April 2025
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) Derive an expression for Planck's law of radiation and show that it reduces to Rayleigh Jean's formula for longer wavelengths. 7
   (b) The equivalent wavelength of a moving electron is 0.24×10^{-10} m. What is the value of the voltage applied between two grids that will bring it to rest? 4
   (c) Derive the Einstein's photoelectric equations. 3

2. (a) Define group velocity of a wave group and derive its expression. Show that the group velocity of the de-Broglie wave associated with a particle is the same as the particle velocity. 1+2+3=6
   (b) The lifetime of an excited state of an atom is about 10^{-8} sec. Calculate the minimum uncertainty in the determination of the energy of the excited state. 6
   (c) Explain the concept of energy and time uncertainty. 2

UNIT–II

3. (a) What do you understand by eigenvalue and eigenfunction? Discuss the properties of wave functions. 2+4=6
   (b) Derive the time-dependent form of Schrödinger equation in three dimensions. 8

4. (a) Calculate the expectation value $<p_x>$ of the momentum of a particle in a one-dimensional box. 2

(b) Show that the probability current density for a plane wave in a medium is equal to the product of probability density and the velocity of a particle in the medium. 8

(c) Normalize the wave function given by, $\Psi(x) = Ae^{ikx}$, over the region $-a \le x \le a$. 4

UNIT–III

5. (a) Can a particle confined in a one-dimensional box have zero energy? What is the minimum value of its energy? How does the idea of a "zero-point energy" match with the requirements of Heisenberg's uncertainty principle? 5

(b) What is a potential step? Find the reflection and transmission co-efficient for potential step of the form, $E > V_0$. 1+8=9

6. (a) What are magic numbers? Explain how the shell model of the nucleus accounts for the existence of magic numbers. 1+6=7

(b) Calculate the binding energy of an α-particle and express the result both in MeV and joules. 3

(c) Discuss the characteristics of nuclear forces. 4

UNIT–IV

7. (a) Estimate the age of the Earth from radioactive studies. 4

(b) Calculate the weight in kg of one curie of Ra B(Pb^{214}) from the half-life of 26.8 minutes. 4

(c) Give the relevant theory of successive disintegration of radioactive elements. What do you mean by radioactive equilibrium? 6

8. (a) Explain how Gamow's theory of alpha decay leads to Geiger-Nuttal law. 8

(b) The mean half-life of radium (226) is 1600 year and that for radon (222) is 3.8 day. Calculate the volume of radon gas that would be in equilibrium with 1 g of radium. 3

(c) Explain the experimental verification of the existence of neutrino. 3

UNIT–V

9. (a) What is chain reaction? Explain the critical size of the fissile material to maintain chain reaction. 1+2=3

   (b) Draw a neat diagram of nuclear reactor and explain its working. 8

   (c) What are thermonuclear reactions? Explain carbon-nitrogen cycle and proton-proton cycle as source of stellar energy. 1+2=3

10. (a) Differentiate between spontaneous and stimulated emissions of radiation. 3

    (b) What are three level and four level lasers? Describe the construction and working of ruby laser. 2+6=8

    (c) Write a short note on the basic technique used in holography. How is it different from photography? 3
