NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

DEPARTMENT OF NATURAL AND APPLIED SCIENCES

QUALIFICATION : BACHELOR OF SCIENCE	
QUALIFICATION CODE: 07BOSC	LEVEL: 7
COURSE CODE: QPH702S	COURSE NAME: QUANTUM PHYSICS
SESSION: JANUARY 2023	PAPER: THEORY
DURATION: 3 HOURS	MARKS: 100

SUPPLEMEMTAY/SECOND OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER(S)	Prof Dipti R Sahu
MODERATOR:	**Prof Vijaya S. Vallabhapurapu**

INSTRUCTIONS
1. Answer any **Five** 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 Consider a one-dimensional bound particle. Show that if the particle is in a stationary state at a given time, then it will always remain in a stationary state. (10)

1.2 Consider a one-dimensional bound particle, Show (10)

$$\frac{d}{dx}\int_{-\infty}^{\infty} \psi^* (x,t)\psi (x,t)dt = 0,\ \Psi \text{ need not be a stationary state.}$$

Question 2 **[20]**

2.1 A one-dimensional harmonic oscillator wave function is Axe^{-bx^2}

2.1.1 Find b (5)

2.1.2 The total energy E (5)

2.2 The wavefunction of a particle confined to the x axis is $\psi = e^{-x}$ for $x > 0$ and $\psi = e^{+x}$ for $x < 0$. Normalize this wavefunction and calculate the probability of finding the particle between $x = -1$ and $x = 1$. (10)

Question 3 **[20]**

3.1 An electron is trapped in a 1-D infinite well of width 5nm. Evaluate the wavelength of radiation emitted when the electron makes a transition from third to first excited states. (5)

3.2 Compare the energies and wavefunctions of 1-D infinite well and harmonic oscillator. (3)

3.3. Explain quantum tunnelling and list three applications of it. (5)

3.4 What does it mean to say that certain operators commute? Give examples of operators that commute and of operators that do not commute. (4)

3.5 Why the de-Broglie wave associated with a moving car is not observable? (3)

Question 4 **[20]**

4.1 A potential barrier is defined by:

$$V(x) = \begin{cases} 1.2\text{ eV} & -\infty < x < -2 \\ 0 & -2 < x < 2 \\ 1.2\text{ eV} & 2 < x < \infty \end{cases}$$

A particle of mass m and kinetic energy 1.0 eV is incident on this barrier from $-\infty$. Evaluate the acceptable wave function of the particle. (10)

4.2 Calculate the expectation value $\langle r \rangle_{21}$ for the hydrogen atom and compare it with the value r at which the radial probability density reaches its maximum for the state $n = 2$, $l = 1$. Given $R_{21}(r) = re^{-r/2a_0}/\sqrt{24a_0^5}$ (6)

4.3 Show explicitly that $S^2 = \hbar^2 s(s+1)\, I$ (4)

Question 5 **[20]**

5.1 What can be said about the Hamiltonian operator if *L*, is a constant in time? (2)

5.2 What you conclude that two operators commuting? (2)

5.3 Evaluate the matrix of L_x for $l = 1$? (6)

5.4 What are the kinetic, potential, and Hamiltonian operators for the hydrogen atom? Write the Schrodinger equation for the H-atom. (5)

5.5 Show explicitly in Cartesian (*x*, *y*, *z*) coordinates that the ∇^2 and L_z operators commute, (5)

i.e., $[\nabla^2, L_z] = 0$

Question 6 **[20]**

6.1 Show that in the usual stationary state perturbation theory, if the Hamiltonian can be written $H = H_o + H'$ with $H_o\Phi_0 = E_o\Phi_0$, then the correction ΔE_0 is (10)

$$\Delta E_0 \approx \langle \Phi_0 | H' | \Phi_0 \rangle$$

6.2 A hydrogen atom is in a superposition state given by:

$$\Psi = \frac{1}{\sqrt{29}}[3\psi_{100} - 4\psi_{210} - 2\psi_{321}]$$

Evaluate

6.2.1 The probability that the atom is found in each of the sub-states. (3)

6.2.2 The expectation value of the energy in this superposition state. Given (7)

$$\varepsilon_n = \frac{\Re}{n^2} = -\frac{13.6}{n^2} eV$$

....

Useful Standard Integral

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

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

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

$$\int_0^{\infty} x^n e^{-x} dx = n!$$