# MAASAI MARA UNIVERSITY

## REGULAR UNIVERSITY EXAMINATIONS

## 2018/2019 ACADEMIC YEAR

## FOURTH YEAR SECOND SEMESTER

## SCHOOL OF SCIENCES

## BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION (SCIENCE)

## COURSE CODE: PHY 410

## COURSE TITLE: QUANTUM MECHANICS 2

**DATE: 17TH APRIL 2019** **TIME: 0830 - 1030 HRS**

**INSTRUCTIONS TO CANDIDATES**

1. Answer Question **ONE** and any other **TWO** questions
2. *Question one carries 30 marks while each of the others carries 20 marks.*
3. *Credit will be awarded for clear explanations and illustrations.*

*This paper consists of **4** printed pages. Please turn over*

## *QUESTION ONE*

a) State four postulates of quantum mechanics.
(4marks)

b) A particle has spin ½. A measurement is made of the sum of its x and z component of spin angular momentum what are the possible results of this measurement.
(5marks)

c) Consider a particle subjected to time independent potential V(r).

i. Assume that the particle is described by a wave function of the form $\Psi(r,t)=\Phi(r)\chi(t)$. Show that $\chi(t)=A^{-i\omega t}$ (A is constant) and $\Phi(r)$ must satisfy the equation $\frac{-\hbar^2}{2m}\nabla^2\Phi(r)+V(r)\Phi(r)=\hbar\omega\Phi(r)$ where m is the mass of the particle (7marks)

ii. Prove that the solutions of the Schrödinger equation of part (i) lead to a time independent probability density.
(4marks)

d) State three properties of Pauli spin matrices
(3marks)

e) Show the components of angular momentum in position space do not commute
(3marks)

f) Calculate the relative populations of the first five rotational levels of the ground vibrational state of $H^{35}Cl$ at 300 K. The ground vibrational state rotational constant $B_0$ = 10.44 $cm^{-1}$
(4marks)

## *QUESTION TWO*

***a)*** Show that the only matrix which commute with Pauli spin matrix is a multiple of the unit matrix.
(5marks)

***b)*** Explain how the Hatree method can be used to solve for the expectation energy for large atoms.
(5marks)

***c)*** Consider a square potential barrier shown in the figure

$$V(x)=\begin{matrix}0 & x<0\\ V_0 & 0<x<l\\ 0 & l<x\end{matrix}$$

Assume that incident particles of energy $E>V_0$ are coming from $x=-\infty$ . find the stationary states . apply the matching conditions at x=0 and x= *l*. find the transmission and reflection coeffieicents.and sketch the transmission coefficient as a functionof the barrier's width *l*
(10marks)

## *QUESTION THREE*

***a)*** Show that momentum operator $\hat{P}$ is Hermitian.
(4marks)

***b)*** A hydrogen atom can be viewed as two point –charged particles a proton and an electron with Coulomb's interacting potential between them. Write a Schrödinger equation for such a system and separate it into two parts: describing the motion of the centre of mass and another describing the relative motion of the proton and the electron.(10marks)

***c)*** Explain how you can include exchange effect in Hatree approximation to find the Hatree-Fock equation. explain how they differ with the Hatree equation
(6marks)

## *QUESTION FOUR*

**a)** Consider one dimensional physical system described by the Hamiltonian : $H=\frac{P^2}{2m}+V(x)$

i. Show that $[H,X]=-i\hbar\frac{p}{m}$ (6marks)

ii. For a stationary state find $\langle p \rangle$ (consider only square integrable states)(4marks)

***b)*** Calculate the commutation $[\sigma_i, \sigma_j]$ where $j = x, y, z \wedge \sigma_i$ are Pauli matrices (7marks)

***c)*** Explain Raman effects as applied in vibrational spectra of molecules.
(3marks)

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