RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Second Year - Semester II Examination – October/ November 2017

PHY2105 – QUANTUM MECHANICS

Time: One (01) hour

Answer any two questions.

Use of a non-programmable calculator is permitted.

Symbols have their usual meaning.

Some fundamental constants and physical data:

Electron mass $m_e = 9.1 \times 10^{-31}$ kg	Planck constant $h = 6.626 \times 10^{-34}$ J s
Speed of light in vacuum $c = 3.0 \times 10^{8}$ m s^{-1}	Electron volt (1 eV) = 1.6×10^{-19} J
Bohr radius $a_0 = 0.529 \times 10^{-10}$ m	Proton mass $m_p = 1.672 \times 10^{-27}$ kg

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1. (a) i. What is Compton effect? **(06 marks)**

ii. What are the assumptions made to explain the above effect? **(07 marks)**

iii. Considering the Compton effect, how would you compare the scattering of photons from bound and free electrons? **(10 marks)**

(b) i. A photon of frequency ν is scattered from a free electron at rest through an angle θ. Show that the energy of the scattered photon $h\nu'$ is equal to $\frac{h\nu}{1+\alpha(1-\cos\theta)}$, where $\alpha = h\nu / m_0 c^2$, m_0 being the rest mass of the electron and ν' is the frequency of the scattered photon.

Hint: Compton shift is $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c}(1-\cos\theta)$. **(15 marks)**

Contd.

ii. For what wavelength of photon does Compton scattering result in a photon whose energy is one-half that of the original photon at a scattering angle 0f 45^0. In which region of the electromagnetic spectrum does such a photon lie? **(12 marks)**

2 (a) i. State Heisenberg's uncertainty principle **(06 marks)**

ii. Describe how the single-slit diffraction experiment using an electron beam illustrates the uncertainty principle. **(10 marks)**

(b) Synapse is a junction that permits a neuron to pass an electrical or chemical signal to another cell in the nervous system. Suppose we have an electrical synapse. They provide a narrow gap between the pre- and post synaptic cells of about 3.5 nm rather than the 20 to 40 nm distance of chemical synapses. If the electron is transmitted from one neuron to the other with a velocity of 5 x 10^6 m s^{-1} with an accuracy of 10% due to variable properties of the synapse;

i. What is the uncertainty in the position of the electron? **(10 marks)**

ii Suppose that the electron described above is not in a synapse, but rather in a hydrogen atom in one of the orbitals around the nucleus. Then, where could be the electron if we assume the 10% uncertainty in the speed?
Diameter of the atom = 1 x 10^{-10} m. **(08 marks)**

iii. If we specify the velocity to be 1% of 5 x 10^6 m s^{-1}, how many atoms (approximately) are needed to delocalize the electron? **(08 marks)**

(c) "Electron Microscope is more suited to see objects of atomic size than an optical microscope". Justify this statement. **(08 marks)**

3. (a) Consider a particle of mass *m*, moving in a one-dimensional infinite square well of width *L*, such that the left corner of the well is at the origin. Obtain the energy eigenvalues and the corresponding normalized wavefunctions of the particle. **(20 marks)**

Contd.

(b) An electron is contained in a one-dimensional box of width 0.1 nm.

i. Draw an energy level diagram for the electron for levels up to $n = 4$.
(06 marks)

ii. Find the wavelengths of all photons that can be emitted by the electron in making transitions that would eventually get it from the $n = 4$ state to the $n = 1$ state. **(14 marks)**

(c) In Quantum mechanics it is possible for the energy E of a particle to be less than the potential energy, but classically this is not possible. Explain.
(10 marks)

End.