EASTERN UNIVERSITY, SRI LANKA

SECOND EXAMINATION IN SCIENCE – 2014/2015

FIRST SEMESTER (PROPER)

PH 201 ATOMIC PHYSICS AND QUANTUM MECHANICS

Time : 02 hour

Answer ALL Questions

Calculator allowed.

You may find the following information useful.

Planck's constant $h = 6.63 \times 10^{-34}\ Js$

Rydberg constant $R_H = 1.097 \times 10^{7} m^{-1}$

Light speed $c = 3 \times 10^{8}\ ms^{-1}$

$1\ eV = 1.602 \times 10^{-19}\ J$

(1)

a. State the postulates of the Bohr theory of a Hydrogen atom. ...(20% marks)

b. Briefly account the limitations of Bohr theory. ...(15% marks)

c. Use these postulates to derive an expression for the total energy of an electron in the n^{th} orbit of the Hydrogen atom. ...(20% marks)

d. Hence show that the wavelength of the electromagnetic radiation emitted in a transition between two states of a Bohr atom is ...(10% marks)

$$\frac{1}{\lambda} = R_H \left[\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2} \right],$$

where λ is the wavelength of the radiation, R_H is the Rydberg constant and n_i and n_f are integers.

e. The Balmer series for the hydrogen atom corresponds to electronic transitions that terminate in the state with quantum number $n = 2$.

i. Find the longest-wavelength photon emitted in the Balmer series and determine its frequency and energy. ...(20% marks)

ii. Find the shortest-wavelength photon emitted in the same series. ...(15% marks)

(2)

a. What do you mean by Zeeman effect and explain briefly the nature of Zeeman effect in a magnetic field. ...(25% marks)

b. State Selection rules for allowed transitions of electron between energy levels in the presence of magnetic field and electron spin. ...(25% marks)

c. Examine the Zeeman spectrum produced by hydrogen atoms initially in the $n = 2$ state when electron spin is taken into account, assuming the atoms are to be in a magnetic field of strength $B = 1.00$ T and the g factor is 2. ...(50% marks)

You may assume the magnetic energy $U = \frac{eh}{2m_e} B(m_l + gm_s)$, where symbols have their usual meaning.

3) What is photoelectric effect? Explain the photoelectric effect experiment by means of a schematic diagram of experimental arrangement. Describe how the classical physics fails to explain the observations in the experiment. ...(40% marks)

Express the energy transfer by means of Einstein's photoelectric equation, relating to measurable quantities in the experiment.

Light of frequency 1.5×10^{15} Hz is incident on an aluminium surface, which has a work function of 4.2 eV. Calculate,

i. the maximum kinetic energy of the photoelectrons;

ii. the stopping potential;

iii. the cut-off frequency.

State the De Broglie's hypothesis and hence find the wavelength of the highest energetic photoelectrons in part (i) above. ... (60% marks)

4) For a particle of mass m moving along the x-direction with momentum p and kinetic energy $E(=p^2/2m)$, the time-dependent position $\psi(x,t)$ is given by

$$\psi(x,t) = A_0 \exp\left\{i\left(\frac{p}{\hbar}x - \frac{E}{\hbar}t\right)\right\},$$

where A_0 is a constant. Show that the momentum and kinetic energy may be represented by the operators $-i\hbar\frac{\partial}{\partial x}$ and $-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$ respectively, where $\hbar = h/2\pi$. ...(35% marks)

The wave function of a particle confined in a one-dimensional infinite potential well of width L is given by $\psi(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$, where $n = \pm1, \pm2, \pm3, \ldots$.

Show that

i. the expectation value of energy of a particle of mass m confined in the well is

$$\langle E \rangle = \frac{h^2}{8mL^2} n^2 ;$$ ...(30% marks)

ii. the average momentum $\langle p \rangle$ of a particle confined in the infinite potential well is zero.

...(25% marks)

For an electron confined in an infinite potential well of width 1 Å find the electronic ground state energy. ...(10% marks)