, log & antilog amplifiers, comparators, waveform generators and regenerative comparator (Schmitt Trigger) using 741 Opamp. Oscillator principles, oscillator types, frequency stability, frequency response, Phase shift oscillator, Sequential Logic Flip-Flop: The RS Flip-Flop, JK- Flip-Flop, JK master slave-Flip-Flop, T Flip-Flop, D- Flip-Flop-Shift Registers, Synchronous and

Asynchronous Counter, Cascade Counters, A/D and D/A Converters, Microprocessors Introduction to microcomputers, input/output- interfacing devices, 8085 CPU – Architecture-BUS timings, Demultiplexing the address bus generating control signals, Instruction Set, Addressing Modes, Illustrative Programmes, Writing Assembly Language Programmes, Looping, Counting and Indexing, Counters and Timing Delays, Stack and Subroutine. Microprocessor Applications, Recent trends in microprocessor technology, Introduction to 8086 microprocessor, Modulation & Communication Systems Basic concepts of communication systems, Need for modulation, Amplitude Modulation, generation of AM waves, Demodulation of AM waves. Frequency modulation, Block diagram of transmitter and superheterodyne receiver, Digital communication, basic idea about delta modulation, PCM, PPM and PWM, DS BSC modulation, generation of DSBSC waves, coherent detection DSBSC wave, SSB modulation, generation and detection of SSB waves, Vestigial sideband modulation, frequency division multiplexing (FDM).

6. STATISTICAL PHYSICS:-

Thermodynamics Basic ideas about heat, temperature, work done, Laws of thermodynamics and their significance, specific heats, thermodynamic potentials, Maxwell relations significance of entropy, Chemical potentials, Phase equilibrium, entropy of mixing and Gibb's paradox, Ensembles Concepts of phase space, microstates, macro states, equal priori probability, ensemble of particles, micro canonical ensemble, macro canonical ensemble, grand canonical ensemble, derivation of partition function, derivation of thermodynamic quantities from each ensembles, Free energy and its connection with thermodynamic quantities, Classical Statistical Mechanics, Link between entropy and probability, Boltzmann's equation, elementary ideas about three different statistics, classical statistics – Maxwell & Boltzmann statistics, classical Ideal gas equation, equipartition theorem. Bose-Einstein Statistics: Bose & Einstein statistics, black body radiation, Rayleigh Jeans" formula, Wien's law, Planck radiation law, Bose Einstein condensation, Einstein model of lattice vibrations, Phonons, Debye's theory of specific heats of solids, Fermi-Dirac Statistics, Basics for quantum statistics, system of identical indistinguishable particles, symmetry of wave functions, bosons, fermions, Fermi-Dirac statistics, Fermi free electron theory, Pauli paramagnetism. Phase transitions and Fluctuations: Type of phase transitions, first and second order phase transitions. Diamagnetism, paramagnetism and ferromagnetism, Ising model, mean-field theories of the Ising model, Thermodynamic Fluctuations, random walk and Brownian motion, introduction to non-equilibrium processes, diffusion equation.

PART-II (60 MARKS)

1. CONDENSED MATTER PHYSICS:-

Crystal Physics Classification of condensed matter-crystalline and non-crystalline solids, Bonding and internal structure of solids - Ionic, covalent and metallic solids, the van der Waals interaction, hydrogen bonding, crystal symmetry, point groups, space groups, lattices and basis, typical crystal structures, reciprocal lattice, Bragg's law of diffraction, X-ray, neutron, and electron diffraction, Brillouin zone, structure factor, Lattice Vibrations and Thermal Properties Monoatomic and diatomic lattices, normal modes of lattice vibration, phonons and density of states, dispersion curves, specific heat – classical, Einstein and Debye

