

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

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

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

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

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



(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

(4)

- (c) Find the expectation value of linear momentum $\langle P_x \rangle$ for the wave function

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

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

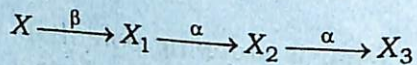
2

- (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 :



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

(5)

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 $h = 6.6 \times 10^{-34}$ Js; $m_0 = 9.1 \times 10^{-31}$ 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

(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

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

