

**2023**  
**B.A./B.Sc.**  
**Fourth Semester**  
CORE – 9  
**PHYSICS**  
*Course Code: PHC 4.21*  
(Elements of Modern Physics)

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

*Pass Mark: 28*

*Answer five questions, taking one from each unit.*

**UNIT-I**

1. (a) Show that Planck's law of radiation reduces to Rayleigh Jean's formula for longer wavelengths. 6  
(b) The equivalent wavelength of a moving electron is  $0.24 \times 10^{-10}$  m. What voltage applied between two grids will bring it to rest? 5  
(c) Derive the Einstein's photoelectric equation. 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) Consider an electron of momentum  $p$  in the Coulomb field of a

proton. The total energy is  $E = \frac{p^2}{2m} - \frac{e^2}{(4\pi\epsilon_0)r}$ ,

where  $r$  is the distance of the electron from the proton. Assuming that the uncertainty  $\Delta r$  of the radial coordinate is  $\Delta r \approx r$  and that

$\Delta p \approx p$ , use Heisenberg's uncertainty principle  $\Delta r \Delta p \approx \hbar$  to obtain an estimate of the size and the energy of the hydrogen atom in the ground state. 6

- (c) Explain the concept of energy and time uncertainty. 2

## UNIT-II

3. (a) What do you understand by eigen value and eigen function? Explain the physical interpretation of wave function. 1+3=4
- (b) Calculate the values of energy of a particle in a one-dimensional box. Graphically indicate some of the wave functions for such a particle. 10
4. (a) 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
- (b) Normalize the wave function given by  $\Psi(x) = Ae^{ikx}$ , over the region  $-a \leq x < a$ . 4
- (c) Calculate the expectation value  $\langle p_x \rangle$  of the momentum of a particle in a one-dimensional box. 2

## UNIT-III

5. (a) What is a potential step? Find the reflection and transmission co-efficient for potential step of the form  $0 < E < V_0$ . Show that there is a finite probability of locating the particle in the region which is forbidden classically. What is the penetration distance? Give its relation to the mass of the incident particle. 6+2+2=10
- (b) 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? 4
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) Explain binding energy of the nucleus. Calculate the binding energy of an  $\alpha$  -particle and express the result both in MeV and joules. 1+2=3
- (c) Discuss the characteristics of nuclear forces. 4

## UNIT-IV

7. (a) Explain how the age of earth can be estimated from radioactive studies. 3  
(b) Calculate the time required for 10% of a sample of thorium to disintegrate. Assume the half-life of thorium to be  $1.4 \times 10^{10}$  years. 3  
(c) Give the relevant theory of successive disintegration of radioactive elements. What do you mean by radioactive equilibrium? Obtain the conditions for secular and transient equilibrium. 8
8. (a) Explain how Gamow's theory of alpha decay leads to Geiger-Nuttall 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) Explain the differences between spontaneous and stimulated emissions. 3  
(b) What are three level and four level lasers? Describe the construction and working of ruby laser. 2+6=8  
(c) Write a shote note on the basic technique used in holography. How is it different from photography? 3