models, Thermal expansion, thermal conductivity, normal and Umklapp processes, Free Electron Theory Dependence of electron energy on the wave vector, E-k diagram. Free electron theory of metals, Thermal and Electrical transport properties, Electronic specific heat, Fermi surface, Motion in a magnetic field: cyclotron resonance and Hall effect, Thermionic emission, Failures of free electron theory, Energy Band Theory, Energy spectra of atoms, molecules and solids- formation of energy bands. Bloch theorem, Kronig-Penny Model, construction of Brillouin zones, extended, reduced and periodic zone schemes, effective mass of an electron, nearly free electron model, tight binding approximation, orthogonalized plane wave method, pseudo-potential method; insulators, conductors and semiconductors,semiconductor materials, crystal structure, valence bonds, energy bands, density of states, intrinsic carrier concentration, donors and acceptors, effective mass, carrier drift, mobility effects, Hall effect in semiconductors, Dielectric properties: Local electric field at an atom, Clausius-Mossotti equation, dielectric constant and polarizability- classical theory of electronic polarizability, dipolar polarizability, piezo-, pyro- and ferroelectric crystals, ferroelectricity, ferroelectric domains, antiferroelectricity and ferrielectricity; Magnetism, Classification of magnetic materials, origin of permanent magnetic moments, Langevin's classical theory of diamagnetism, quantum theory of paramagnetism, ferromagnetism, Weiss molecular field, ferromagnetic domains, antiferromagnetism, ferrimagnetism and ferrites, magnons, neutron scattering; Superconductivity: Meissner effect, London equation, Type I and II superconductors, thermodynamics, superconducting band gap, Cooper pairs, flux quantization, BCS theory (qualitative), Josephson Effect, SQUIDS, high temperature superconductors. Physics of nanomaterials: Mesoscopic Physics, quantum wire, well and dot, quantum confinement and Coulomb blockade, imaging techniques for nanostructures - electron microscopy, scanning tunnelling microscopy and atomic force microscopy, Defects in Crystals Point defects - Frenkel and Schottky defects, colour centres, excitons, Dislocations - models of screw and edge dislocations, Burgers vector, Surface imperfections – grain boundaries, tilt boundaries, twin boundaries and stacking faults, Volume defects.

2. <u>NUCLEAR PHYSICS:-</u>

Nuclear Masses and Nucleon-Nucleon Interaction, Analysis of nuclear masses, nuclear mass formula, stability of nuclei, beta decay and double beta decay. Properties of nuclear states: quantum numbers, angular momentum, Parity, Isotopic spin (isobaric spin, isospin), deuteron problem, Nucleon-Nucleon Interaction Exchange forces and tensor forces, Meson theory of nuclear forces, Nucleon-Nucleon scattering, Spin dependences of nuclear forces, Effective range theory, Symmetry and nuclear force, Isospin invariance and operator, general form of the nuclear potential, Yukawa theory of nuclear interaction, Nuclear Structure, The Nuclear Shell, Shell Model, Magic Numbers, Spin-Orbit couplings, Valence Nucleons and Ground State Spin of Nuclei, collective structure of Odd-A nuclei, The Nuclear Collective Model: Nuclear Collective Vibrations, Nuclear Collective Rotation, Single-particle motion in a deformed potential, Nuclear Reaction, Types of nuclear reactions, wave function and scattered waves, differential cross-sections, coupled equations and scattered potential, Partial waves, total differential cross-sections and Optical theorem, Optical Potential-average interaction potential for nucleons, energy dependence of potential, Compound nucleus formation and direct reactions, Compound resonances, Breit-Wigner formula.

