2024
B.A./B.Sc.
Fourth Semester
CORE – 9
PHYSICS
Course Code: PHC 4.21
(Elements of Modern Physics)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five questions, taking one from each unit.

UNIT–I

1. (a) What is Compton effect? Obtain an expression for the shift in wavelength of X-ray beam. 6
   (b) Find the de Broglie wavelength associated with
   (i) a 46 gm golf ball moving with velocity 36 m/s
   (ii) an electron with a velocity 10^7 m/s
   Which of these two show wave character and why? 5
   (c) Explain the concept of matter waves. 3

2. (a) State Heisenberg's uncertainty principle and give one illustration. Explain the non-existence of free electrons in the nucleus. 1+3+3=7
   (b) Describe Davisson and Germer experiment for study of electron diffraction. Show that it directly verifies de Broglie's hypothesis of the wave nature of moving bodies. 7

UNIT–II

3. (a) Explain the normalization and orthogonality of wave functions. 2+2=4
   (b) Show that the momentum operator and the total energy operator in 3-D are given by $\hat{p} = -i\hbar\nabla$ and $\hat{H} = \frac{-\hbar^2}{2m}\nabla^2 + V(r)$ respectively. 3+3=6

(c) The wave-function of a particle confined in a box of length L is

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\frac{\pi x}{L}$$ in the region $0 < x < L$ and zero elsewhere.

Calculate the probability of finding the particle in the region

$0 < x < \frac{L}{2}$. 4

4. (a) Show that the probability density ρ and the probability current density J satisfy the continuity equation; $\frac{d\rho}{dt} + \nabla.J = 0$. Explain the physical significance of this equation in quantum mechanics. 7

(b) Normalize the wave function given by, $\Phi(X) = e^{-|x|}\sin\alpha x$. 7

UNIT–III

5. (a) Calculate the values of energy of a particle in a one-dimensional box. Graphically indicate some of the wave functions for such a particle. 6

(b) A particle of mass m and energy $E < V_0$ travelling along x-axis has a potential barrier defined by

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

Derive the reflection and transmission coefficient of the particle. 8

6. (a) On the basis of liquid drop model, give a simple derivation of Weizascker's semi-empirical mass formula giving arguments for each term. What are the important conclusions drawn from this formula? 5

(b) What is binding energy? Explain the stability of nucleus. 1+4=5

(c) Assuming that the energy released by the fission of a single uranium atom is 202 MeV. Calculate the number of fission per second required to produce 1 Watt of power. 4

UNIT–IV

7. (a) Give four properties each of α-rays and β-rays. 2+2=4

   (b) The half-value period of radium is 1590 years. In how many years will one gram of pure element

   (i) lose one centigram, and

   (ii) be reduced to one centigram? 5

   (c) Define the terms: decay constant, half-life and average life as applied to a radioactive substance. Find the relation between them. 1+1+1+2=5

8. (a) Explain the energy spectrum of β-particles using magnetic spectrograph and discuss the neutrino theory of β-decay for continuous β-ray spectrum. 5+3=8

   (b) Discuss the origin and the theory of γ-emission. 6

UNIT–V

9. (a) What is nuclear fission? On the basis of Bohr and Wheeler theory, explain the process of nuclear fission. 1+3=4

   (b) A deuterium reaction that occurs in experimental fusion reactor is $H^2(d, p)H^3$ followed by $H^3(d, n)He^4$. 3×2=6

   (i) Compute the energy released in each of the above reactions.

   (ii) Calculate the total energy release per gram of the deuteron used in the fusion.

   (c) Explain the working of atom bomb. 4

10. (a) What is population inversion? Explain in detail the working of a He-Ne LASER. 2+5=7

    (b) Derive the Einstein coefficients. How do they contribute to the understanding of LASER operation and efficiency? 2+5=7