This question paper contains 4+2 printed pages]

Your Roll No.....

1222

B.Sc. (Hons.)/II **A**

PHYSICS—Paper XII

(Quantum Mechanics and Nuclear Physics)

Time : 3 *Hours* *Maximum Marks* : 38

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

Attempt *one* question from each Section.

Q. No. 1 is compulsory.

Use of scientific calculator is allowed.

1. Attempt any *five* questions :

   (*a*) Determine the frequency of light needed to produce electrons of kinetic energy 3 eV from illumination of Lithium surface (work function = 2.93 eV).

   (*b*) What is the energy of γ photons having a wavelength of 1 Å ?

   (*c*) A microscope using photons is employed to locate an electron in an atom to within a distance of 0.2 Å. What is the uncertainty in the velocity of the electron located in this manner ?

P.T.O.

(*d*) If the lowest energy state wave function is :

$$\psi = \sqrt{\frac{2}{a}} \sin \frac{\pi x}{a},$$

determine the probability density at $x = \frac{a}{3}$.

(*e*) What are the values of S, L and J for the following states ?

(*i*) $^2P_{1/2}$

(*ii*) $^2D_{3/2}$

(*f*) Determine the ratio of the nuclear radii of C_6^{12} and O_8^{16}.

(*g*) A sample of F^{18} has $t_{1/2}$ = 110 minutes. How much time does it take for 99% of the F^{18} to decay ? 5×2

Section A

2. (*a*) What is Compton effect ? Derive an expression for the Compton shift. Show that the ratio of the kinetic energy of the recoil electron to the energy of the incident photon is :

$$\frac{\alpha (1 - \cos\theta)}{1 + \alpha (1 - \cos \theta)}$$

where $\alpha = \frac{h\nu}{m_0 C^2}$, ν is the frequency of incident radiation, m_0 is the rest mass of the electron and θ is the angle between the incident and scattered photon. 5

(*b*) An X-ray photon is found to have doubled its wavelength on being Compton scattered by 90°. Determine the wavelength of the scattered photon and the energy of the recoil electron. 2

3. (*a*) Describe the Davisson Germer experiment. How did this experiment verify the de Broglie hypothesis ? 4

(*b*) Prove that the de Broglie wavelength of a particle of rest mass m_0 and kinetic energy k is :

$$\frac{hc}{\sqrt{k(k+2m_0c^2)}}$$

where C is the velocity of light. 3

Section B

4. Consider a particle of mass m and energy E approaching a potential barrier of height V_0 and width L. Assume $E < V_0$, obtain an expression for the transmission coefficient T.

Prove that :

$$T = \frac{16E}{V_0}\left(1 - \frac{E}{V_0}\right)e^{-2kL}$$

in the limit $kL >> 1$ with $k^2 = \frac{2m}{\hbar^2}(V_0 - E)$. 7

5. (*a*) Using the radial equation for hydrogen atom :

$$\frac{d^2R}{dr^2} + \frac{2}{r}\frac{dR}{dr} + \frac{2m}{\hbar^2}\left(E + \frac{Ze^2}{4\pi\epsilon_0 r} - \frac{l(l+1)\hbar^2}{2mr^2}\right)R = 0$$

obtain an expression for the energy eigenvalues. 5

(*b*) The ground state wave function for hydrogen is :

$$\psi(r) = \frac{1}{\sqrt{\pi a_0^3}} e^{-r/a_0}$$

Calculate the probability of finding the electron at a distance less than a_0. 2

Section C

6. (*a*) Derive an expression for the total magnetic moment of an electron in an atom due to the interaction of its orbital and spin angular momenta. Hence obtain an expression for the Lande's 'g' factor. 5

(*b*) The quantum numbers of 2 electrons in a 2 valence electron atom are :

(*i*) $l_1 = 3, s_1 = 1/2$

(*ii*) $l_2 = 2, s_2 = 1/2$

Assuming L–S coupling, find the possible values of L and J. 2

7. (*a*) On the basis of quantum theory, explain the normal Zeeman effect. Derive the expression for the Zeeman shift. 5

(*b*) What is the value of Bohr magneton ? Use that value to calculate the energy difference between $m_l = 0$ and $m_l = +1$ components in the $2p$ state of atomic hydrogen placed in an external field of strength 2 Tesla. 2

Section D

8. Describe Gamow's theory of α decay of a radioactive substance. Discuss the agreement of this theory with the experimental results. 7

9. (*a*) Discuss the liquid drop model of the nucleus and derive the semi-empirical mass formula. State the advantages and disadvantages of this model. 5

(*b*) A sample of P_O^{210}, which α decays with a half life of 138 days, is observed to have 2000 disintegration/s : 2

(*i*) What is the activity in microcurie for this source ?

(*ii*) What is the activity in Becquerel ?

Physical Constants :

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

$C = 2.998 \times 10^{8}$ ms^{-1}

1 amu = 1.6605×10^{-27} kg

Rest mass of electron = 9.109×10^{-31}kg

$e = 1.6 \times 10^{-19}$ coulombs.