3. HIGH ENERGY PHYSICS:-

Introduction and Overview Historical development, Particle classification: Bosons, Fermions, Particles and Antiparticles, Quarks and Leptons; Basic ideas about the interactions and fields in Particle Physics, Types of interactions: Electromagnetic, Weak, Strong and Gravitational, Natural System of Units in High Energy Physics, Invariance Principles and Conservation Laws Conservation of electric charge, Baryon number, Lepton number, Continuous symmetry transformations: translation and rotation; Parity, Pion parity, Charge conjugation, Strangeness and Isospin, Two Nucleon System, Pion-Nucleon System, G-parity, Time reversal invariance, Associated production of particles and Gell-Mann Nishijima scheme, 0−0 doublet, CP violation in K- decay, CPT theorem, Electromagnetic Interactions, Form factors of nucleons. Parton model and Deep inelastic scattering structure functions, Cross Section and Decay Rates. QCD and Quark Model: Asymptotic freedom and Infrared slavery, confinement hypothesis, Classification of hadrons by flavor symmetry: SU(2) and SU(3) multiplets of Mesons and Baryons, The Baryon Octet and Decuplet, Pseudoscalar mesons and Vector mesons, Weak Interactions Classification of weak processes, Fermi theory of β- decay, Parity non conservation in - decay, two component theory of neutrino and determination of helicity, V-A interaction, Strangeness changing and non-changing decays, Cabibbo's theory. Gauge invariance and Unification schemes: Global and Local invariance of the Action, Noether's theorem, Spontaneous breaking of symmetry and Goldstone theorem. Abelian and Non-Abelian gauge fields.

4. NUMERICAL METHODS AND PROGRAMMING:-

Roots of Equations, Non-linear equation: Approximate values of roots, Bisection Method, Regula-Falsi Method, Newton-Raphson method, Solution of set of non-linear equations. Solution of Simultaneous Linear equation: Direct Method: Gauss elimination, Pivoting, Gauss-Jordon method, Matrix inversion. Iterative methods: Jacobi and Gauss Seidel iteration method. Precision and accuracy, Error analysis, propagation of errors, Linear and non-linear curve fitting–least squares fitting, chi-square test, Curve Fitting and Interpolation Method of least squares, straight line, parabola, Weighted least squares approximation, Method of least squares for continuous functions, Interpolation, Newton's formula for forward and backward interpolation, Divided difference, Symmetry of divided differences, Newton's general interpolation formula, Lagrange's interpolation formula, Cubic splines, Interpolation in multi dimension. Eigenvectors and Eigenvalues: homogeneous equations, characteristic equation. Secant method, Order of convergence in different Power method, Jacobi method, Applications, Integration: Newton – cotes formula – Trapezoidal rule, Simpson's rule, Simpson's 3/8 rule, Error estimates in trapezoidal and Simpson's rule, Gauss quadrature, Numerical evaluation of singular integrals, Numerical calculation of Fourier integrals. Differential Equations: Ordinary differential equation: Euler's method, Modified Euler's method, Runge-Kutta Method, system of coupled first order ordinary differential equations, shooting method, Partial differential equations, solution of Laplace equation, Poisson Equation, and heat equation, Programming With C++, Representation of constant, variables and functions, arithmetic expressions and their evaluation. Assignment statements, Logical constants variables and expression, input and output statements, control statements, Ternary Operator, goto statement, Switch Statement, Unconditional and Conditional Looping,while loop. do-while loop, for loop. Break and Continue Statements. Nested Loops, sequencing

alternation, arrays, Manipulating vectors and matrices. Programming with MATLAB: Basic features of MATLAB: Variables, comments, MATLAB workspace, simple math,complex numbers, mathematical function, operation on vectors and matrices, logical arrays, control structure: for loops, while loops, if-else end, switch-case statements, optimization tools in MATLAB.

5. ATOMIC AND MOLECULAR PHYSICS:-

Fine structure of hydrogenic atoms, mass correction, spin-orbit term and Darwin term, intensity of fine structure lines, Effect of magnetic and electric fields: Zeeman, Paschen-Bach and Stark effects, The ground state of two-electron atoms, perturbation theory and variational methods, Many-electron atoms, Central Field Approximation-LS and JJ coupling schemes, Lande interval rule, The Hartrec-Fock equations. The spectra of alkalis using quantum defect theory, Selection rules for electric and magnetic multipole radiation, Auger process, Molecular Structure, Born-Oppenheimer approximation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Spectroscopic terms, Centrifugal distortion, Electronic structure-Molecular symmetry and the states, Molecular orbital and valence bond methods for and H_2, Basic concepts of correlation diagrams for heteronuclear molecules, Molecular Spectra Rotational spectra of diatomic molecules-rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules, harmonic and anharmonic vibrators, Intensity of spectral lines, dissociation energy, vibration-rotation spectra, Electronic spectra of diatomic molecules- vibrational structure of electronic transitions, Rotational structure of electronic bands, Intensities in electronic bands-The Franck-Condon principle, The electron spin and Hund's cases, Raman Effect, Electron Spin Resonance, Nuclear Magnetic Resonance, Lasers: Life time of atomic and molecular states, Multilevel rate equations and saturation, Coherence and profile of spectral lines, Laser pumping and population inversion, He-Ne Laser, Solid State laser, Free-electron laser (qualitative only), liquid and gas lasers, semiconductor lasers.

