Syllabus for PhD entrance examination

Physics

Condensed Matter Physics and Electronics:

Crystal structure, Bravais lattices and basis. Miller indices. X-ray diffraction and Bragg's law; Intrinsic and extrinsic semiconductors, variation of resistivity with temperature. Fermi level. p-n junction diode, I-V characteristics, Zener diode and its applications, BJT: characteristics in CB, CE, CC modes. OPAMP and applications: Inverting and non-inverting amplifier. Boolean algebra: Binary number systems; conversion from one system to another system; binary addition and subtraction. Logic Gates AND, OR, NOT, NAND, NOR exclusive OR.

Moderns Physics (Relativity, Quantum Mechanics, EM theory):

Inertial frames and Galilean invariance. Postulates of special relativity. Lorentz transformations. Length contraction, time dilation. Relativistic velocity addition theorem, mass energy equivalence.

Blackbody radiation, photoelectric effect, Compton effect, Bohr‘s atomic model, X-rays. Wave-particle duality, Uncertainty principle, the superposition principle, calculation of expectation values, Schrödinger equation and its solution for one, two and three dimensional boxes. Solution of Schrödinger equation for the one dimensional harmonic oscillator.

Gauss’s law and its applications, Laplace and Poisson equations, Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations, boundary conditions on the fields at interfaces. Dynamics of charged particles in static and uniform electromagnetic fields, Lorentz invariance of Maxwell’s equation.

Experimental Method:

Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting,

Mathematical Methods:

Taylor expansion, Fourier series. Vector algebra, Vector Calculus, Multiple integrals, Divergence theorem, Green‘s theorem, Stokes ‘theorem. First order equations and linear second order differential equations with constant coefficients. Matrices and determinants, Algebra of complex numbers

Oscillations, Waves and Optics:

Differential equation for simple harmonic oscillator and its general solution. Superposition of two or more simple harmonic oscillators. Damped and forced oscillators, resonance.

Wave equation, traveling and standing waves in one-dimension. Energy density and energy transmission in waves. Group velocity and phase velocity.

Interference of light, optical path retardation. Fraunhofer diffraction. Rayleigh criterion and resolving power. Diffraction gratings. Polarization: linear, circular and elliptic polarization. Double refraction and optical rotation.

Mathematics

Calculus: Functions of two or more variables, continuity, directional derivatives, partial derivatives, total derivative, maxima and minima, saddle point, method of Lagrange's multipliers; Double and Triple integrals and their applications to area, volume and surface area; Vector Calculus: gradient, divergence and curl, Line integrals and Surface integrals, Green's theorem, Stokes' theorem, and Gauss divergence theorem.

Linear Algebra: Finite dimensional vector spaces over real or complex fields; Linear transformations and their matrix representations, rank and nullity; systems of linear equations, characteristic polynomial, eigenvalues and eigenvectors, diagonalization, minimal polynomial, Cayley-Hamilton Theorem, Finite dimensional inner product spaces, Gram- Schmidt orthonormalization process, symmetric, skew-symmetric, Hermitian, skew- Hermitian, normal, orthogonal and unitary matrices; diagonalization by a unitary matrix, Jordan canonical form; bilinear and quadratic forms.

Complex Analysis: Functions of a complex variable: continuity, differentiability, analytic functions, harmonic functions; Complex integration: Cauchy's integral theorem and formula; Liouville's theorem, maximum modulus principle, Morera's theorem; zeros and singularities; Power series, radius of convergence, Taylor's series and Laurent's series; Residue theorem and applications for evaluating real integrals; Rouche's theorem, Argument principle, Schwarz lemma; Conformal mappings, Mobius transformations.

Ordinary Differential Equations: First order ordinary differential equations, existence and uniqueness theorems for initial value problems, linear ordinary differential equations of higher order with constant coefficients; Second order linear ordinary differential equations with variable coefficients; Cauchy-Euler equation, method of Laplace transforms for solving ordinary differential equations, series solutions (power series, Frobenius method); Legendre and Bessel functions and their orthogonal properties; Systems of linear first order ordinary differential equations, Sturm's oscillation and separation theorems, Sturm-Liouville eigenvalue problems, Planar autonomous systems of ordinary differential equations: Stability of stationary points for linear systems with constant coefficients, Linearized stability, Lyapunov functions.

