5403

**Your Roll No.....**

a) Name of Course : B.Sc. Hons.–(Physics)_NEP: UGCF-2022

b) Semester : II- Semester (GE Paper)

c) Name of the Paper: **Modern Physics**

d) Unique Paper Code : 2224001203

Duration: **3 hours** Maximum marks: **90**

**Instructions for Candidates**

Write your Roll No. on the top immediately on receipt of this question paper.

All Questions carry equal marks.

**Q. No. 1 is compulsory.**

**Answer any four of the remaining five questions.**

Use of non-programmable scientific calculators are allowed

1. Attempt any six questions out of seven.
   a) Light of wavelength $\lambda = 400$ nm falls on a metal surface with a work function $\phi = 2.0$ eV. Find the maximum kinetic energy of the emitted photoelectrons. Given: $h = 6.626 \times 10^{-34}$Joule $-$ second
   b) Why can Compton scattering not be explained by classical wave theory?
   c) Give the reason for nonexistence of electrons inside the nucleus by uncertainty principle.
   d) Evaluate the commutator (i) $[\hat{x},\ \hat{p}_x]$ (ii) $[\hat{y},\ \hat{p}_z]$ (iii) $[\hat{x},\ \hat{p}_x^2]$.
   e) Explain the term (i) stimulated absorption (ii) stimulated emission (iii) spontaneous emission.
   f) 10 mg of radioactive substance of half-life period two years is kept in store for four years. How much of the substance remains unchanged?
   g) Explain the lower binding energy of lighter nuclei. $(6 \times 3 = 18)$

2. a) An X-ray photon of wavelength $\lambda = 0.050$ nm is scattered by a free electron at rest. If the scattering angle is 90°, calculate:
   (i) The change in wavelength of the photon.
   (ii) The wavelength of the scattered photon.
   (iii) The energy of the recoiling electron.
   Given: mass of the electron $m = 9.11 \times 10^{-31}$kg. and $h = 6.626 \times 10^{-34}$Joule $-$ second

   (10)

b) Explain the concept of group velocity and phase velocity in the context of wave motion. Show that for a dispersive medium, the group velocity can be expressed in terms of phase velocity as:

$$v_g = v_p + k\frac{dv_p}{dk} \quad (8)$$

3. a) Explain the origin of the natural width of emission lines in atomic spectra. Derive an expression using the energy-time form of the Heisenberg Uncertainty Principle. (10)

b) An excited electron in a hydrogen atom decays to a lower energy state and emits a photon. The average lifetime of the excited state is estimated to be $1.0 \times 10^{-8}$s. Calculate the corresponding uncertainty in frequency. Given: $\hbar = 1.05 \times 10^{-34}$ Js. (8)

4. a) An electron is confined in a one-dimensional infinite potential well (also called a particle in a box) of width L=1.0 nm
   (i) Calculate the energy of the electron in the ground state (n=1)
   (ii) Calculate the wavelength of the electron in this state. (10)

b) Explain two-slit interference experiment with electrons, covering the core concepts. (8)

5. a) Explain the process of lasing action in a laser system. How does the population inversion created within the gain medium lead to the emission of coherent light? (10)

b) For the 2P→ 1S transition in the hydrogen atom calculate $\omega$. Assuming the spontaneous emission lifetime of the 2P state to be 1.6 ns, and energy difference between 2P and 1S is 10.2 eV, calculate the Einstein B coefficient. Assume $n_o = 1$. (8)

6. a) The atomic mass of $C_6^{12}$ is 12.000000 amu and that of $C_6^{13}$ is 13.003354 amu. Find the energy required to remove a neutron form $C_6^{13}$ in MeV. The mass of neutron is 1.008665 amu. (10)

b) Discuss the fundamental principles of the Liquid Drop model in nuclear physics. How does this model conceptualize the structure and behavior of atomic nuclei? (8)