***

{Master Degree (Mathematics) level}

PART-I (60 MARKS)

1. REAL ANALYSIS

Metric spaces: Definition, properties and examples, Convergence of sequences, Open and closed subsets, Continuity, Cauchy sequences; completeness, Baire category theorem, contraction mapping theorem, connectedness, compactness, Heine-Borel theorem,Weierstrass approximation theorem.

Riemann-Stieltjes Integral: Definition and Existence of Riemann-Stieltjes Integral, Properties of the Integral, Integration and Differentiation, Fundamental theorem of calculus, first and second mean value theorems.

2. ABSTRACT ALGEBRA

Groups: Review of groups, subgroups and group homomorphism; group actions, class equation, Sylow's theorems, simplicity of alternating groups, direct product of groups, fundamental theorem of finite abelian groups.

Rings: Review of basic ring theory, ideals and their properties, Chinese Remainder Theorem, prime and maximal ideals, rings of fractions, factorization in integral domains, principal ideal domains, Euclidean domains, unique factorization domains, polynomial rings over unique factorization domains.

Fields: Irreducible polynomials and Eisenstein criterion, Adjunction of roots, Algebraic extensions, algebraically closed fields, Splitting fields, Normal extensions, Multiple roots.

3. ORDINARY DIFFERENTIAL EQUATIONS

Existence, uniqueness and continuation of solutions of first order differential equations and system of differential equations, differential and integral inequalities, fixed point methods.

Linear systems, properties of homogeneous and non-homogeneous systems, behaviour of solutions of nth order linear homogeneous equations.

Power series solution of second order homogeneous equations, ordinary points, regular singular points, Legendre's and Bessel's equations,

Boundary value problems for second order differential equations, Green's function and its applications, eigenvalue problems, self-adjoint form, Sturm-Liouville problem and its applications.

4.OPERATIONS RESEARCH

Basics of LPP: Different Types of OR Models, Convex Sets, Graphical Method, Simplex Method, Big –M Method, Two Phase Method, Revised Simplex Method.

Duality Theory: Duality theory, Dual Simplex Method, Sensitivity Analysis, Parametric Linear Programming.

Transportation Problems: Balanced and unbalanced transportation problems-formulation, Dual problem, North West Corner Method, Least Cost Method and Vogel's Approximation Method, *u-v* method.
Assignment Problems: Formulation, Hungarian method.
Game Theory: Minimax (Maximin) criterion, Saddle point, Notion of dominance, Graphical and Linear Programming Methods for Rectangular Games.
Queuing Theory: Steady-state solutions of Markovian Queuing Models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1.

5. FLUID DYNAMICS

Basic Concepts: A broad perspective of fluid dynamics, Definition of fluid, Distinction between solid and fluid, Concept of continuum, pressure and stress in a fluid, Fluid properties.
Description of Fluid Motion: Lagrangian and Eulerian approaches, Continuity of mass flow, Circulation, Rotational and irrotational flows, Boundary surface, Streamlines, Path lines, Streak lines, Vorticity.
Equations of Motion and Mechanical Energy: Inviscid case, Bernoulli's theorem, Compressible and incompressible flows, Kelvin's theorem, Constancy of circulation, Concepts of static pressure, Flow through orifices and mouthpieces.
Equations of Motion and Mechanical Energy: Inviscid case, Bernoulli's theorem, Compressible and incompressible flows, Kelvin's theorem, Constancy of circulation, Concepts of static pressure, Flow through orifices and mouthpieces.
Incompressible Viscous Flow: Reynolds transport theorem, Derivation of NavierStokes equations, Derivation of energy equation, Dissipation of energy, Diffusion of vorticity, Couette flow, Poiseuille flow, Hagen-Poiseuille flow, Annular flow.
Laminar Boundary Layers: Dynamical similarity, Dimensional analysis, Large Reynold's numbers, Laminar boundary layer equations, Similar solutions.

