EASTERN UNIVERSITY, SRI LANKA

SECOND EXAMINATION IN SCIENCE - 2009/2010

FIRST SEMESTER (PROPER/REPEAT)

(June 2011)

PH 201 ATOMIC PHYSICS AND QUANTUM MECHANICS

Time: 02 hour.

Answer ALL Questions

Mass of an electron $m_e = 9.109 \times 10^{-31}\ kg$

Planck's constant $h = 6.625 \times 10^{-34}\ J\,s$

Velocity of light in free space $c = 3 \times 10^{8}\ m\,s^{-1}$

1. Briefly describe the Compton experiment together with the experimental results. Derive the Compton's description to explain the observed shift in the wavelength $\Delta\lambda = \frac{h}{m_e c}(1 - Cos\phi)$, where ϕ is an angle of scattered photon to the direction of the incident beam.

A beam of x-rays of wavelength 1.00 Å is incident on a carbon target. The scattered x-rays are detected at an angle of 90^o to the direction of the incident beam. Find the Compton shift in the wavelength.

2. The electron configuration of an atom determines it's physical and chemical properties. How many quantum numbers are needed to completely describe an electron in an atom? Describe these with their notations.

   a. State *Pauli's Exclusion Principle* and *Hund's Rule* for filling electrons in atomic orbital.

   b. Outline the allowed combinations (values) of quantum numbers of electrons in an atom.

   c. Identify the combinations (values) of electronic quantum numbers of Carbon (Z=6) atom.

   d. Outline the order of electron filling in the 2p orbital of Fluorine (Z=9) atom and find it's spin quantum number.

3. State the *Heisenberg's uncertainty principle* associated with time-energy and position-momentum.

An atom can radiate at any time after it is excited. It is found that in a typical case the average excited atom has a life time of about 10^{-8} sec. i.e. during this period it emits a photon and is de-excited.

a) Calculate the uncertainty ΔE in the energy of the excited state of the atom.
b) What is the minimum uncertainty $\Delta \upsilon$ in the frequency of the photon?
c) Most photons from Sodium atoms are in two spectral lines at about wavelength $\lambda = 5890$ Å. What is the fraction $\dfrac{\Delta \upsilon}{\upsilon}$ of either line?

4. A particle of mass m and Energy E is moving in a potential V inside an infinite square potential well of width a, described by,

$$V = 0, \quad for\ 0 \le x \le a$$
$$V \to \infty, \quad for\ x > a\ \&\ x < 0$$

a) Write down the time-independent Schrödinger equation in a rectangular cartesian co-ordinate system, for the motion of the particle.
b) State clearly the boundary conditions and normalization condition for the wave function $\varphi_{(x)}$.
c) Using the above conditions, show that the wave function of the particle is $\varphi = \sqrt{\dfrac{2}{a}} \sin\left(\dfrac{n\pi}{a}\right)x$.
d) Calculate the possible values of Energies E_1, E_2, E_3 for an electron in an atom.