KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

FIRST SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF MASTERS (PHYSICS)

COURSE CODE: SPH 812

COURSE TITLE: QUANTUM MECHANICS

DURATION: 2 HOURS

DATE: 13/12/2022   **TIME: 9:00-11:00AM**

INSTRUCTIONS TO CANDIDATES
- Answer **any three** (3) Questions.
- Indicate **answered questions** on the front cover.

Start every question on a new page and make sure question's number is written on each page

This paper consists of **3** printed pages. Please Turn Over

KIBU observes ZERO tolerance to examination cheating

QUESTION ONE [20 Marks]

[@ 1Mark]

a) Explain the meaning of the following terms;
(i) State vector
(ii) Linear operator
(iii) Orthogonal eigen vector
(iv) Bra of a vector space
(v) Dynamical variable
(vi) Scattering amplitude

b) Show that the momentum and kinetic energy operators are hermitian. [8Marks]

c) Show that (i) $[L_x, L_y] = i\hbar L_z$ (ii) $[L_x, y] = i\hbar Z$ [6Marks]

QUESTION TWO [20 Marks]

a) What is a perturbation method? [4 Marks]
b) Differentiate between degenerate and non-degenerate perturbation theory [4 Marks]
c) Assuming a non-degenerate system with an unperturbed Hamiltonian H_0 with eigenstate $|n>$ and energy ε_n with a perturbing Hamiltonian V, show that the first energy correction is given by $\langle n|V|n \rangle$ [6 Marks]
d) Consider a perturbation of the form $\frac{1}{2}bx^2$ to the linear harmonic oscillator problem and determine the associated angular frequency, w_n [6 Marks]

QUESTION THREE [20 Marks]

a) Write down the Pauli matrices σ_x, σ_y and σ_z [3Marks]
b) Show that they are Hermitian matrices [3Marks]
c) Obtain the values of σ_x^2, σ_y^3 and $\sigma_x^2 + \sigma_y^2 + \sigma_z^2$ [5Marks]
d) Obtain the values of $\sigma_x\sigma_y$, $\sigma_y\sigma_z$ and $\sigma_z\sigma_x$ [3Marks]
e) Show that the only matrix which commutes with the spin matrices is a multiple of the unit matrix [6Marks]

QUESTION FOUR [20 Marks]

a) Define the term 'differential cross section' in scattering theory [2Marks]
b) Explain the general procedure for determination of differential cross section using the Born approximation [5Marks]
c) Explain the main ideas of the Born approximation and Born series [5Marks]
d) Elastic scattering from heavy nucleus can be represented by;
$$v(r) = \begin{cases} -v_0, & r < R \\ 0, & r > R \end{cases}$$

Use the Born approximation in the central field potential to calculate the differential cross section in the lowest order in v(r) [8Marks]

QUESTION FVE [20 Marks]

a) What is variation method? [4Marks]

b) List and explain the steps for the application of the variation method for the determination of ground state energies [8Marks]

c) Consider a particle of mass, m bouncing vertically and elastically in the z-direction on a reflecting hard floor. Treat this as a quantum particle and write down a possible trial wave function and the Hamiltonian of the system [8Marks]

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