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RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Second Year - Semester II Examination – September/ October 2020

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

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1. a) i. What is Compton effect? Give a schematic diagram of an experimental arrangement for observing this effect. **(12 marks)**

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

iii. The Compton scattering formula suggests that objects viewed from different angles should reflect light of different wavelengths. Explain why don't we observe a change in color of objects as we change the viewing angle? (Use the following data; the wavelength of green light from a mercury vapor streetlight is 546.1 nm, the maximum Compton shift of this light would occur when it's backscattered at 180^0) **(12 marks)**

Contd.

b) i. Show that when a photon of energy E is scattered from a free electron at rest, the maximum kinetic energy of the recoiling electron is given by

$$k_{max} = \frac{E^2}{E+\frac{m_e c^2}{2}}$$

Hint: Compton shift is $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1-\cos\theta)$. **(12 marks)**

ii. In a Compton scattering a photon cannot transfer all of its energy to a free electron. Give an example where a photon is able to transfer all its energy to a free electron. **(07 marks)**

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

ii. A classical physicist wants to use the Heisenberg microscope to disprove the uncertainty principle. To reduce the unknown momentum imparted to the electron, he reduces the lens diameter to one-third of its original value. How does this change the product of $\Delta P_x \Delta x$? **(10 marks)**

iii. Having failed to disprove the uncertainty principle in a) ii, he tries to reduce Δx by halving the object distance l. How does this change the product of $\Delta P_x \Delta x$? **(09 marks)**

b) i. Calculate the uncertainty in the momentum of a proton confined in a nucleus of radius 10^{-14} m. Thus, estimate the kinetic energy of the proton. **(15 marks)**

ii. How does the answer to b) i change if the value of the Planck constant is assumed to be 2π J s. **(10 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 wave functions of the particle. **(20 marks)**

Contd.

b) i. The lowest energy possible for a particle entrapped in a box is 40 eV. What are the next three higher energies that the particle can have? **(10 marks)**

ii. Can we measure the energy levels of a ball of mass 10 g moving in a one-dimensional box of length 10 cm? Explain. **(10 marks)**

c) In Quantum mechanics it is possible for the energy E of a particle to be less than the potential energy, but not in classical mechanics. Explain.

(10 marks)

End.