Algebra: Groups, subgroups, normal subgroups, quotient groups, homomorphisms, automorphisms; cyclic groups, permutation groups, Group action, Sylow's theorems and their applications; Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domains, Principle ideal domains, Euclidean domains, polynomial rings, Eisenstein's irreducibility criterion; Fields, finite fields, field extensions, algebraic extensions, algebraically closed fields

Numerical Analysis: Systems of linear equations: Direct methods (Gaussian elimination, LU decomposition, Cholesky factorization), Iterative methods (Gauss-Seidel and Jacobi) and their convergence for diagonally dominant coefficient matrices; Numerical solutions of nonlinear equations: bisection method, secant method, Newton-Raphson method, fixed point iteration; Interpolation: Lagrange and Newton forms of interpolating polynomial, Error in polynomial interpolation of a function; Numerical differentiation and error, Numerical integration: Trapezoidal and Simpson rules, Newton-Cotes integration formulas, composite rules, mathematical errors involved in numerical integration formulae; Numerical solution of initial value problems for ordinary differential equations: Methods of Euler, Runge-Kutta method of order 2.

Partial Differential Equations: Method of characteristics for first order linear and quasilinear partial differential equations; Second order partial differential equations in two independent variables: classification and canonical forms, method of separation of variables for Laplace equation in Cartesian and polar coordinates, heat and wave equations in one space variable; Wave equation: Cauchy problem and d'Alembert formula, domains of dependence and influence, non-homogeneous wave equation; Heat equation: Cauchy problem; Laplace and Fourier transform methods.

Discrete Mathematics: Propositional and first-order logic. Sets, relations, functions, partial orders and lattices. Monoids, Groups. Graphs: connectivity, matching, colouring. Combinatorics: counting, recurrence relations, generating functions.

Probability and Statistics: Random variables, Uniform, normal, exponential, Poisson and binomial distributions. Mean, median, mode,
and standard deviation. Conditional probability and Bayes theorem.

Digital Logic: Boolean algebra. Combinational and sequential circuits. Minimization. Number representations and computer arithmetic (fixed and floating point)

Computer Organization and Architecture: Machine instructions and addressing modes. ALU, data-path and control unit. Instruction pipelining, pipeline hazards. Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode).

Programming and Data Structures: Programming in C. Recursion. Arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs.

Algorithms: Searching, sorting, hashing. Asymptotic worst-case time and space complexity. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph traversals, minimum spanning trees, and shortest paths.

Chemistry

Inorganic Chemistry

1. Chemical periodicity
2. Structure and bonding in homo- and heteronuclear molecules, including shapes of molecules (VSEPR Theory).
3. Concepts of acids and bases, Hard-Soft acid base concept, Non-aqueous solvents.
4. Main group elements and their compounds: synthesis, structure and bonding, industrial importance of the compounds.
5. Transition elements and coordination compounds: structure, bonding theories, spectral and magnetic properties, reaction mechanisms.
6. Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis.
7. Analytical chemistry - separation, spectroscopic, electro- and thermoanalytical methods.
8. Environmental chemistry

Physical Chemistry:

1. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated π-electron systems.
2. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities – selection rules; basic principles of magnetic resonance.
3. Chemical thermodynamics: Laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria; temperature and pressure dependence of thermodynamic quantities; Le-Chatelier principle; thermodynamics of ideal and non-ideal gases, and solutions.
4. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Battery – Principles and applications; Debye - Huckel theory; electrolytic conductance – Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations.
5. Chemical kinetics: Empirical rate laws and temperature dependence; determination of reaction mechanisms; collision and transition state theories of rate constants; unimolecular reactions; homogeneous catalysis; physisorption and chemisorption. Langmuir, Freundlich and Brunauer–Emmett–Teller (BET) isotherms.
6. Solid state: Crystal structures; Bragg's law and applications; band structure of solids.
7. Polymer chemistry: Polymerization mechanism; Molar masses; kinetics of polymerization. Properties of polymers. Applications of commercially important industrial polymers

