KISII UNIVERSITY

UNIVERSITY EXAMINATIONS

SPECIAL EXAMINATION

FOURTH YEAR EXAMINATION FOR THE AWARD OF THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

FIRST SEMESTER 2021/2022

(JULY, 2022)

PHYS 411: QUAMTUM MECHANICS

STREAM: Y4 S1 **TIME: 2 HOURS**

DAY: THURSDAY, 8:00 AM – 10:00 AM **DATE: 28/07/2022**

INSTRUCTIONS:

1. ***Do not write anything on this question paper.***
2. ***Answer Question ONE (Compulsory) and any other TWO questions.***

QUESTION ONE

a) What are the Main differences between spin wave function and the regular wave function? [2 marks]

b) Define the term Hermitian operator and using the wave function ($\boldsymbol{\psi}$) gives its mathematical expression. [2 marks]

c) Show that: [4mks]

$$L_+L_- = L^2 - L_Z^2 + \hbar L_Z$$

d) Derive the following commutation relationship: [4 marks]

i. $[L_+, L_Z] = -\hbar L_+$

ii. $[L_-, L_Z] = -\hbar L_-$

e) Given that the electrons total momentum vector is given by; [4 marks]
$J = LxS$and that $L \times L = i\hbar L$ and $S \times S = i\hbar s$
Find $J \times J$

f) What problem does stationary perturbation theory try to solve in quantum mechanics. [2 marks]

g) Differentiate between degenerate perturbation theory and non-degenerate perturbation theory. (4 marks)

h) Prove that;
$J^2 = L^2 + S^2 + 2L.s$ [4 marks]

i) Write $L_x, L_y \; and \; L_z$ in the spherical polar coordinates using r, $\theta \; and \; \varphi$. [3 marks]

QUESTION TWO

a) Systematically show that in the degenerate perturbation theory, the first order correction in the energy is given by; [10 marks]

$\sum_{\alpha=1}^{f}(\widehat{H}_{P,\beta\alpha}\text{-}E_n^{(1)}\delta_{\alpha,\beta})a\alpha=0$

Where $\beta = 1,2,3, \ldots \ldots \ldots$f

b) In the first order correction in energy E_n^1 show that; [10 marks]

$$I\psi_n >= I\varphi_n >= \sum_{m\neq n} \frac{\langle \varphi_m | \widehat{H}_p | \varphi_n \rangle}{E_n^{(0)} - E_m^{(0)}}$$

QUESTION THREE

a) Use the Wentzel-Kramers-Brilliuon method to estimate the level of one dimensional harmonic oscillator. [7 marks]

b) Use the Wentzel-Kramers-Brilliuon approximation to calculate the levels of spinless particle of mass M moving in a one dimensional box with walls at x=0 and x=L. [6 marks]

c) Use Wentzel-Kramers-Brilliuon approximation to estimate the transmission coefficient of a particle of mass M and energy E moving in the following potential barriers. [7 marks]

$$V_{(x)} = \begin{cases} 0, & x < 0 \\ V_o - \lambda, x & x > 0 \end{cases}$$

QUESTION FOUR

a) What are the goals of time dependent perturbation theory. [3 marks]

b) Show that; [6 marks]

$$\sum_n i\hbar \frac{\partial c_n}{\partial t} - c_n(t)V(t)e^{\frac{-iE_nt}{\hbar}} In >= 0$$

c) What are the main differences between time independence perturbation theory and time dependent perturbation theory. [4 marks]

d) For time dependent perturbation theory, show that; [7 marks]
$i\hbar \frac{dc_n(t)}{dt} = \sum_m H_{nm}(t) \exp(i\boldsymbol{\omega_{nm}t})\, \boldsymbol{C_m(t)}$

QUESTON FIVE

a) A particle of charge q and mass M, which is moving in one dimension. Harmonic potential of frequency ω is subjected to a weak electric field E in the x-direction.

i) Find the expression for the energy. [5 marks]

ii) Calculate the energy to the first non-zero correction and compare it to the exact result obtained in (a) [10 marks]

b) By clearly showing each step, prove that the following equation are correct;

$[L^2, L_x] = 0$ [5 marks]