MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS 2023/2024

FOURTH YEAR SECOND SEMESTER EXAMINATION

FOR

THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS AND BACHELOR OF EDUCATION (SCIENCE)

PHY4245-1: QUANTUM MECHANICS II

QUESTION PAPER

DATE: 17th APRIL, 2024.   TIME: 0830-1030___ Hrs

Duration: 2 Hours

INSTRUCTIONS

1. This paper contains FOUR (4) questions.
2. Question ONE (1) is mandatory and contains 20 mks.
3. Answer any other Two (2) questions @ 15mks each.
4. Do not forget to write your Registration Number.
5. Read through the instructions on the answer booklet carefully.

You may use the following Integral formulae

- $\int r^{2n+1} e^{ar^2} dr = 0$

- $\int_{-\infty}^{\infty} r^{2n} e^{-ar^2} dr = \frac{1 \times 3 \times 5 \times .....(2n-1)}{(2\alpha)^n} \sqrt{\frac{\pi}{\alpha}}$

- $\int_{-\infty}^{\infty} r^n e^{\alpha x} dx = \frac{n!}{\alpha^{n+1}}$

QUESTION ONE (20 MARKS)

a) State the equation for potential energy of a hydrogen atom. [1]

b) Briefly explain the **Four** quantum numbers and state which ones define the wave function of a quantum mechanical electron particle.   [4]

c) Explain **one** applications of Scattering.   [1]

d) All Hermitian matrices are normal. Explain   [2]

e) In the special case of spin-1/2 σ_x, σ_y and σ_z are the three Pauli matrices.

   Define σ_y [2]

f) Explain the wave function postulate in quantum mechanics.   [2]

g) Explain one application of perturbation theory in simplification of a quantum mechanical approximation.   [2]

h) Quantize the three components of angular momentum operators L_x, L_y, and L_z [3]

i) Obtain the energy up to the first order perturbation for harmonic oscillator in an external field given by $\lambda H_1 = bx^2$.   [3]

QUESTION TWO (15 MARKS)

a) Explain the Variation method in quantum mechanics. [3]

b) Given the trial function $\psi(r) = Ce^{-ar}$, Compute the values for:

    (i) $H\psi(r)$ [3]

    (ii) $\psi^* H\psi(r)$ [3]

c) Hence obtain an approximate value for the lowest energy of hydrogen atom using variation principle. [6]

QUESTION THREE (15 MARKS)

a) What are the three causes of perturbation in a system of particles? [6]

b) Briefly explain the term 'an harmonic oscillator'? [2]

c) Solve an an-harmonic oscillator problem with the Hamiltonian to the first energy and eigen value approximation. [7]

$$\hat{H} = -\frac{h^2}{2\mu}\frac{\partial^2}{\partial x^2} + \frac{1}{2}kx^2 + \frac{1}{6}\gamma x^3$$

QUESTION FOUR (15 MARKS)

a) Distinguish between lowering and raising operators in quantum mechanical systems. [2]

b) Show that:

    (i) $\left[\hat{H}, \hat{a}^+\right] = h\omega\hat{a}^+$. [4]

    (ii) $\left[\hat{a}, \hat{a}^+\right] = 1$ and [4]

    (iii) $\hat{H} = h\omega\left(\hat{a}^+\hat{a} + \frac{1}{2}\right)$ [5]

END