

**CC/M/EXAM.
2020**

PHYSICS

PAPER—II

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) A 50 MeV beam of protons is fired over a distance of 10 km. If the initial size of the wave packet is 1.5×10^{-6} m, what would be the final size upon arrival?
- (b) How long will it take for the wave packet of a proton confined to 10^{-15} m to grow to a size equal to the distance between the Earth and the Sun, if this distance is equal to 1.5×10^8 km?
- (c) A particle of mass m , which moves freely in an infinite potential well of length a , has the following wave function at $t = 0$:

$$\psi(x, 0) = \frac{A}{\sqrt{a}} \sin\left(\frac{\pi x}{a}\right) + \sqrt{\frac{3}{5a}} \sin\left(\frac{3\pi x}{a}\right) + \sqrt{\frac{1}{5a}} \sin\left(\frac{5\pi x}{a}\right)$$

where A is real constant.

- (i) Find A so that $\psi(x, 0)$ is normalized.
- (ii) If measurements of the energy are carried out, what are the values that will be found?
- (d) Write the position operator \hat{x} and momentum operator \hat{p} in terms of ladder operators. Hence find $[\hat{x}, \hat{p}]$.
- (e) Describe how Stern-Gerlach experiment led to the concept of space quantization. How does it demonstrate existence of magnetic moment and electron spin?
- (f) Discuss Zeeman splitting of sodium D lines in weak magnetic field.
- (g) What is Raman effect? Explain theoretically, the observed characteristics of the Raman spectrum of a diatomic molecule.

2. Answer the following questions :

- (a) A particle of energy E is incident on a one-dimensional potential step defined by

$$V(x) = \begin{cases} 0 & , \text{ if } x \leq 0 \\ V_0 & , \text{ if } x \geq 0 \end{cases}$$

Find the reflection and transmission coefficients when (i) $E > V_0$ and (ii) $E < V_0$. 20

- (b) Normalize the wave function $\langle x | \psi \rangle = \begin{cases} N e^{-kx} & , x > 0 \\ N e^{kx} & , x < 0 \end{cases}$. Determine the probability that a measurement of the momentum p finds the momentum between p and $p + dp$ for the wave function. 15

- (c) Given $\psi(x) = 5 \cos^2\left(\frac{2\pi x}{L}\right) + 2 \sin\left(\frac{4\pi x}{L}\right)$. Find the possible values of p and corresponding probabilities for obtaining them. So use the un-normalized function to read off the relative odds. Then rescale them to get the absolute probabilities. 15

3. Answer the following questions :

- (a) (i) Consider the function $\psi(x) = A e^{-\frac{m\omega x^2}{2\hbar}}$. Find A to normalize it.
(ii) Consider a harmonic oscillator whose energy in the classical theory is given by $E = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$, so that in the quantum version of the oscillators, the wave function for a state of definite energy obeys

$$-\frac{\hbar^2}{2m} \frac{d^2 \psi_E(x)}{dx^2} + \frac{1}{2}m\omega^2 x^2 \psi_E(x) = E \psi_E(x)$$

Show that ψ in (i) satisfies this equation with $E = \frac{\hbar\omega}{2}$. 20

- (b) Find the energy function ψ_E in a box using $e^{\pm ikx}$ instead of $\sin kx$ and $\cos kx$. 15

- (c) Consider a free particle $V(x) = 0$ moving in a ring of circumference L . Let $\psi_n(x)$ be the normalized state of momentum $p = \frac{2\pi n\hbar}{L}$.

