KATHMANDU UNIVERSITY
End Semester Examination
August, 2018

Marks scored:

Level : B.Sc.
Year : III

Course : PHYS 311
Semester : II

Exam Roll No. :

Time: 30 mins.

F. M. : 20

Registration No.:

Date AUG 0 8 2018

SECTION "A"
[20 Q × 1 = 20 marks]

I. Choose and tick the most appropriate answer. The symbols, unless mentioned otherwise, have their usual meanings.

1. The relation between de-Broglie's phase velocity v_p and velocity of light c is

[a] $v_p > c$ [b] $v_p < c$ [c] $v_p = c$ [d] $v_p = c^2$

2. Two wave functions $\psi_m(x)$ and $\psi_n(x)$ are orthogonal if

[a] $\int \psi_m(x)\psi_n(x)dx = 0$ [b] $\int \psi_m^*(x)\psi_n(x)dx = 1$

[c] $\int \psi_m(x)\psi_n(x)dx = 1$ [d] $\int \psi_m^*(x)\psi_n(x)dx = 0$

3. Ratio of $[\hat{L}_x, \hat{P}_y]$ and $[\hat{L}_x, \hat{P}_z]$ is

[a] $\frac{\hat{P}_z}{\hat{P}_y}$ [b] $\frac{\hat{P}_y}{\hat{P}_z}$ [c] $-\frac{\hat{P}_z}{\hat{P}_y}$ [d] $-\frac{\hat{P}_y}{\hat{P}_z}$

4. For a particle trapped in a box of length l, the average value of momentum $< p >$ is

[a] $\frac{h}{l}$ [b] 1 [c] $\frac{h}{2l}$ [d] 0

5. Trace of Pauli spin matrices is

[a] 0 [b] 1 [c] -1 [d] 2

6. Energy level of one dimensional harmonic oscillator are

[a] equally spaced [b] 2-fold degenerate
[c] 3-fold degenerate [d] not degenerate

7. Number of Eigen function for $n = 2$, $l = 1$ and $m = 0$ in hydrogen problem is

[a] 1 [b] 2 [c] 3 [d] 4

8. For harmonic oscillator the value of $< 4 | x^2 | 6 >$ is equal to

[a] $\frac{\hbar}{2m\omega}\sqrt{30}$ [b] $\frac{\hbar}{2m\omega}\sqrt{24}$ [c] $\frac{\hbar}{2m\omega}$ [d] 0

9. The value of $\hat{L}_z^2 Y_2^2(\theta,\phi)$ is equal to

[a] $\hbar^2 Y_2^2(\theta,\phi)$ [b] $2\hbar^2 Y_2^2(\theta,\phi)$ [c] $6\hbar^2 Y_2^2(\theta,\phi)$ [d] 0

10. In normal Zeeman effect, a level of given l splits into
[a] (2l+1) levels [b] l levels
[c] 2l levels [d] (2l-1) levels

II. Fill in the following blanks with appropriate answer. The symbols, unless mentioned otherwise, have their usual meanings.

11. The ratio of wavelength of deuteron and proton accelerated through the same potential difference is .....

12. Ehrenfest's theorem can be written as .....

13. If the Zero-point energy of a linear harmonic oscillator is $1.66\times10^{-32}J$, then its frequency is.....

14. The value of Bohr magnetron is .....

15. The value of $Y_1^0(\theta,\phi)$ is equal to .....

16. The hyperfine splitting of hydrogen atom at ground state is approximately equal to .....

17. The expectation value of $\frac{1}{r^2}$ in the ground state hydrogen atom is .....

18. The x-component of angular momentum operator in spherical polar coordinates is .....

19. The commutation relation between S^2 and S_{1z} is .....

20. Reflection coefficient for particle incident on potential step with energy E less than the height of the step is .....

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SECTION "B"
[5Q × 4 = 20 marks]

1. What do you mean by the term degeneracy? Explain the term degeneracy in hydrogen atom.

2. Show that $< n | \frac{1}{2} m\omega^2 x^2 | n > = < n | \frac{p_x^2}{2m} | n >$ implies that the expectation value of P.E and K.E are equal.

OR

Find the components of angular momentum operators in the case of spherical coordinate system and hence find $\hat{L}^2$.

3. Find the matrix element of $\hat{S}^2$ in two spin system. Discuss the physical significance of non-diagonal element that exists in the matrix of $\hat{S}^2$.

4. Write a short note on normal Zeeman effect.

OR

Normalize the wave function $\psi(x) = \frac{1+ix}{1+ix^2}$ describing 1-D motion of a particle within - a to + a and hence find the expectation value for momentum.

5. What do you mean by bound state? Show that the bound state energy is always greater than or equal to $-V_0$ (i.e. minimum particle energy)

SECTION "C"
[5Q × 7 = 35 marks]

6. Prove the relation $\frac{\partial \rho}{\partial t} + \nabla . \vec{J} = 0$ where $\vec{J}$ is the probability current density and ρ is the probability density. Write the physical interpretation of this equation.

OR

Derive the time dependent and time independent Schrödinger wave equation. Give the significance of the wave function.

7. A particle is moving in one dimensional potential step given by

$$V(x) = \begin{cases} 0 \; for \; x < 0 \\ 0 \; for \; x \geq 0 \end{cases}$$

Find the reflectance and transmittance for E>V where E represents the total energy of the particle.

8. Establish the Schrödinger equation for a linear harmonic oscillator and solve it to obtain its Eigen value and Eigen functions. Discuss the significance of energy.

9. Discuss time independent perturbation theory and hence obtain an expression for energy Eigen values and Eigen function correct up to 2^{nd} order. Also, show that the perturbation $H^1 = \in e^{-\beta x^2}$ shifts the ground state of a harmonic oscillator by $E_0^1 = \in \left(\frac{\alpha}{\alpha+\beta}\right)^{\frac{1}{2}}, \alpha = \frac{m\omega}{\hbar}$

OR

A charged oscillator is placed in a constant electric field. Write down the Hamiltonian for the free oscillator. Write the perturbation potential due to electric field. Show that the first order correction to energy is zero. Calculate the second order correction to the ground state energy.

10. What do you mean by a vector operator? Show that the matrix element of an observable V is proportional to those of total angular momentum.