RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

Bachelor of Science in Applied Sciences
Second Year - Semester I Examination – July/August 2023

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
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
Stefan Boltzman Constant $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
$\Delta x \Delta p \geq \frac{\hbar}{2}$

---

1. 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)**

Contd.

c) An electron is confined to a tube of length L. The electron's potential energy in one half of the tube is zero, while the potential energy in the other half is 10 eV. If the electron has a total energy $E = 15$ eV,

i. what will be the ratio of the De Broglie wavelength of the electron in the 10 eV region of the tube to that in the other half of the tube? **(08 marks)**

ii. sketch the wave function ψ for the electron along the tube. **(08 marks)**

2. a). The general meaning of energy-time uncertainty principle is that a quantum state that exists for only a short time cannot have a definite energy.

i. Obtain the energy-time uncertainty relation using Heisenberg's uncertainty relation for position and momentum. **(12 marks)**

ii. If the uncertainty in the time during which an electron remains in an excited state is 10^{-7} s, what is the least uncertainty in the energy (in J) of the excited state? **(10 marks)**

iii Is it possible to calculate the lifetime of a short lived excited state using the uncertainty principle? Justify your answer. **(10 marks)**

b) i. If Planck's constant was $h' = 660$ J s, what would be the de Broglie wavelength of a 100 kg football player running at 5 m s^{-1}? Determine the least uncertainty of his location if the uncertainty in his momentum is equal to his momentum. **(10 marks)**

ii. Explain why we don't notice Heisenberg's uncertainty principle in everyday life. **((08 marks)**

3. The total power per unit area from a blackbody radiator can be obtained by integrating the Planck's radiation formula $I(\lambda,T) = \dfrac{2\pi hc^2}{\lambda^5(e^{hc/\lambda kT}-1)}$ over all wavelengths. This will leads to the Stefan-Boltzman law of blackbody radiation $E = \sigma T^4$, where E and T are the total power per unit surface area and the surface temperature in kelvins of the blackbody respectively.

Contd.

a) What is it meant by ultraviolet catastrophe? **(10 marks)**

b) The Sun behaves like an idealized blackbody. The dark center of Sunspots (irregularly shaped dark regions of the surface of the Sun) also behaves like an idealized blackbody. The dark center of a Sunspot emits 35% of radiation compared to an equal area on the surface of the Sun without Sunspots. The Surface temperature of the Sun is estimated to be 5700 K.

i. Calculate the temperature of the dark center of the Sunspot. **(12 marks)**

ii. Using the Weins displacement law $\lambda_{max}T = 0.0029$ m K, calculate the shift in the wavelength of the peak emission of radiation from the dark center of Sunspot compared to the wavelength of peak emission of radiation from the normal surface of the Sun. **(18 marks)**

iii. What changes in appearance would you expect to observe in the Sun, if the number of Sunspots per unit area of the Sun's surface increases significantly? Explain your answer using the blackbody radiation spectrum. **(10 marks)**

End.