Organic Chemistry

1. IUPAC nomenclature of organic molecules.
2. Principles of stereochemistry: Configurational and conformational isomerism; stereoselectivity, enantioselectivity, diastereo-selectivity.
3. Aromaticity: Benzenoid and non-benzenoid compounds – generation and reactions.
4. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes.
5. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species.
6. Common named reactions and rearrangements – applications in organic synthesis.
7. Organic transformations and reagents: Functional group interconversion including oxidations and reductions; common catalysts and reagents (organic, inorganic and organometallic).
8. Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S).
9. Structure determination of organic compounds by IR, UV-Vis, ^{1}H & ^{13}C NMR and Mass spectroscopic techniques.

English

Unit	Title	Major Areas
Unit I	**Drama**	Medieval, Renaissance, Elizabethan, Jacobean, Restoration, Eighteenth Century, Romantic, Victorian, Modern and Contemporary Drama; Tragedy, Comedy, Theatre of the Absurd, Epic Theatre; Major dramatists from British, American, Indian and Postcolonial literatures.
Unit II	**Poetry**	Old English, Middle English, Renaissance, Metaphysical, Cavalier, Neoclassical, Romantic, Victorian, Modern and Contemporary Poetry; Poetic forms, prosody, figures of speech, major poets from British, American, Indian and World literatures in English.
Unit III	**Fiction and Short Story**	Evolution of the Novel; Eighteenth Century, Victorian, Modernist, Postmodern and Contemporary Fiction; Short Story traditions; Narrative techniques; Major novelists and short story writers from literatures in English.
Unit IV	**Non-Fictional Prose**	Essays, Biography, Autobiography, Memoir, Letters, Speeches, Travel Writing, Literary Journalism and Nature Writing; Major prose writers from British, American, Indian and World literatures in English.
Note (Units I–IV)	**Critical Reading & Comprehension**	Literary comprehension passages from the 14th to the 21st century to assess critical reading, interpretation, analytical thinking, vocabulary, literary appreciation and academic writing skills.
Unit V	**Language: Basic Concepts, Theories and Pedagogy. English in Use**	Nature of language, Linguistics (Phonetics, Phonology, Morphology, Syntax, Semantics, Pragmatics), Sociolinguistics, Psycholinguistics, Applied Linguistics, Language Teaching Methods, English Grammar, Vocabulary, Academic Writing, Communication Skills and English Language Teaching (ELT).
Unit VI	**English in India: History, Evolution and Futures**	History of English in India, Macaulay's Minute, English Education, Indian English, World English, English in Higher Education, English for Academic and Specific Purposes (EAP/ESP), Digital English, AI and English Language Learning, Future of English in India.
Unit VII	**Cultural Studies**	Culture and Society, Popular Culture, Media Studies, Film Studies, Gender Studies, Feminism, Queer Theory, Identity, Race, Class, Ethnicity, Diaspora, Globalization, Ecocriticism, Ecofeminism, Performance Studies, Disability Studies and Digital Culture.
Unit VIII	**Literary Criticism**	Classical, Renaissance, Neoclassical, Romantic, Victorian and Modern Literary Criticism; Indian Poetics (Rasa, Dhvani, Vakrokti, Auchitya); Major Western and Indian critics.
Unit IX	**Literary Theory (Post World War II)**	Structuralism, Poststructuralism, Deconstruction, Reader-Response Theory, Marxism, Feminism, Psychoanalysis, New Historicism, Cultural Materialism, Postcolonialism, Subaltern Studies, Queer Theory, Ecocriticism, Trauma Studies, Memory Studies, Digital Humanities and Contemporary Critical Theory.
Unit X	**Research Methods and Materials in English**	Research Methodology, Research Design, Literature Review, Qualitative and Quantitative Research, Mixed Methods, Data Collection, Academic Writing, Research Proposal, Citation Styles (MLA, APA, Chicago), Research Ethics, Plagiarism, Digital Resources (JSTOR, Project MUSE, Shodhganga, INFLIBNET, Google Scholar, Scopus, Web of Science).