6. MEASURE THEORY

Measure on the real line: Introduction, Lebesgue outer measure, Measurable sets, Borel sets, Regular Measure, Measurable functions, Borel and Lebesgue Measurable Functions.
Integration of Functions of a real variable: Integration of non-negative functions, Lebesgue Integral, Fatou's Lemma, Lebesgue Monotone Convergence theorem, The General Integral, Lebesgue dominated convergence theorem, Integraion of Series, Riemann and Lebesgue Integrals.
Differentiation: The four derivatives, functions of bounded variation, Lebesgue differentiation theorem, absolutely continuous functions, integrating derivatives.

7. PARTIAL DIFFERENTIALS EQUATIONS

Introduction: Surfaces and curves, simultaneous differential equations of the first order and first degree, integral curves of vector fields, methods of solution of $dx/P = dy/Q = dz/R$, orthogonal trajectories of a system of curves on a surface, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables.

First order PDE: Classification, initial value problem for quasi-linear first order equations: existence and uniqueness of solution, nonexistence and non-uniqueness of solutions, orthogonal surfaces, nonlinear PDEs of first order, Cauchy's method of characteristics, compatible systems of first order equations, Charpit's method, derivation of one complete integral from another, Jacobi's method.

Second order PDE: Equations with variable coefficients, classification and canonical forms of second order equations, characteristic curves of second order equations in two variables, importance of characteristic curves.

Laplace and Poisson equations: Laplace equation in Cartesian, polar, spherical and cylindrical coordinates and its solution by Fourier series method, Poisson equation in 2D, Green's function, eigenfunction method for finding Green's function, method of images.

Wave equation: One and two dimensional wave equations, solution by method of characteristics, existence and uniqueness results.

Diffusion equation: Solution of homogeneous and non-homogeneous diffusion equation (1D), existence and uniqueness results.

PART-II (60 MARKS)

1. LINEAR ALEGEBRA AND MATRIX ANALYSIS

Inner Product Spaces: Review on basic concept of inner product, orthogonal projections, positive definite, adjoint, self-adjoint, unitary and normal operators, spectral theorem for self-adjoint and normal operators on finite-dimensional vector spaces, factorization of matrices, Schur decompositions, spectral decomposition,Singular value decomposition.

Matrix norms:Frobenius norm, spectral norm, maximum column/row sum matrix norm, unitarily invariant norms, weakly unitarily invariant norms, matrix/operator monotone, convexity and their characterizations.

2. PROBABILITY AND STATISTICS

Random variables: Distribution functions, probability mass function and probability density function, moments and moment generating functions.

Special distributions: Binomial, Poisson, Geometric, Uniform, Exponential, Normal.

Bivariate random variables: Joint, marginal and conditional distributions, statistical independence, product moments, correlation, regression, functions of random variables and their probability distributions.

Convergence of random variables: Modes of convergence, Chebyshev's inequality, law of large numbers, central limit theorem

Sampling: Sampling distribution of samples from normal population: normal, t, χ^2, F distributions.

Theory of estimation: Basic concepts of estimation, point estimation, method of maximum likelihood, unbiasedness, consistency, interval estimation.

Testing of hypothesis: Null and alternative hypothesis, type I and II errors, power function, Neyman Pearson lemma, uniformly most powerful tests, tests for one sample for normal populations, tests for proportions.

