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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2019 /2020 ACADEMIC YEAR

SECOND YEAR FIRST SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHY 314**

COURSE TITLE: **QUANTUM MECHANICS 1**

DATE: 10TH DECEMBER 2019 **TIME: 2:00PM-5:00PM**

INSTRUCTION TO CANDIDATES

- **SEE INSIDE**

THIS PAPER CONSISTS OF 4 PRINTED PAGES **PLEASE TURN OVER**

REGULAR-MAIN EXAM

PHY 314: QUANTUM MECHANICS 1

STREAM: BED (Science) **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

i. *Answer questions ONE and TWO in SECTION **A** and any other **THREE** questions in SECTION **B**.*

ii. *You may need to use the following constants*

- *Planck's constant* $h = 6.625 \times 10^{-34}\ m^2kgs^{-1}$
- *Mass of an electron,* $M_e = 9.11 \times 10^{-31}$ *Kg*
- *Mass of a proton,* $M_p = 1.67 \times 10^{-27}$ *Kg*
- *Electronic charge,* $e = 1.6 \times 10^{-19}$ *C*
- $1eV = 1.6 \times 10^{-19} J$

SECTION A (28 MARKS)

Question One (14 marks)

(a) State the boundary conditions in quantum mechanics (3 Marks)

(b) Normalize the wave function given by $\Psi(\phi) = Ae^{i\phi}$ in the region $0 \le \phi \le 2\pi$ (3 Marks)

(c) A particle of mass *m* is trapped in a one dimensional box with a potential described by

$$V(x) = \begin{cases} 0 & 0 \le x \le a \\ \infty & \text{Otherwise} \end{cases}$$

Solve the Schrödinger equation for this potential (4 Marks)

(d) (i) What is degeneracy? (1 Mark)

(ii) State Heisenberg's momentum and position uncertainty principles. (3 Marks)

Question Two (14 Marks)

(a) State two properties of Schrodinger's equation (2 Marks)

(b) Prove that eigenvalue of the Hermitian operator is real (5 Marks)

(c) What is the smallest possible uncertainty in the position of an electron moving with velocity 10^6 m/s? (3 Marks)

(d) Consider the wavefunction $\Psi(x) = A(ax - x^2)$ for $0 \le x \le a$, normalize the wavefunction (4 Marks)

SECTION B (42 MARKS)

Question Three (14 Marks)

(a) Consider the hydrogen atom eigenfuction $\Psi_{432}(r, \theta, \phi)$ *what is the*
   (i) Total energy of an electron in this state in eV (2 Marks)
   (ii) Total orbital angular momentum. (2 Marks)

(b) Discuss the failures of classical mechanics from the photoelectric experiment (6 Marks)

(c) Explain the meaning of the quantum numbers n, l, m_1 (3 Marks)

(d)Explain the meaning of Zeeman effect. (1 Mark)

Question Four (14 Marks)

(a) Consider a particle of mass m held in a one-dimensional potential $V(x)$. Suppose that in some region $V(x)$ is constant $V(x) = V$. For this region, find the stationary states of the particle when (i) $E > V$,(ii) $E < V$, and (iii) $E = V$, where E is the energy of the particle. [10 Marks]

(b) Show that_$[x, p_x] = i\hbar$, explain the meaning of these results. (4 Marks)

Question Five (14 marks)

(a) Calculate the wavelength associated with a particle of mass 2 g moving with velocity of 3.3125km/s (3 Marks)

(b) Given the wave equation$\Psi = Ae^{i(kx-\omega t+\Phi)}$, construct the one- dimensional Schrödinger wave equation. (9 Marks)

Question Six (14 marks)

(a) Write short notes on operators used in quantum mechanics. (4 Marks)

(b) Consider the wave function; $\Psi(r, t) = \left[Ae^{-ipx/\hbar} + Be^{ipx/\hbar}\right]e^{-ip^2t/2m\hbar}$
Find the probability current corresponding to this wave function (10 Marks)

Question Seven (14 Marks)

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

a) Assume that a state of the particle is described by a wave function of the form $\Psi(r,t) = \phi(r)\chi(t)$. Show that $\chi(t) = Ae^{-i\omega t}$ (A is a constant) and that $\phi(r)$ 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. (10 Marks)

b) Prove that the solution of the Schrödinger equation of part (a) leads to a time–independent probability density. (4 Marks)

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