



# KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS  
2020/2021 ACADEMIC YEAR

FIRST SEMESTER  
MAIN EXAMINATIONS

FOR THE DEGREE OF MASTERS (PHYSICS)

**COURSE CODE:** SPH 812

**COURSE TITLE:** QUANTUM MECHANICS

**DURATION:** 2 HOURS

**DATE:** 15<sup>TH</sup> JUNE 2021      **TIME:** 2.00P.M – 4.00P.M

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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]
- State vector
  - Linear operator
  - Orthogonal eigen vector
  - Bra of a vector space
  - Angular momentum
  - Dynamical variable
  - Scattering amplitude
  - Adjoint of an operator
- b) Show that eigenvalues and eigen-functions of Hermitian operators are real and orthogonal respectively [6Marks]
- 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,  $w_n$  [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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