3. COMPLEX ANALYSIS

Introduction: Algebra of Complex Numbers, inequalities. Stereographic Projection, Topological structure of Complex Plane, Simply connected and multiply connected domains.
Analytic Functions: Functions of a complex variable. Limits, continuity, uniform continuity, differentiability and analyticity of functions, C-R equations, necessary and sufficient conditions, applications to the problems of potential flow, Harmonic functions, Harmonic conjugates, Milne's method. Sequences, Series, Uniform convergence, power series, Hadamard's formula for the radius of convergence, elementary functions, exponential, trigonometric and hyperbolic functions and their identities in the complex plane, multiple valued functions, logarithmic functions and functions with complex exponent.
Complex integration: Rectifiable arcs, contours, complex line integration, Cauchy's theorem for simply and multiply connected domains, Cauchy's integral formula for the derivatives of an analytic function, Winding Numbers, Cauchy's estimate, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra. Maximum modulus principle, Schwarz Lemma, Taylor series, Laurent series, Zeros and poles of a function, Meromorphic function.
Residue Calculus: The residue at a singularity, Residue theorem, the argument principle, Rouche's theorem, contour integration and its applications to improper integrals, evaluation of a real integrals, improper integrals involving sines and cosines, definite integrals involving sines and cosines, integration through branch cut. Poisson Integral Formula. Dirichlet problem for the Unit disc and half plane.

4. CLASSICAL MECHANICS

Lagrangian formalism: Constrains in motion, generalised co-ordinates, virtual work and D'Alembert's principle, Lagrangian equation of motion, Symmetry and cyclic co-ordinates, Hamilton variational principle,Lagrangian equation of motion from variationalpriniciple, Simple applications.
Hamiltonian formalism: Hamilton's equations of motion- from Legendre transformations and the variational Principle, Simple applications, Canonical transformations,Ignorable coordinates, The Routhian function, The form of Hamiltonian function, Modified Hamilton's principle. Principle of least action (different form of Least action principle), Poisson brackets-Canonical equations of motion in Poisson bracket notation, Hamilton-Jocobi equations.

5. TOPOLOGY

Elementary Set Theory: Finite, countable and uncountable sets, functions, relations, axiom of choice, Zorn's lemma, Partial ordered sets and lattices. Metric Spaces.
Topological spaces and continuous functions: Open sets, closed sets, basis for a topology, sub basis, Hausdorff spaces, order topology, product topology, subspace topology, limit

points, continuous functions, general product topology, metric spaces and their topology, quotient topology, gluing, and identification spaces.

Connectedness and compactness: Connected spaces, connected subspaces, path connected spaces, locally connected spaces, connected components, compact spaces, limit point compactness, local compactness, one-point compactification.

Countability and separation axiom: Countability axioms, separation axioms, regular and normal spaces, Urysohn's lemma, Urysohnmetrization theorem, Tietze extension theorem, Tychonoff theorem.

6. FUNCTIONAL ANALYSIS

Normed linear spaces: Definition, examples, convergence and absolute convergence of series in a normed linear space,

BanachSpaces: The definition and some examples, continuous linear transformations. The Hahn-Banach Theorem, the Open Mapping Theorem, the Closed Graph Theorem, the Uniform Boundedness Theorem, the natural embedding of N in N**, reflexivity.

Hilbert Spaces: The definition and some simple properties, orthogonal complements, orthonormal sets, the conjugate space H*, the adjoint of an operator, self-adjoint normal and unitary operators, projections.

Spectral Theory of Linear Operators in Normed spaces: Spectral Theory in Finite Dimensional Normed Spaces. Basic Concepts. Spectral Properties of Bounded Linear Operators. Further Properties of Resolvent and Spectrum. Use of Complex Analysis in Spectral Theory. Banach Algebras. Further Properties of Banach Algebras.

7. INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS

Definition and classification of linear integral equations, conversion of initial and boundary value problems into integral equations, conversion of integral equations into differential equations, integro-differential equations.

