PHYSICS

92

PAPER—I

Time Allowed : Three hours *Maximum Marks* : 300

The figures in the margin indicate full marks for the questions

Candidates should answer Question Nos. **1** and **5** which are compulsory and *other* **three** of the remaining questions, selecting at least **one** from each Section

Assume suitable data if considered necessary and indicate the same clearly

SECTION—A

1. Answer any *three* of the following : 20×3=60

(a) Deduce what happens when equal objects having any two velocities hit each other. How is the principle of conservation of momentum applied in rocket propulsion? How is the total angular momentum related to the total torque? State and illustrate the law of conservation of angular momentum. 7+3+3+7=20

(b) What is a gyroscope? Describe with a diagram. Write the equations describing its behaviour, and hence mention the properties. Write its modern uses. 4+12+4=20

(c) Describe the important properties of simple harmonic motion, and explain how SHM can be combined to give more general oscillations. Explain free, damped and forced oscillations in terms of forces and energy transfers. 8+12=20

(d) What do temporal and spatial coherences physically signify? Explain with the help of Michelson interferometer and Young's double-hole experiments. 4+16=20

2. *(a)* Discuss scattering of positively charged particles, i.e., α-particles, from the nucleus and obtain Rutherford's scattering cross-section. 20

(b) Define holonomic and non-holonomic constraints. What types of difficulties are introduced by the constraints when solving mechanical problems? How are these problems eliminated? Obtained the general form of the Lagrange equation, and apply this equation in the case of the equation of motion of the one-dimensional harmonic oscillator. 2+2+2+10+4=20

(c) Define and explain Eulerian angles. Express the orthogonality condition in terms of the matrix elements for the rotation of a body in a plane, and hence find out the value of A (matrix of complete transformation $\tau'' = Ax$, A being the triple product of separate rotations) in terms of Eulerian angles. 5+15=20

3. (a) What does the Minkowski diagram provide? What does it illustrate? Give a description of Minkowski diagram in special relativity. What is the Minkowski force? 2+2+14+2=20

(b) State and explain Huygens' principle. Establish the laws of reflection and refraction with the help of this principle. What are phase and group velocities? 4+12+4=20

(c) Describe spherical and chromatic aberrations for a thin lens. How can these defects be eliminated? 12+8=20

4. (a) Explain how Newton's rings are formed. Account for perfect blackness of the central spot. Derive the relation for the diameter of bright rings. What is the difference between the rings observed by reflected light and by transmitted light? How does the pattern appear when white light is used? Why does the focal length of the plano-convex lens long? 4+2+6+4+2+2=20

(b) Differentiate between Fresnel and Fraunhofer types of diffraction. Give the theory of the plane diffraction grating. In a plane transmission grating, the angle of diffraction for the second-order principal maximum for the wavelength 5000 Å is 30°. Calculate the LPI (lines per inch) of the grating surface. 4+12+4=20

(c) What do the Einstein coefficients signify? Why are the gas lasers more monochromatic than the solid state lasers? With the help of a schematic diagram, describe the He-Ne laser. Show three prominent transitions in the energy-level diagram of this laser. 3+2+10+5=20

SECTION—B

5. Answer any *three* of the following : 20×3=60

(a) Extending Gauss' theorem, obtain Poisson's and Laplace's equations for an electric field. Where do these equations find application? 18+2=20

(b) A sinusoidal emf is applied to a circuit with inductance, capacitance and resistance in series. Derive an expression for the instantaneous current and power factor. A choking coil of resistance 5 Ω and inductance 0·6 H is in series with a capacitance of 10 μF. If the voltage of 200 volts is applied and the frequency is adjusted to resonance, find the current in the circuit and the voltage across the coil and the capacitor. 14+6=20

(c) Find the amplitudes of the reflected and the refracted waves in terms of the incident wave amplitude assuming plane monochromatic waves incident normally on the boundary surface between two dielectrics. Hence obtain the reflectance by computing the time averages of the respective poynting vectors. 14+6=20

(d) How did Einstein introduced the quantum theory of Planck to develop a theory of the specific heat of solids? How were the drawbacks in his theory modified by Debye? 10+10=20

6. (a) What is a magnetic shell? Define its strength. Deduce an expression for the potential at a point due to a thin magnetic shell. Hence deduce the intensity of the magnetic field at a point along the axis of a flat circular magnetic shell. 2+2+8+8=20

(b) What is an electric dipole? Determine the potential energy of a dipole in an external electric field. Calculate also the torque on the dipole in a uniform electric field. Find the potential energy due to dipole-dipole interaction. What is electrostatic shielding? 2+5+5+5+3=20

(c) State and explain Biot-Savart law. Explain how the magnetic field due to the current in a straight wire of finite length can be determined with its help. A current I flows through a wire shaped in the form of an infinite parabola of latus rectum $4a$. Calculate the magnetic field at the focus of the parabola. 8+8+4=20

7. (a) Explain the concept of 'displacement current' and show its importance. Write Maxwell's equations for vacuum and derive the wave equation for the electric field in vacuum. 10+10=20

(b) Obtain the Stefan-Boltzmann law for emission from a blackbody. How is this law experimentally verified? 15+5=20

(c) State Rayleigh-Jeans law of blackbody radiation. What was Planck's assumption in the derivation of his law? Obtain the forms in which Planck's law is given. What is ultraviolet catastrophe? 2+2+12+4=20

8. *(a)* What are the features that a process must not possess in order to be reversible? How should one perform to make a process reversible? Describe Carnot's engine, and obtain the efficiency of a Carnot engine with a perfect gas. 2+1+9+8=20

(b) What does the term 'equation of state' mean? What are isothermals? What were the observations at high pressures and low temperatures when PV was plotted as ordinate against P as abscissa? Describe the Joule-Thomson experiment, and explain the characteristics of the result. 2+2+4+12=20

(c) Obtain the Saha ionisation formula in the form originally given by Saha. Taking the concentration of electrons as an independent constituent, obtain the equation in the complete form. Mention a few applications of this equation. 10+6+4=20

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