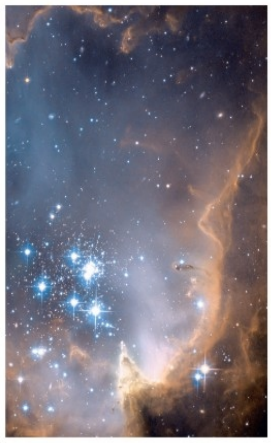

UPKAR'S

CSIR-UGC NET/JRF/SET

Physical Sciences

ANSHUL GUPTA
&
Dr. SUREKHA TOMAR

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By
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Dr. Surekha Tomar

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Preface of the Revised Edition

This revised version of the book consists of material covering the latest syllabus prescribed by CSIR–UGC/GATE as well as other competitive examinations of national level. This book is remarkable for its comprehensive coverage.

One aspect in each area of the problems spans a wide spectrum of topics. The problems themselves are remarkable for their versatility in applying the physical laws and principles, their up-to-date realistic situations and their scanty demand on mathematical skills.

The solutions presented generally just provide a guidance to solving the problems, rather than step by step manipulation, and leave much to the students to work out for themselves, of which much is demanded of the basic knowledge in physics. Thus, the book would provide an invaluable complement to the text books. International units are used whenever possible, but in order to conform to some of the problems, Gaussian units are also used. This in fact would give the student broader training and wider experience. Great pains have been taken to trace the logical steps from the first principles to the final solutions. These efforts hopefully will enhance the value of the book to students and teachers alike.

—Dr. Surekha Tomar

Contents

GENERAL INFORMATION

EXAM SCHEME

Time : 3 Hours **Max. Marks : 200**

Single Paper Test having Multiple Choice Questions (MCQs) is divided in three parts.

Part 'A'

This part shall carry 20 questions pertaining to General aptitude with emphasis on logical reasoning graphical analysis, analytical and numerical ability, quantitative comparisons, series formation, puzzles etc. The candidates shall be required to answer any 15 questions. Each question shall be of two marks. The total marks allocated to this section shall be 30 out of 200.

Part 'B'

This part shall contain 25 Multiple Choice Questions (MCQs) generally covering the topics given in the Part 'B' of syllabus. Candidates are required to answer any 20 questions. Each question shall be of 3·5 marks. The total marks allocated to this section shall be 70 out of 200.

Part 'C'

This part shall contain 30 questions from Part 'C' & 'B' of the syllabus that are designed to test a candidate's knowledge of scientific concepts and/or application of the scientific concepts. The questions shall be of analytical nature where a candidate is expected to apply the scientific knowledge to arrive at the solution to the given scientific problem. A candidate shall be required to answer any 20 questions. Each question shall be of 5 marks. The total marks allocated to this section shall be 100 out of 200.

- There will be negative marking @25% for each wrong answer.
- To enable the candidates to go through the questions, the question paper booklet shall be distributed 15 minute before the scheduled time of the Exam. The answer sheet (OMR sheet) shall be distributed at the scheduled time of the Exam.

SYLLABUS

Part 'A'

This part shall carry 20 questions pertaining to General aptitude with emphasis on logical reasoning graphical analysis, analytical and numerical ability, quantitative comparisons, series formation, puzzles etc. The candidates shall be required to answer any 15 questions. Each question shall be of two marks. The total marks allocated to this section shall be 30 out of 200.

Part 'B'

I. Mathematical Methods of Physics

Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.

II. Classical Mechanics

Newton's laws. Dynamical systems, Phase space dynamics, stability analysis. Central force motions. Two body Collisions—scattering in laboratory and Centre of mass frames. Rigid body dynamics—moment of inertia tensor. Non-inertial frames and pseudoforces. Variational principle. Generalized co-ordinates. Lagrangian and Hamiltonian formalism and equations of motion.

Conservation laws and cyclic co-ordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity—Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. Electromagnetic Theory

Electrostatics : Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, Fresnel's law, interference, coherence and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields.

IV. Quantum Mechanics

Wave-particle duality. Schrödinger equation (time-dependent and time-independent). Eigenvalue problems (particle in a box, harmonic oscillator, etc.). Tunneling through a barrier. Wave-function in co-ordinate and momentum representations. Commutators and Heisenberg uncertainty principle. Dirac notation for state vectors. Motion in a central potential: orbital angular momentum, angular momentum algebra, spin, addition of angular momenta; Hydrogen atom. Stern-Gerlach experiment. Time-independent perturbation theory and applications. Variational method. Time dependent perturbation theory and Fermi's golden rule, selection rules. Identical particles, Pauli exclusion principle, spin-statistics connection.

V. Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro and macro-states. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.

VI. Electronics and Experimental Methods

Semi-conductor devices (diodes, junctions, transistors, field effect devices, homo and hetero-junction devices), device structure, device characteristics, frequency dependence and applications. Opto-electronic devices (solar cells, photo-detectors, LEDs). Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similar circuits). A/D and D/A converters. Microprocessor and microcontroller basics. Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting.

Part 'C'

I. Mathematical Methods of Physics

Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first order differential equation using Runge-Kutta method. Finite difference methods. Tensors. Introductory group theory : SU(2), O(3).

II. Classical Mechanics

Dynamical systems, Phase space dynamics, stability analysis. Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem. Hamilton-Jacobi theory.