Fredholm integral equations of the second kind, solution of integral equations with separable kernels, eigenvalues and eigenfunctions, solution by successive approximations, Neumann series and resolvent kernel, Adomian decomposition method, Fredholm alternative, solution of integral equations with symmetric kernels, Green's function approach, Hilbert-Schmidt theorem, Fredholm integral equations of the first kind, method of regularization and homotopy perturbation method.

Volterra integral equations, successive approximations, Neumann series and resolvent kernel, equations of convolution type kernels, solution of integral equations by transform methods, singular integral equations, Abel's integral equations, Hilbert-transform, Cauchy type integral equations.

Basic concepts of the calculus of variations, functionals, extremum, variations, function spaces, the brachistochrone problem, necessary condition for an extremum, Euler-Lagrange equation with the cases of one variable and several variables, conditional extremum, variational derivative, invariance of EulerLagrange equations, variational problem in parametric form, applications to eigen value problems.

General variation, functionals dependent on one or two functions, derivation of basic formula, arviational problems with moving boundaries, broken extremals, Weierstrass-Erdmann conditions, second variation, weak and strong extremum.

8. DISCRETE MATHEMATICS

Logic and Proofs: Propositional logic, propositional equivalences, predicates and quantifiers, introduction to proofs, proof methods and strategy.

Counting: The basic counting, the pigeonhole principle, permutations and combinations, binomial coefficients, generalized permutations and combinations.

Advanced Counting Techniques: Recurrence relations, solving linear recurrence relations, generating functions, inclusion-exclusion, applications of inclusion-exclusion, divide-and-conquer algorithms and recurrence relations. Growth of functions: big O, big Θ and big Ω notations.

Boolean Algebra: Boolean functions, Boolean expressions and Boolean functions, Boolean algebra, representing Boolean functions, logic gates, minimization of circuits, Karnaugh maps.

Graphs: Graphs and graph models, basic terminology and special types of graphs, graph isomorphism, connectivity, Euler and Hamiltonian paths and cycles, shortest-path problems, graph coloring, introduction to trees, application of trees, spanning trees, minimum spanning trees.

***

Master Degree in Forensic Science
(specialization in Forensic Physics & Ballistics) level

PART-I (60 MARKS)

FORENSIC PHYSICS

1. **Foot/Footwear/Tyre Impression/Skid marks/Gait Pattern:** Collection, Tracing, Lifting, Casting of impressions, Enhancement of Footwear Impression, Analysis & comparison of foot impressions, Moulds, Identification characteristics, Importance of skid marks in vehicular accident investigation, Gait pattern analysis methods.**2. Tool Marks**: Compression marks, Striated marks, Combination of compression and striated marks, Repetitive marks, Comparison of tool marks. Features: Class characteristics, Sub class characteristics, Individual characteristics, development of tool marks. **3. Paint, Lacquer & Varnishes**: Nature, composition, Forensic examination: microscopic examination, Micro chemical tests, Differential solubility and TLC, Infra-red spectroscopy, FT-IR Micro spectrophotometry, Pyrolysis Gas Chromatography- Mass Spectrometer, Elemental analysis of paint flakes using Emission Spectrography and EDXRF spectrophotometry.

2. **Fiber:** Nature, Types, Structure, Fiber as Physical Evidence, fibre recovery, FiberIdentification: Physical matching, Microscopic Examination, solubility test, Chromatographic and Spectroscopic analysis (UV-Vis & FTIR) of Fibre. **2. Paper**: Physical examination, Watermark Examination, Chemical Analysis, Analysis by FTIR.

3. **Dust and Soil:** Nature, Types, Sample preparation, Removal of contamination, Microscopic Examination, Particle Size Distribution, Ignition Test, Density distribution, pH Measurement, UV, DTA and TGA Analysis of soil. **2. Cement, Mortar and Concrete**: General Composition, Bromoform Test, Fineness Test, Loss on Ignition Test, Physical method: Determination of compressive Strength, Setting Times, Initial and final Setting Time, Standard Consistency, Preparation of Cube **3. X-Ray Diffractometry**: Identification of adulterated cement and adulterants, **4. Mortar and Concrete**: Analysis of mortar and concrete, Forensic relevance.

