April 2025
B.A./B.Sc.
Fourth Semester
GENERIC ELECTIVE – 4
PHYSICS
Course Code: PHG 4.11
(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) Derive the formula for Planck's radiation law. 7
   (b) What is photoelectric effect? Briefly explain Einstein's theory of photoelectric effect. Calculate the maximum kinetic energy of a photoelectron emitted on shining light of wavelength 6.0×10^{-6} m on a metal surface. The work function of the metal is 0.1 eV. 1+4+2=7

2. (a) X-ray of wavelength 2.0 Å are scattered from a carbon block. The scattered photons are observed at right angles to the direction of the incident beam. Calculate the wavelength of the scattered photon and the energy of the recoil electron. 4
   (b) Calculate the shortest and longest wavelength in Balmer series of hydrogen atom. 4
   (c) Write the conclusions given by Rutherford in his alpha particle scattering experiment for the model of an atom and its limitations. 6

UNIT–II

3. (a) Derive the Schrodinger's equation for non-relativistic particles. 6
   (b) Give the requirements of a wavefunction along with graphical interpretation. 3+2=5
   (c) What are eigenvalues and eigenfunctions? Explain with a simple example. 1+2=3

4. (a) Derive the formula for probability current density. Explain operators in quantum mechanics and write the formula for energy, momentum, and Hamiltonian operator. 8

(b) Normalised the wavefunction and find the probability current density, if the wavefunction is $\Psi = Ae^{ikx}$ over the region $-a \le x \le a$. 4

(c) Find the normalisation constant for a wavefunction $\Psi = Ae^{\frac{-\alpha^2 x^2}{2}} e^{ikx}$ in all space. 2

UNIT–III

5. (a) Derive the expression for energy eigen value and the corresponding wavefunction for a particle confined between $x = 0$ to $x = a$ in a 1-D infinite potential well. 10

(b) A proton is confined to move in a 1-D box of width 0.1nm. 4

(i) Find the lowest possible energy of proton.

(ii) What is the lowest possible energy of an electron confined to the same box?

6. (a) What is tunnelling? Explain the phenomenon of tunnelling using potential barriers. 10

(b) A small object of mass 0.1 μg is confined to move between two rigid walls separated by a distance of 1.0 mm: 4

(i) Calculate the minimum speed of the object.

(ii) If the speed is 1.5×10^6 m s^{-1}, find the corresponding value of n.

UNIT–IV

7. (a) Explain Heisenberg gamma ray microscope thought experiment. 7

(b) Show that an electron cannot exists within an atomic nucleus based on the Heisenberg uncertainty principle. 5

(c) Briefly explain the impossibility of an electron following a trajectory. 2

8. (a) Using uncertainty principle, estimate the minimum energy of a confined particle. 2

(b) Obtain the relationship between size and structure of atomic nucleus and atomic weight. 3

(c) An electron in a molecule travel at a speed of 40 m/s. The uncertainty in the momentum Δp of the electron is 10^{-6} of its momentum. Calculate the uncertainty in position. 2

(d) Explain uncertainty principle and use it to derive energy-time uncertainty relation. 7

UNIT–V

9. (a) Explain the stability of an atomic nucleus using neutron-proton ratio. 8

(b) Explain pair production by high energy photons. 6

10. (a) Determine the most stable isotope for $A = 27$. 2

(b) A radioactive nucleus D undergoes a series of decays as follows:

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta} D_2 \xrightarrow{\alpha} D_3 \xrightarrow{\gamma} D_4$$

The mass number and atomic number of D are 180 and 72, respectively. What are these number for D_4? 2

(c) What is β-decay? Discuss the neutrino hypothesis on account of β-decay and briefly explain the different types of β-decay with examples. 10