[This question paper contains 2 printed pages.]

Your Roll No.....

Sr. No. of Question Paper : 5537 **J**

Unique Paper Code : 2222012401

Name of the Paper : Modern Physics (DSC)

Name of the Course : **B.Sc. (Hons.) Physics – NEP UGCF-2022**

Semester : IV

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Question No. 1 is compulsory.
3. Attempt any four from the remaining five questions.
4. All questions carry equal marks.
5. Use of non-programmable calculators is allowed.

1. Attempt any **six** of the following questions: (6×3=18)
   (a) In the Compton scattering experiment, radiation scattered at each angle generally consists of two distinct wavelengths. Briefly discuss the origins of these wavelengths?
   (b) If the uncertainty in a photon's wavelength is one part in a million, determine the uncertainty in its position if the photon's wavelength is 500 nm.
   (c) Evaluate the commutator (i) $[\hat{x}, \hat{p}_x]$, (ii) $[\hat{x}, \hat{p}_y]$, and (iii) $[\hat{x}, \hat{p}_x{}^2]$
   (d) A particle of kinetic energy 8.5 eV is incident on a potential step of height 4.5 eV. Calculate the reflection coefficient.
   (e) Explain the terms (i) induced absorption (ii) spontaneous emission, and (ii) stimulated emission.
   (f) State Moseley's law and discuss its significance.
   (g) Calculate the radius of ^{235}U. What would be the mass of 1 mm^3 of nuclear matter? Given: $1u = 1.66 \times 10^{17}$ kg/m^3.

2. (a) Draw the experimental setup for studying photoelectric effect. What are the main features of the observations? Discuss how classical wave theory fails and how Einstein's quantum theory of light successfully explains the phenomenon. (10)

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(b) Determine the wavelength of the incident photon in Compton scattering if the maximum energy imparted to the electron is 50 keV? (8)

3. (a) Obtain the time-dependent Schrodinger equation in one dimension and discuss the statistical interpretation of wave function. (10)

(b) A particle is described by the wave function

$$\psi(x) = 0 \qquad x < 0$$
$$= \sqrt{2}e^{-x/L} \qquad x \geq 0$$

where L=2 nm. Calculate the probability of finding the particle in the region $x \geq 1$ nm. (8)

4. (a) Sketch the first three wave functions and corresponding probability densities for a particle confined in a one-dimensional box of length L. What are the energy eigenvalues corresponding to these wave functions? Discuss the differences between the classical and quantum mechanical descriptions of such a particle. (10)

(b) A particle of kinetic energy 2.5 eV is incident on a potential step of height 4.0 eV. Calculate the penetration depth of the particle into the classically forbidden region. (8)

5. (a) On what condition does the quantum physics yield the same results as classical physics according to Bohr correspondence principle. Discuss the validity of the principle on the basis of classical and quantum pictures of the Bohr model for hydrogen atom. (10)

(b) Calculate the ratio of Einstein's A and B coefficients, and the ratio of probabilities of spontaneous and stimulated emission for a system in thermal equilibrium at room temperature (T = 300 K) for transition that occur in the visible region ($h\nu$ = 2 eV). Given: $k_B = 1.38\times10^{-23}$ J/K. (8)

6. (a) Discuss the various contributions to the binding energy of a nucleus of atomic number Z and mass number A, and obtain the Weizsaecker semi-empirical mass formula. (10)

(b) Calculate the binding energy of α-particle and express it in MeV and joules. Given: $m_p = 1.00758$ amu, $m_n = 1.00897$ amu and $m_{He} = 4.0028$ amu. (4)

(c) Calculate the distance in free space over which the intensity of a 2 eV neutron beam be reduced by a factor of one-half? Given: Mass of neutron = 1.67×10^{-27} kg, Decay constant for a free neutron = 1.14×10^{-3} s^{-1}. (4)