4. **Glass:** Composition and Types of Glass-Soda lime glass, Borosilicate glass, Safety glass, Laminated, Light sensitive glass, Tampered/toughened glass, Wire glass, Coloured glass. **2. Physical characteristics of glass:** Fluorescence under UV radiation, Density and Specific gravity, Density measurements for bigger fragments of glass, Density comparison by flotation and density gradient tubes technique. **3. Refractive Index Measurement (RI):** Glass refractive index measurement (GRIM), Immersion method, Becke line concept, Examination of RI using hot stage microscope, Elemental analysis, Glass fracture analysis and its Forensic significance.

PART-II (60 MARKS)

BALLISTICS

1. **Firearms**: Forensic importance, History, Matchlock, wheel lock and flintlock firearms, Muzzle loaders, classification and characteristics of Modern firearms, components of firearms, Definition of bore and calibre, choke, significance and types, Indian Arms Act,1959 key sections related to Firearm and Ammunition (sections 2-7). Purpose of rifling, types of rifling and methods of producing rifling, trigger and firing mechanism, Theory of recoil, Classification of Country made firearms, improvised/ imitation firearms and their constructional features, Ammunition and their components, classification and constructional features of different types of cartridges, head stamp markings, various types of bullets and compositional aspects, latest trends in their manufacturing and design, Types of primers and priming composition, propellant Types and their compositions. Velocity and Pressure characteristics under different conditions. The Explosive Act, 1984 relevant sections 2,5,6.

2. **Internal Ballistics:** Definition, ignition of propellants, shape and size of propellants, Piobert's law, manner of burning, various factors affecting the internal ballistics: lock time, ignition time, barrel time, erosion, corrosion and gas cutting, Le Duc formula, **External Ballistics**: Vacuum trajectory, effect of air resistance on trajectory, base drag, drop, drift, yaw, shape of projectile and stability, trajectory computation, ballistics coefficient and limiting velocity, Measurements of trajectory parameters, introduction to automated system of trajectory computation and automated management of ballistic data, **Terminal Ballistics**: Effect of projectile on hitting the target: function of bullet shape, striking velocity, striking angle and nature of target, Tumbling of bullets, effect of instability of bullet, effect of intermediate targets, influence of range, Ricochet and its effects, stopping power.

3. **Principles of identification of firearms**, different types of marks produced during firing process on cartridge cases -firing pin marks, breech face marks, chamber marks, extractor and ejector marks, Different types of marks produced during firing process on bullet, number of lands and grooves, direction of twist, depth of grooves and width of land/grooves, class and individual characteristics, Techniques for obtaining test material from various types of weapons, basic methodology used in comparison microscopy, linkage of fired bullets/cartridge cases with firearms, Automated examination and comparison of fired bullets/cartridge cases and ballistics imaging database of the markings of fired bullets/cartridge cases, Determination of range of fire/ bullet hole identification: Burning, scorching, blackening, tattooing and metal fouling, shots dispersion and GSR distribution, bullet hole identification, bullet penetration and trajectory through glass. Issues and challenges in linkage of fired cartridges and bullets in case of country-made firearms.

4. **Analysis of Gunshot Residues**: Mechanism of formation of GSR, source and collection, spot test, chemical test, identification of shooter using instrumental methods of GSR Analysis, Management and reconstruction of crime scene in shooting incidents, Medico-legal Evidence in cases of suicide, murder, accidental shooting and self-defence cases, Firearm injuries: Characteristics, postmortem and anti-mortem firearm injuries, Threshold velocity for

penetration of skin/flesh/bones, cavitations – temporary and permanent cavities, nature of wounds of entry, exit, bullet track with various ranges and velocities with various types of projectiles, explosive wounds, Evaluation of injuries caused due to shot-gun, rifle, handguns and country made firearms, methods of measurements of wound ballistics parameters, preparation of gel block penetration of projectiles in gel block and other simulated targets.

Sd/
Under Secretary
H. P. Public Service Commission