RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

BSc in Applied Sciences
Second Year - Semester I Examination – June/ July 2022

PHY2105 – QUANTUM MECHANICS

Time: One (01) hour

Answer any two questions.

Symbols have their usual meaning.
Calculators are provided.

Some useful information:

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

$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\Delta x \Delta p \geq \frac{\hbar}{2}$

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

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1. a) The energy-time Heisenberg uncertainty principle is useful in the determination of natural linewidth $\Delta\lambda$ of photons emitted from atoms when electrons change orbits.

   i. Obtain the energy-time uncertainty relation using Heisenberg's uncertainty relation for position and momentum.

   (10 marks)

   ii. The average lifetime of an excited atomic state is 10^{-8} s. If the wavelength of the spectral line associated with the transition from this state to the ground state is 6000 $\overset{0}{\mathrm{A}}$, estimate the linewidth.

   (16 marks)

Contd.

b) Evaluate the validity of the statement: *Measurements are continually being refined so that in the future there will come a time when scientists will be able to measure the exact position and velocity of a small particle such as an electron.* (10 marks)

c) Assume that the uncertainty in the position of a particle is equal to its de Broglie wavelength. Show that the uncertainty in its velocity is equal to or greater than $1/(4\pi)$ times its velocity. (14 marks)

2. The photoelectric effect is the process of interaction between light and metal in which electrons from metal are emitted when light irradiates metal. Einstein extended Planck's idea to explain this effect.

a) UV light of wavelength λ incident on an emitter surface gives rise to photoelectrons with maximum kinetic energy 2.0 eV whereas for a wavelength of $3\lambda/4$, the maximum kinetic energy of emitted photoelectrons from the same surface is 3.47 eV.

i. Calculate the wavelength λ (in nm) of these UV light. (10 marks)

ii. Find the work function of the emitter. (07 marks)

b) Explain why don't the metals in your home lose their electrons when you turn on the lights? (07 marks)

c) Values of stopping potential (V_0) versus the wavelength (λ) for the photoelectric effect using Sodium are as follows:

$\lambda(\pm 2$ nm$)$	200	300	400	500	600
$V_0(\pm 0.01$ volts$)$	4.20	2.06	1.05	0.41	0.03

i. Plot these data roughly. (10 marks)

Answer questions (ii) and (iii) from the graph obtained for question (i)

ii. The work function (in eV) of Sodium (07 marks)

iii. The ratio $\frac{h}{e}$, and compare with the known value. (09 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 eigenfunctions (wave functions) of the particle. (16 marks)

b) An electron that has an energy approximately 6.0 eV moves between rigid walls which are 1.0 nm apart.

i. Find the quantum number n for the energy state that the electron occupies (10 marks)

ii. Calculate the precise energy of the electron. (08 marks)

c) Explain the followings,

i. 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. (08 marks)

ii. The probability density at certain points for a particle in a box is zero. Does this imply that the particle cannot move across these points? (08 marks)

End.