EASTERN UNIVERSITY, SRI LANKA

SECOND EXAMINATION IN SCIENCE – 2015/2016

FIRST SEMESTER (PROPER/REPAET)

(NOVEMBER/DECEMBER 2017)

PH 201 ATOMIC PHYSICS AND QUANTUM MECHANICS

Time: 02 hour

Answer ALL Questions

Calculator allowed.

You may find the following information useful.

Electron Charge $e = 1.602 \times 10^{-19}\,\mathrm{C}$

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

Permittivity in free space $\varepsilon_o = 8.854 \times 10^{-12}\,\mathrm{Fm}^{-1}$

Velocity of light $c = 3 \times 10^{8}\,\mathrm{ms}^{-1}$

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

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

(1) a) Explain the experimental observations that suggest particle nature electromagnetic radiation. ... (30% mark

b) Explain how wave character of an electron beam is established by Davisso Germer Experiment. ... (30% mark

c) A beam of X- rays of wavelength 0.01 nm is incident on a carbon target. T scattered X-rays are detected at an angle of 60^0 to the direction of the incide beam. Find the wavelength of the scattered X-rays. Explain why the wavelen of scattered X-rays is different from the incident X-rays? ... (40% mark

You may take the observed Compton shift is $\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$, where ϕ is t scattered angle of X-rays, and other symbols have their usual meanings given front page.

(2) a) Name three experimental evidences for the existence of atoms. ... (15% mark

b) Atomic and molecular spectra are discrete. What does discrete mean? ...(10% mark

c) Briefly describe how is the de Broglie wavelength of electrons related to t quantization of their orbits in atoms and molecules? ... (15% mark

d) Briefly explain the important features of Rutherford's scattering of α-particles gold foil, which supported the nuclear model of the atom against Thomso model. ... (15% mark

i. Show that the Rutherford's scattering formula is,

$$b = \frac{Qq_\alpha}{4\pi\varepsilon_o m_\alpha v^2}\cot\frac{\vartheta}{2}$$ with usual notations.

... (25% mark

ii. A 5 MeV α-particles approaches a gold (Z=79) nucleus with an impa parameter of 2.6×10^{-13} m, through what angle will it be scattered. ... (20 % mark

(3)

a) Motivate the single-particle wave-function using the modified Young's double slit experimental observations, and interpret the physicality of a particle when undetected and detected. ... (35% marks)

b) Define *probability amplitude* and *expectation value* with their physical meaning. ...(15% marks)

c) The single-particle 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 $\langle E\rangle=\frac{h^2}{8mL^2}n^2$; ...(25% marks)

ii. the average momentum $\langle p\rangle$ of a particle confined in the infinite potential well is zero. ...(25% marks)

You may take the *momentum* and *kinetic energy* operators to be $-i\hbar\frac{\partial}{\partial x}$ and $-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$ respectively, where $\hbar = h/2\pi$.

(4)

a) Define the term *angular momentum* and *intrinsic spin angular momentum*. ... (10% marks)

b) Explain the physical significance of quantum numbers, which are characterize the energy level of the electron in a hydrogen atom. Write down the allowed values for each quantum numbers? ... (20% marks)

c) State the *selection rules* for one electron spectra. ... (10% marks)

d) State Pauli's exclusion principle for electron in an atom and show that each shell has maximum of $2n^2$ electrons, where n is the principle quantum number. ...(15 % marks)

e) Briefly describe the spin-orbit coupling in an atom? How does it lead to the observed fine – structure splitting of the spectral lines of the hydrogen atom? ... (10% marks)

f) Distinguish between *normal* Zeeman effect and *anomalous* Zeeman effect. ... (10% marks)

g) Consider a hydrogen atom excited to the n = 3 state is placed in a magnetic fi
the component of the magnetic quantum number m_l is along the external fi
direction.

i. Evaluate the splitting of the energy levels according to the values of m_l.
...(10 % mark

ii. Draw split level diagram and spectrum of a hydrogen atom excited to the n
3 state, when it is placed in a magnetic field. ...(15 % mark

You may use the magnetic potential energy is $\hbar\omega_L m_l$ with usual notations.