**Useful data :**

mass of the proton = $1.67 \times 10^{-27}$ kg = 1.00081 amu

charge of an electron = $1.602 \times 10^{-19}$ C

electron mass = $9.1 \times 10^{-31}$ kg

velocity of light in vacuum, $c = 3 \times 10^8$ m/s

$r_0$ = 1.2 fm

Compton wave length $\lambda_C$ = 2.426 pm

Mass of neutron = $1.65 \times 10^{-27}$kg = 1.0089 amu

Planck's constant, $h = 6.63 \times 10^{-34}$Js

$\varepsilon_0 = 8.8541 \times 10^{-12}$ $C^2/N.m^2$



[This question paper contains 8 printed pages.]

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

**Sr. No. of Question Paper : 4066** **H**

Unique Paper Code : 2222012401

Name of the Paper : Modern Physics

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. Attempt only **five** questions.
3. Question No. **1** is compulsory.
4. **All** questions carry equal marks.
5. Use of non-programmable scientific calculator is allowed.

1. Attempt all of the following : (6×3=18)

(i) Discuss how Classical Physics fails to explain the main features of photoelectric effect.

(ii) Write the conditions required for physical acceptability of wave function. State the Born probabilistic interpretation of the wave function.

(iii) Consider an electron is confined to a one-dimensional infinite potential well of width L=1.0 nm. Calculate the energies of the ground state and the first two excited states.

(iv) Explain the terms "stimulated emission" and "spontaneous emission", clarifying the difference.

(v) Discuss the meson theory of nuclear forces. Give the main properties of these forces.



6. (i) What is the average binding energy of a nucleus and how is it different from the binding energy? Discuss how does the average binding energy varies with the mass number (M) with the help of graph between the average binding energy versus the mass number. (8)

(ii) State the principle of linear accelerator (LINAC). For a LINAC, deduce the velocity of the emergent ion at nth tube and length of this tube. Protons are accelerated in a drift tube portion of a LINAC from 0.75 MeV to 100 MeV and if the length of the first tube is 3 cm. Find the frequency of the applied AC voltage. (10)

5. (i) Write the general equation of the lines of hydrogen spectrum and draw the energy level diagram of various series in the hydrogen spectrum. Assume that the electron in a hydrogen atom is replaced by a muon of mass $m \approx 200\ m_e$, where $m_e$ is the mass of an electron. Determine the change in the wavelength of the $H_\alpha$ line of Balmer series. Assume $m << m_p$, where $m_p$ is the mass of a proton. (10)

(ii) State the differences between the laser light and the ordinary light. Explain the working principle of a 4-level laser with diagram. Which type of laser is the He-Ne laser? (8)



(vi) A cyclotron with the applied potential of 20KeV across the dees of radius of 28 cm is subjected to a transverse magnetic field of 1.1 Tesla. Calculate them energy to which a proton can be accelerated. Why the cyclotrons cannot be used to accelerate electrons?

2. (i) Discuss the Compton scattering in terms of the interaction between the high energy incident photons and the target matter. A photon of energy 1.02MeV is scattered through 90° by a free electron. Find the energy carried away by the recoil electron. (8)

(ii) Explain that the Heisenberg's uncertainty principle has significance in quantum mechanics. Using the uncertainty principle, calculate the

value of the first Bohr's radius and the value of the ground state energy of the hydrogen atom. (10)

3. (i) What are the time dependent and time independent Schrodinger's equations? Starting from Schrodinger's time dependent equation, obtain Schrodinger's time independent equation. (10)

(ii) Write the expressions of the probability density, $\rho(x, t)$ and the probability current density, $\vec{J}(x, t)$. Find the current density, $\vec{J}(x, t)$ carried by a plane wave,

$$\psi(x, t) = A \exp(ikx)$$

in one dimension. Can a real wave function have a current? (8)



4. (i) Explain quantum mechanical tunnelling phenomenon. Give example of any process which can be explained on the basis of this phenomenon. (3)

(ii) A particle of mass "m" is trapped inside a one-dimensional infinite potential well of length "L". Solve the time independent Schrodinger's equation for the system and obtain the eigen values and normalized eigen functions of the particle. Determine the three lowest normalized wave functions for an electron inside a one-dimensional infinite potential well of width $2\times10^{-10}$ m. (15)

P.T.O.