NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF HEALTH AND APPLIED SCIENCES

DEPARTMENT OF NATURAL AND APPLIED SCIENCES

QUALIFICATION : BACHELOR OF SCIENCE	
QUALIFICATION CODE: 07BOSC	**LEVEL:** 7
COURSE CODE: QPH 702S	**COURSE NAME:** QUANTUM PHYSICS
SESSION: JANUARY 2019	**PAPER:** THEORY
DURATION: 3 HOURS	**MARKS:** 100

SUPPLEMENTARY/SECOND OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER(S)	Prof Dipti R. Sahu
MODERATOR:	Dr Habatwa V. Mweene

INSTRUCTIONS

1. Answer ALL the questions.
2. Write clearly and neatly.
3. Number the answers clearly.

PERMISSIBLE MATERIALS

Non-programmable Calculators

THIS QUESTION PAPER CONSISTS OF 3 PAGES (Including this front page)

Question 1 **[20]**

1.1 Given that the wavefunction of an electron is $\Psi = (\pi a_o^{3})^{-1/2} e^{-r/a_o}$, where $0 < r < \infty$ and a_o is Bohr radius, evaluate:

1.1.1 The probability density p(x). (5)

1.1.2 The probability that the electron is within $0 < r < 2a_o$ (10)

1.2 Explain how to describe a system in quantum mechanics? (5)

Question 2 **[20]**

2.1 The potential function for a particle in a finite box is defined as (10)

$$V(x) = \begin{cases} V_o; & 0 \le x \le L \\ 0; & \text{otherwise} \end{cases}$$

Sketch the graph of potential V(x) and find the solution for wavefunction in different region.

2.2 Obtain the binding energy of a particle of mass m in one dimension due to the short-range potential $V(x) = -V_0\, \delta(x)$ (10)

Question 3 **[20]**

3.1 Calculate the value of r at which the radial probability density of the hydrogen atom

reaches its maximum

3.1.1 n=1, l=0, m=0 (5)

3.1.2 l = n-1, m=0 (10)

Given

$$R_{nl}(r) = -\left(\frac{2}{na_0}\right)^{3/2} \sqrt{\frac{(n-l-1)!}{2n[(n+l)!]^3}} \left(\frac{2r}{na_0}\right)^{l} e^{-r/na_0} L_{n+l}^{2l+1}\left(\frac{2r}{na_0}\right)$$

3.2 What can be said about the Hamiltonian operator if L_z is constant in time? (5)

Question 4 **[20]**

4.1 Evaluate the matrix of L_2 for $l = 2$. Why is the matrix not diagonal? (10)

For $l = 2$, $m_l = 2, 1, 0, -1, -2$

4.2 Evaluate the spin matrices S_y and S_z for a particle with spin $s = \frac{1}{2}$ (10)

Question 5 **[20]**

5.1 A particle is placed in a deformed infinite potential well defined by the potential V(x), (10)

$$V(x) = \begin{cases} 0; & -\frac{L}{2} < x < 0 \\ 0.5\varepsilon_o; & 0 < x < \frac{L}{2} \end{cases},$$

where ε_o is the ground state energy of the infinite well and L is the width of the well. Evaluate the correction to the ground state energy of the system, regarding the infinite well as the unperturbed system. Given, $\Psi_o = \sqrt{\frac{2}{L}} \cos\frac{\pi}{L} x$

5.2 A charged particle is bound in a harmonic oscillator potential $V = \frac{1}{2}kx^2$. The system is placed in an external electric field E that is constant in space and time. Calculate the shift of the energy of the ground state to order E^2. The wave function of the ground state of a harmonic oscillator is given as (10)

$$\psi(x) \equiv \langle x|0\rangle = \sqrt{\frac{\alpha}{\pi^{1/2}}} \exp\left(-\frac{1}{2}\alpha^2 x^2\right)$$

where

$$\alpha = \sqrt{\frac{m\omega}{\hbar}}, \quad \omega = \sqrt{\frac{k}{m}}$$

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Useful Standard Integral

Plank constant h = 6.63×10^{-34} Js

$$\int_{-\infty}^{\infty} e^{-y^2} dy = \sqrt{\pi}$$

Speed of light c = 3×10^8 m/s

$$\int_{-\infty}^{\infty} y^n e^{-y^2} dy = \frac{\sqrt{\pi}}{n}; \quad n \text{ even}$$
$$0; \quad n \text{ odd}$$

Mass of electron m = 9.11×10^{-31} kg

$$\int_{-\infty}^{\infty} e^{-\alpha y^2} e^{-\beta y} dy = \left(\frac{\pi}{\alpha}\right)^{\frac{1}{2}} e^{\frac{\beta^2}{4\alpha}}$$

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