EASTERN UNIVERSITY, SRI LANKA

SECOND EXAMINATION IN SCIENCE 2005/2006 (AUG-SEP. 2007)

FIRST SEMESTER

REPEAT

PH 201 - ATOMIC PHYSICS AND QUANTUM MECHANICS

Time: 02 hours.
Answer ALL Questions.

You may use the following information.

Electron charge $e = 1.6 \times 10^{-19}\, C$
Mass of an electron $m_e = 9.109 \times 10^{-31}\, kg$
Permittivity in free space $\varepsilon_0 = 8.85 \times 10^{-12}\, Fm^{-1}$
Velocity of light $c = 3 \times 10^{8}\, ms^{-1}$
Planck's constant $h = 6.625 \times 10^{-34}\, Js$

01. Derive Rutherford's Scattering formula and mention the important features of Rutherford's Scattering of α-particles by gold foil, which supported the nuclear model of the atom against Thomson's model.

Calculate the distance of closest approach when α particles of energy $5MeV$ are scattered back by a thin sheet of copper $(Z = 29)$.

02. State the postulates of the Bohr theory.

Derive an expression for total energy of the allowed state and frequency of the electromagnetic radiation, emitted in a transition between two states, of a Bohr atom.

(a) In respect of transition between adjacent states of quantum numbers n and $n+1$, find the relevant frequency of radiation, and show that when n is very large, this frequency is equal to the frequency of orbital motion of the electron in the n^{th} orbit.

(b) A beam of electrons bombards a sample of hydrogen atom. Through what potential difference must the electrons have been accelerated if the first line of Balmer series is to be emitted?
The ionization energy of hydrogen atom is $13.6eV$.

03. State the Heisenberg uncertainty principle which refers to the simultaneous determination of the position and the momentum of the particle.
Describe this principle with an example.

The velocity of an electron and that of a riffle bullet of mass $30gram$ are measured with an uncertainty of $\Delta V_x = 10^{-3} ms^{-1}$. Determine the minimum uncertainties in their positions using Heignberg uncertainty principle and discuss the results.

04. (a) The wave function of the electron in a hydrogen atom is given by

$$\psi(r) = Ae^{-\left(\frac{r}{a}\right)}$$, where A and a are constant.

Estimate,
(i) the normalization constant
(ii) the expectation of position of the electron

You may assume that $\int_0^\infty r^n e^{-\left(\frac{r}{a}\right)} dr = n! a^{n+1}$.

(b) (i) Write down the time-independent Schrödinger equation in a rectangular Cartesian Co-ordinate system, for a particle of mass m and energy E moving in a potential V.

(ii) Calculate the possible values of energies for an electron in an atom which may be considered as a particle moving inside an infinite square potential well of width a, described by

$$V = 0,\ 0 \le x \le a$$
$$V = \infty,\ |x| \ge a.$$