- (i) Show that $\psi_n(x)$ is also the state of definite energy E and find its energy by showing that it satisfies $H\psi = E\psi$

$$\text{where (in general) } H\psi(x) \equiv -\frac{\hbar^2}{2m} \frac{d^2 \psi(x)}{dx^2} + V(x)\psi(x).$$

- (ii) Let $\psi(x, 0) = 3\psi_2(x) + 4\psi_3(x)$. Normalize this and find $\psi(x, t)$. 15

4. Answer the following questions :

- (a) Distinguish between $\overline{L}-\overline{S}$ and $\overline{J}-\overline{J}$ coupling schemes in case of two-valence electron system. Under what conditions an $L-S$ and $J-J$ coupling scheme has been observed? Give examples. 20
- (b) What is anomalous Zeeman effect? Discuss the Zeeman patterns to the resonance (D_1, D_2) lines of sodium. 15
- (c) The absorption spectrum of HCl molecule consists of 4 consecutive lines with wave numbers 83.03 cm^{-1} , 103.73 cm^{-1} , 124.30 cm^{-1} and 145.03 cm^{-1} . What J values do they correspond? Calculate the moment of inertia and the internuclear separation. Also find the region of e.m. spectrum where the spectrum lies. 15

SECTION—B

5. Answer *any five* of the following questions :

10×5=50

- (a) Cl^{33} decays by positron emission of energy 4.3 MeV. Write the decay equation and find the nuclear radius of the product nucleus.
- (b) Calculate the binding energy and specific binding energy for ${}_{28}\text{Ni}^{64} = 63.9280 \text{ u}$ and ${}_{29}\text{Cu}^{64} = 63.9298 \text{ u}$, given that $m_p = 1.007825 \text{ u}$ and $m_n = 1.00965 \text{ u}$. Compare the stability of Ni^{64} and Cu^{64} .
- (c) The linear absorption coefficient μ_e of lead for 1 MeV gamma rays is 74 m^{-1} . Calculate the thickness of lead to reduce the intensity of gamma rays to $\frac{1}{100}$ of its original value and half-value thickness.
- (d) Describe the success and failures of the nuclear shell model with suitable examples.
- (e) The interplanar spacing of (110)-plane is 2.2 \AA for a cubic crystal. Calculate the atomic radius.
- (f) Write the characteristics of an ideal OP-AMP. Draw the electronic symbol of an OP-AMP and label its pins.
- (g) State and prove De Morgan's theorem. What is meant by De Morganization?

6. Answer the following questions :

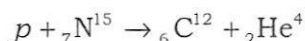
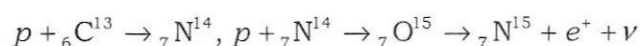
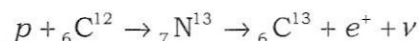
- (a) A simple cubic crystal illuminated with X-rays of wavelength 0.09 nm is rotated and the first-order Bragg reflection occurs at a minimum glancing angle of 8.8° . Which set of crystal planes is responsible for this reflection? Find the spacing between these planes and the angle for the first-order reflection from the (110) crystal planes. 20
- (b) Describe band theory of solids on the basis of Kronig-Penney model. Distinguish among conductors, semi-conductors and insulators. 15
- (c) Discuss the Fermi level in *n*-type and *p*-type semiconductors with temperature. 15

7. Answer the following questions :

- (a) What is a JFET? Describe the principle of operation of an FET. 20
- (b) Describe in short, high temperature T_c superconductivity. 15
- (c) The critical fields for a sample are $1.4 \times 10^5 \text{ Am}^{-1}$ and $4.2 \times 10^5 \text{ Am}^{-1}$ at $T_c = 14 \text{ K}$ and 13 K respectively. What are the transistor temperatures and critical field at 0 K and 4.2 K? 15

8. Answer the following questions :

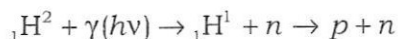
- (a) In a star there is the following carbon–nitrogen cycle to produce energy :



Calculate the total energy released in the above cycle by taking

$$m_{\text{H}} = 1.007825 \text{ u}, m_{\text{He}} = 4.0026034 \text{ u}, m_e = 5.4 \times 10^{-4} \text{ u} \text{ and } 1\text{u} = 931.5 \text{ MeV.} \quad 20$$

- (b) Explain the difference between nuclear fission and nuclear fusion. Outline the properties of nuclear fission. 15
- (c) Calculate the threshold energy for the following photon–disintegration reaction—



$$\text{Given that } m(d) = 2.0140 \text{ u, } u = 940 \text{ MeV} \quad 15$$

★ ★ ★