Total No. of Printed Pages—7

4 SEM TDC PHYH (CBCS) C 9

2025

(May/June)

PHYSICS

(Core)

Paper : C–9

(Elements of Modern Physics)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct option from the following : 1×5=5

(a) Compton shift depends on

(i) incident radiation

(ii) scattering substance

(iii) angle of scattering

(iv) None of the above

(b) That electron cannot exist within the nucleus of atoms is understood from

(i) Bohr's atomic model

(ii) de-Broglie's hypothesis

(iii) Heisenberg's uncertainty principle

(iv) None of the above

(c) The Hamiltonian operator is expressed as

(i) $\hat{H} = -\frac{\hbar^2}{2m}\frac{\partial}{\partial x} + V(x)$

(ii) $\hat{H} = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x)$

(iii) $\hat{H} = \frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x)$

(iv) $\hat{H} = \frac{\hbar^2}{2m}\frac{\partial}{\partial x} + V(x)$

(d) The function of the component of a nuclear reactor called control rod is to

(i) slow down the emitted neutrons

(ii) stop the neutrons from escaping the fuel

(iii) absorbing the excess neutron and prevent explosion

(iv) None of the above

(e) The size of nucleus of an atom of mass number A is proportional to

(i) $A^{\frac{3}{4}}$

(ii) $A^{\frac{2}{3}}$

(iii) $A^{\frac{1}{3}}$

(iv) A

2. (a) What is stopping potential? Write down the Einstein's photoelectric equation. 2

(b) The wave function of a particle is given by $\psi = Ae^{i(kx-\omega t)}$. Show that probability current density $J = \frac{\hbar k A^2}{m}$, where m is the mass of the particle and A is a constant. 2

(c) Find the expectation value of linear momentum $< P_x >$ for the wave function

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\frac{\pi x}{L}, \quad 0 \le x \le L$$

$$= 0 \quad , \text{ otherwise}$$

2

(d) An electron is trapped in one-dimensional infinitely rigid box of length 0·2 nm. Calculate the energy required by the electron to rise from its ground state to the fourth state. 2

(e) What is quantum tunneling? Does quantum tunneling violate energy conservation? 1+1=2

(f) A radioactive nucleus disintegrates according to the following sequence :

$$X \xrightarrow{\beta} X_1 \xrightarrow{\alpha} X_2 \xrightarrow{\alpha} X_3$$

If the mass number and atomic number of X_3 are 172 and 69 respectively, what is the mass number and atomic number of X? 2

3. (a) Prove that the particle velocity is equal to the group velocity of wave packet. 3

(Continued)

Or

An X-ray photon of wavelength 0·2 Å is scattered at an angle 90° with its original direction after collision with an electron at rest. Calculate the change of wavelength and the loss of energy of the photon due to scattering. (Given that $h = 6{\cdot}6 \times 10^{-34}$ Js; $m_0 = 9{\cdot}1 \times 10^{-31}$ kg and $c = 3 \times 10^8$ m/sec).

(b) Explain wave particle duality. 3

Or

Using Heisenberg's uncertainty principle, find the minimum energy of a linear harmonic oscillator.

(c) Derive the one dimensional time independent Schrödinger equation. 3

Or

If the operator

$$\left(x + \alpha\frac{d}{dx}\right)$$

has the eigenvalue λ, find the corresponding eigenfunction.

(d) Show that an electron cannot reside inside the nucleus. 3

(Turn Over)

(e) How does the nuclear fission occur? Explain nuclear fission on the basis of liquid drop model. 1+2=3

(f) Define Einstein's A and B coefficients. Why is a metastable state required for laser action? 3

4. (a) Describe the Davisson-Germer experiment. 4

(b) A particle of mass m and kinetic energy E is moving along positive X-axis towards a finite potential step. The potential function of the potential step is given by

$$V(x) = \begin{cases} 0 & \text{for } x < 0 \\ V_0 & \text{for } x > 0 \end{cases}$$

Show that for $E > V_0$ the incident particle has a finite probability of being reflected and a finite probability of being transmitted. 4

5. (a) What is the binding energy of a nucleus? Write an expression for it. How does the binding energy per nucleus explain the stability of the nucleus? 1+1+3=5

Or

Discuss the liquid drop model. 5

(*Continued*)

(b) Define half-life ($T_{\frac{1}{2}}$) and mean life (τ) of a radioactive substance. Derive the expression for $T_{\frac{1}{2}}$ from the radioactive decay law $N = N_0 e^{-\lambda t}$. 5

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