EASTERN UNIVERSITY, SRI LANKA

SECOND EXAMINATION IN SCIENCE - 2002/2003

FIRST SEMESTER

(JUNE/JULY 2003)

PH 201 ATOMIC PHYSICS AND QUANTUM MECHANICS

Time: 02 hour.

Answer ALL Questions

You may find the following information useful.

$e = 1.6 \times 10^{-19} Coulomb$
$m_e = 9.1 \times 10^{-31} Kg$
$h = 6.6 \times 10^{-34} Js$
$\varepsilon_0 = 8.85 \times 10^{-12} Fm^{-1}$
$c = 3 \times 10^8 ms^{-1}$
$1eV = 1.602 \times 10^{-19} J.$
The symbols have their usual meanings.

1. (i) State the postulates of the Bohr Theory of the Hydrogen atom. Use these postulates to derive an expression for the total energy of the electron in the n^{th} orbit of the Hydrogen atom. Briefly account the limitations of Bohr Theory.

   (ii) A Hydrogen-like atom is formed when a μ-meson of mass $210m_e$ and charge e is captured by a doubly ionized Helium (He^{++}) ion where m_e and e are the mass and the charge of the electron respectively. Calculate the energy(in eV) of the μ-meson when it is in the $n = 2$ orbit.

2. What is Zeeman effect?. Distinguish between normal and anomalous Zeeman effect. Explain the effect of magnetic field on energy levels of an atom in Zeeman effect on the basis of quantum theory and obtain an expression for Zeeman shift.
   The Zeeman components of a $500nm$ spectral line are $0.0116nm$ apart when the magnetic field is $1.00T$. Find the ratio of $\frac{e}{m}$ for the electron.

3. State the Heisenberg uncertainty principle which refers to the simultaneous determination of the position and the momentum of the particle. Describe this principle with examples.
   The velocity of an electron and that of a riffle bullet of mass $30gram$ are measured with an uncertainty of $\triangle V_x = 10^{-3}ms^{-1}$. Determine the minimum uncertainties in their positions using Heisenberg uncertainty principle. Discuss your results of minimum uncertainties in positions of electron and bullet.

4. The wave function $\psi(x,t)$ for a lowest energy state of a simple harmonic oscillator can be expressed as

$$\psi(x,t) = Ae^{-\left(\frac{\sqrt{Cm}}{2\hbar}\right)x^2}e^{-\left(\frac{i}{2}\right)\sqrt{\frac{C}{m}}t}$$

   where A, C are constants and the other symbols have their usual meanings.

   (i) verify that this expression is a solution of the time dependent Schrodinger equation for the potential given by $V(x) = \frac{Cx^2}{2}$

   (ii) using normalization condition show that

$$A = \frac{(Cm)^{\frac{1}{8}}}{(\pi\hbar)^{\frac{1}{4}}}$$

(iii) find the expectation value of x and x^2

You may find the following information useful.

$$I_n = \int_0^\infty x^n e^{-\lambda x^2} dx$$

, and when

$$n = 0, \quad I_0 = \frac{1}{2}\left(\frac{\pi}{\lambda}\right)^{\frac{1}{2}}$$

when

$$n = 1 \quad I_1 = \frac{1}{2\lambda}$$

and when

$$n = 2 \quad I_2 = \frac{1}{4}\left(\frac{\pi}{\lambda^3}\right)^{\frac{1}{2}}$$

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