III. Electromagnetic Theory

Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation from moving charges and dipoles and retarded potentials.

IV. Quantum Mechanics

Spin-orbit coupling, fine structure. WKB approximation. Elementary theory of scattering : phase shifts, partial waves, Born approximation. Relativistic quantum mechanics : Klein-Gordon and Dirac equations. Semi-classical theory of radiation.

V. Thermodynamic and Statistical Physics

First and second-order phase transitions. Diamagnetism, paramagnetism and ferromagnetism. Ising model. Bose-Einstein condensation.

Diffusion equation. Random walk and Brownian motion. Introduction to non-equilibrium processes.

VI. Electronics and Experimental Methods

Linear and non-linear curve fitting, chi-square test. Transducers (temperature, pressure/ vacuum, magnetic fields, vibration, optical and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques.

High frequency devices (including generators and detectors).

VII. Atomic & Molecular Physics

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers : spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.

VIII. Condensed Matter Physics

Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermo-electric power. Electron motion in a periodic potential, band theory of solids : metals, insulators and semi-conductors. Superconductivity : type-I and type-II super-conductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter : translational and orientational order, kinds of liquid crystalline order. Quasi crystals.

IX. Nuclear and Particle Physics

Basic nuclear properties : size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.

Physical Sciences

CSIR-UGC NET/JRF Exam.

Solved Paper

June 2013
Physical Sciences

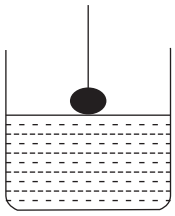
PART A

1. There is an equilateral triangle in the XY plane with its centre at the origin. The distance of its sides from the origin is 3·5 cm. The area of its circumcircle in cm^2 is—

   (A) 38·5 (B) 49

   (C0 63·65 (D) 154

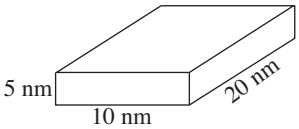
2. A sphere of iron of radius R/2 fixed to one end of a string was lowered into water in a cylindrical container of base radius R to keep exactly half the sphere dipped. The rise in the level of water in the container will be—



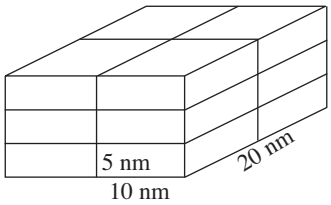
   (A) R/3 (B) R/4

   (C) R/8 (D) R/12

3. A crystal grows by stacking of unit cells of 10 × 20 × 5 nm size as shown in the diagram given below. How many unit cells will make a crystal of 1 cm^3 volume ?



Unit Cell (not to scale)



Crystal (not to scale)

   (A) 10^6 (B) 10^9

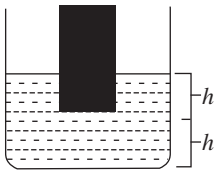
   (C) 10^{12} (D) 10^{18}

4. What is the value of $\frac{1}{1 \times 2} + \frac{1}{2 \times 3} + \frac{1}{3 \times 4} +$ … to ∞ ?

   (A) 2/3 (B) 1

   (C) 2 (D) ∞

5. A solid cylinder of basal area A was held dipped in water in a cylindrical vessel of basal area 2A vertically such that a length h of the cylinder is immersed. The lower tip of the cylinder is at a height h from the base of the vessel. What will be the height of water in the vessel when the cylinder is taken out ?



   (A) $2h$ (B) $\frac{3}{2}h$

   (C) $\frac{4}{3}h$ (D) $\frac{5}{4}h$

6. Of all the triangles that can be inscribed in a semicircle of radius R with the diameter as one side, the biggest one has the area—

   (A) R^2 (B) $R^2\sqrt{2}$

   (C) $R^2\sqrt{3}$ (D) $2R^2$

7. Choose the largest number—

   (A) 2^{500} (B) 3^{400}

   (C) 4^{300} (D) 5^{200}

8. A daily sheet calendar of the year 2013 contains sheets of 10 × 10 cm size. All the sheets of the calendar are spread over the floor of a room of 5m × 7·3 m size. What

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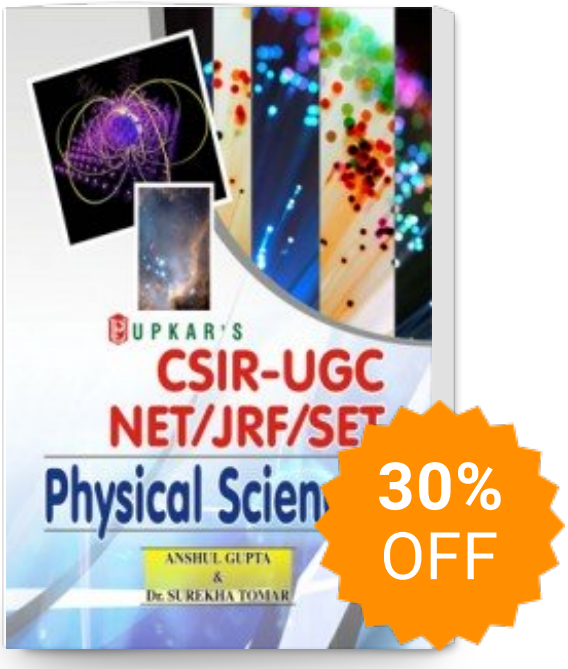

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