



# 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

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### 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]

a) Explain the meaning of the following terms;

[@ 1Mark]

- (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  $|n\rangle$  and energy  $\epsilon_n$  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,  $\omega_n$

[6 Marks]

### QUESTION THREE [20 Marks]

a) Write down the Pauli matrices  $\sigma_x$ ,  $\sigma_y$  and  $\sigma_z$

[3Marks]

b) Show that they are Hermitian matrices

[3Marks]

c) Obtain the values of  $\sigma_x^2$ ,  $\sigma_y^2$  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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