CC/M/EXAM.
2020

PHYSICS

PAPER—I

Time : 3 hours] [Full Marks : 250

Note : Question Nos. **1** and **5** are compulsory and out of the remaining, any **three** are to be attempted choosing at least ONE question from each Section. The number of marks carried by a question/part is indicated against it.

SECTION—A

1. Answer *any* **five** of the following questions : 10×5=50

(a) Are the following fields conservative? If yes, what are the potentials $U(x, y)$?

(i) $\vec{F} = \vec{i}y\sin x + \vec{j}\cos y$ and *(ii)* $\vec{F} = \vec{i}2xy^3 + \vec{j}3y^2x^2$

(b) A 3·00 kg object is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^2 + 2$, where x and y are in meters and t in second. Find the magnitude of the force acting on this object at $t = 2{\cdot}00\,\text{s}$.

(c) A space transportation vehicle releases a 470 kg communication satellite while in an orbit 280 km above the surface of the earth. A rocket engine on the satellite boosts it into geosynchronous orbit. How much energy does the engine have to provide?

(d) Let Σ and Σ' be two inertial systems. Σ' moves relative to Σ with the velocity $v = \frac{3}{5}c$ in the Z-direction. At time $t = t' = 0$ both the systems coincide $\Sigma' = \Sigma$. Let now an event in Σ' have the coordinates $x' = 10\text{ m}$, $y' = 15\text{ m}$, $z' = 20\text{ m}$, $t' = 4\times10^{-8}\text{ s}$. Determine the coordinates of the event in the Σ system.

(e) You apply a 4·9 N force to a block attached to the free end of a spring stretching the spring from its relaxed length by 12 mm. Find the spring constant of the spring. What force does the spring exert if you stretch it by 17 mm?

(f) What is a damped oscillation? A mass of 1 kg is suspended from a spring of stiffness constant 25 Nm^{-1}. If the undamped frequency is $\frac{2}{\sqrt{3}}$ times the damped frequency, find the damping factor.

(g) What do you mean by Fermat's principle? How laws of refraction are established through this principle?

2. Answer the following questions :

(a) If escape velocity and orbital velocity of a body be v_e and v_o respectively, then show that $\frac{v_e}{v_o} = \sqrt{2}$. 20

(b) What do you mean by perpendicular and parallel axes of theorem of moment of inertia? A hoop of mass 5×10^3 gm and radius 0·5 m rolls along the ground at a rate of 10 m per sec. Calculate its kinetic energy. 15

(c) Certain radiation of a distant nebula appears to have a wavelength 6560×10^{-10} m instead of 4340×10^{-10} m as observed in the laboratory. *(i)* If the nebula is moving in the line of sight of the observer, what is its speed? *(ii)* Is the nebula approaching or receding? 15

3. Answer the following questions :

(a) I have a chord massless speaker emitting sound at $f = 600$ Hz on top of a mass connected to a spring. The mass-spring system oscillates horizontally at 4 Hz with amplitude A. Given $v_s = 330\ ms^{-1}$ and differences between highest and lowest frequencies I hear is 2 Hz, what is A? 20

(b) If the earth suddenly stopped in its orbit, assumed to be circular, find the time that would elapse before it falls into the sun. 15

(c) What do you mean by group velocity and phase velocity? The phase velocity of light exceeds the speed of light. Does this violate the principle of special theory of relativity? Explain. 15

4. Answer the following questions :

(a) A thin convex lens produces a real image of an object magnified m-fold. If this lens is moved by a distance d towards the object, the magnification becomes m'. Show that the focal length f of the lens is given by $\frac{dmm'}{m-m'}$. 20

(b) Show that the diameter D_n of the Newton's ring, when two surfaces of radii R_1 and R_2 are placed in constant, is given by $\frac{1}{R_1} \pm \frac{1}{R_2} = \frac{4n\lambda}{D_n^2}$, λ is the wavelength of light. 15

(c) What do you mean by Einstein's A and B coefficients? Show that the ratio $\frac{A_{nm}}{B_{nm}} = \frac{8\pi h\nu^3}{c^3}$. Symbols have their usual meanings. 15

SECTION—B

5. Answer *any* **five** of the following questions : 10×5=50

(a) What is meant by dipole moment? Obtain an expression for the intensity of an electric field at a point in broadside on position due to an electric field.

(b) Electric potential of a system at any point in a field is given by $V = (20 + 6x^2 - 5xy + 4y^2 + 3z^2)$, calculate the force acting on the charge 2×10^{-15} C located at a point $(2, 0, -3)$ in the field region in terms of unit vectors $\vec{i}$, $\vec{j}$ and $\vec{k}$.

(c) Calculate the frequency of oscillation produced in a circuit composed of an inductance of 9H, a capacity of $0\cdot1\mu F$ and a resistance of $400\,\Omega$. What will be the frequency if the resistance is reduced to a negligible value?

(d) An alternating e.m.f. of 200 V and 50 Hz is applied to a condenser in series with 20 V–5 W lamp. Find the capacity required to light the lamp.

(e) Two parallel wires are separated by a distance d carrying same current i in opposite directions. What will be the magnetic induction for a point between the wires at a distance x from one wire?

(f) State and explain Stefan-Boltzmann law. The sun radiates energy at the rate of $6\cdot3\times10^{7}\ Jm^{-2}s^{-1}K^{-4}$ and Stefan constant is $5\cdot669\times10^{-8}\ Wm^{-2}$. What will be the temperature of the sun's surface?

(g) A Carnot's engine whose low temperature reservoir is at 7 °C has an efficiency of 50%. By how many degrees should the temperature of the source be increased?

6. Answer the following questions :

(a) Show that for a van der Waals gas, $C_P - C_V = \dfrac{R(p + \frac{a}{V^2})}{p - \frac{a}{V^2} + \frac{2ab}{V^3}}$, symbols have their usual meanings. 20

(b) Establish the following Debye's expression for heat capacity

$$C_V = 3Nk\left(\frac{T}{\theta}\right)^3 \int_0^{\frac{\theta_D}{kT}} \frac{x^4 e^x}{(e^x - 1)}\,dx$$ 15

(c) Write Maxwell's equations for thermodynamic potentials and establish the Clausius-Clapeyron equation. 15

7. Answer the following questions :

(a) Write Maxwell's field equations in SI system for isotropic dielectrics and establish the following equation :

$$\nabla^2 \vec{E} - \mu\varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = 0$$

Also discuss Cherenkov radiation. 20

(b) From the theory of dispersion, show that in case of transparent gaseous substances in the region remote from the natural frequencies, the index of refraction is given approximately by the formula

$$\eta^2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^3} + \ldots$$

where A, B, C, etc., are the constants, λ is the wavelength of the incident light. Also obtain an expression for the dispersion power of the medium under consideration. 15

(c) If a linearly polarized wave is reflected from the boundary at an incident angle greater than the critical angle, the reflected wave will be elliptically polarized. Establish the relevant expression. 15

8. Answer the following questions :

(a) Find general expression for electric field due to an electric dipole and hence obtain electric field at $\theta = 0$ and $\theta = \frac{\pi}{2}$. 20

(b) An electric field 10 WC^{-1} exits along the x-axis in space. Calculate the potential difference $V_B - V_A$ where the points A and B have the coordinates (4 m, 2 m) and (6 m, 5 m). Now, if a charge -10^{-4} C is moved from A to B, find the change in potential energy. 15

(c) Explain the construction and working of transformers. What are the causes of loss of energy in a transformer? How are they minimized? 15

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