[This question paper contains 6 printed pages.]

Your Roll No. .....

Sr. No. of Question Paper : 1379 **A**

Unique Paper Code : 32221402

Name of the Paper : Elements of Modern Physics

Name of the Course : **B.Sc. (Hons.) Physics**

Semester : IV – CBCS Part–II

Duration : 3.5 Hours Maximum Marks : 75

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 **five** questions in all.
4. **All** questions carry equal marks.
5. Symbols have their usual meanings.

1. Attempt any **five** parts :

(a) If $f = x^n$, show that f is an eigen function of the operator $x\left(\frac{d}{dx}\right)$. Also find the eigenvalue.

P.T.O.

(b) David Beckham takes a free-kick of a football of mass 400 g. The curving ball moves with a velocity of 170 km/hr while reaching the goalpost. Find the deBroglie wavelength associated with the ball at that time. Will this wavelength have any physical significance for the goalkeeper facing the free-kick?

(c) Can the following two functions be physically acceptable solution of the Schrödinger wave equation

(i) (A/2) tan (x)

(ii) (3/2C) sin (x),

where A and C are non-zero constants.

(d) A 60 pm X-ray is incident on a calcite crystal. Find the wavelength of the X-rays scattered through an angle of 30°. What is the largest shift in wavelength that can be expected in this experiment?

(e) Find the combined kinetic energy of an electron and an antineutrino, when a free neutron decays into proton, electron and antineutrino. Given $m_n = 1.008984$ u, $m_p = 1.00759$ u, $m_e = 0.00055$ u, $1u = 1.673 \times 10^{-27}$ kg

(f) If ^{235}U loses 0.1% of its mass on undergoing fission, then how much energy is released when 1 Kg of ^{235}U undergoes fission?

(g) Why stimulated emission is necessary for lasing action? (5×3)

2. (a) The work function of potassium is 2.30 eV. UV light of wavelength 3000 Å and intensity $2Wm^{-2}$ is incident on the potassium surface.

(i) Determine the maximum kinetic energy of the photo electrons.

(ii) If 40% of incident photons produce photo electrons, how many electrons are emitted per second if the area of the potassium surface is 2 cm^2?

(b) The energy of a free electron including its rest mass energy is 10 MeV. Calculate the group velocity and the phase velocity of the wave packet associated with the motion of this electron.

(c) Deduce the Heisenberg's uncertainty principle for position and momentum from gamma ray microscope thought experiment. (5+5+5)

P.T.O.

3. (a) Explain why it is plausible to define probability current density in quantum mechanics by the following expression

$$J = (-i\hbar/2m)\ (\psi^* \text{ grad } \psi - \psi \text{ grad } \psi^*)$$

The symbols have usual meaning.

(b) Name and explain an electron diffraction experiment. Give the physical significance of this experiment in relation to the wave particle duality. (10+5)

4. (a) Explain nuclear binding energy and packing fraction. Discuss graphically the variation of average binding energy per nucleon with mass number, A and hence explain nuclear stability and phenomena of fusion and fission.

(b) Calculate the binding energy per nucleon of $_{26}Fe^{56}$ in MeV using semi-empirical mass formula. Given a_1 = 14.1 MeV, a_2 = 13.0 MeV, a_3 = 0.595 MeV, a_4 = 19.0 MeV, a_5 = 33.5 MeV. (10+5)

5. A particle of mass m is confined in a field free region between impenetrable walls at x=0 and x=L.

(a) Obtain an expression for energy of the particle.

(b) Obtain and draw the first three normalized wave functions.

(c) Find the minimum energy of the particle with mass 9.1×10^{-31} kg for L=1 Å. (5+5+5)

6. (a) Given the half life of ^{210}Po is 138 days, find

(i) the decay constant of Po.

(ii) the activity of 1 g of Po.

(iii) how many decays per second occur when the sample is one week old.

(b) What are the main differences among alpha, beta and gamma decay?

(c) Name and explain which conservation laws seemed to be violated in beta decay. How did Pauli resolve these discrepancies? (5+5+5)

7. (a) What are the assumptions made in liquid drop model of atomic nucleus? How do asymmetry and pairing of the nucleons affect the nuclear stability?

(b) How are decay constant, half-life and average life time of a radioactive nuclide related with one another? Derive the equations connecting them. (10+5)

Some Physical Constants

Planck constant, $h = 6.626 \times 10^{-34} Js$

$h = 1.055 \times 10^{-34} Js$

Boltzmann constant, $K_B = 1.38 \times 10^{-23} JK^{-1}$

Mass of electron, $m_e = 9.1 \times 10^{-31}$ kg

Charge of electron, $e = 1.6 \times 10^{-19}$ C

Speed of light in vacuum, $c = 3 \times 10^8 ms^{-1}$

Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8} Wm^{-2}K^{-4}$

Rest mass energy of electron = 512 KeV

Velocity of electron in free space = $3 \times 10^8 ms^{-1}$