End Semester Examination, 2021

Semester - V

Physics

PAPER - CC11T

Full Marks : 40

Time : 2 Hours

<u>Group - A</u>

Answer any <u>five</u> of the following :-

1.a) Determine the energy levels of a particle of mass m moving in a potential 2

$$V = \frac{1}{2}kx^2 (x > 0)$$
$$= \infty (x \le 0)$$

b) Show that the dimensions of Planck's constant are the same as those of angular momentum. 2

c) What is the speed of a proton with a de Broglie wavelength $0.1\ \overset{0}{A}$? 2

d) Show that the operator relation $\vec{L} \times \vec{L} = i5\vec{L}$ holds. 2

e) Draw a diagram showing the space quantization for $l = 3$ 2

f) In the Stern-Gerlach experiment, a beam of neutral nickel atoms splits into nine components. What is the angular momentum of a nickel atom in its ground state ? 2

(Turn Over)

g) Show that the annihilation operator a annihilates two quanta of energy while operating twice on a harmonic oscillator eigenket. 2

h) Show that if the potential energy function is symmetric about $x = 0$, then the non-degenerate eigen functions of the Schrödinger equation are either symmetric or anti-symmetric function of x.

<u>Group - B</u>

Answer any <u>four</u> of the following :-

2. Use the uncertainty principle to estimate the minimum energy of a particle in a simple harmonic potential $Kx^2/2$. Determine the maximum value of x for a classical harmonic oscillator for this minimum energy. 3+1

3. Consider a one-dimensional box of length $10\,\overset{0}{A}$. What is the lowest energy of a system consisting of (a) two electrons in the box ? (b) three electrons in the box ? Ignore the conlomb interaction between the electrons. 2+2

4. The wave function of the hydrogen atom for IS state is $\Psi_{100} = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2} e^{-r/a_0}$

   where $a_0 = \frac{\hbar^2}{me^2}$ is the Bohr's radius. Calculate the expectation value of the potential energy $\left(-\frac{e^2}{r}\right)$ of electron in 1s state (only the expression). 4

5. Consider two operators A Nd B each of which commute with their commutator. Prove the following identity $e^A e^B = enp\left\{A + B + \frac{1}{2}[A,B]\right\}$ 4

6. Write down the Pauli spin matrices. Show that they anticommute. 1+3

7. The wave function of a particle in a stationary state with an energy E_o at the time $t = 0 is \psi(x)$. After how much time will the wave function again be $\psi(x)$? What do you mean by stationary state ? 3+1

Answer any one of the following :

8. Write down the schrödinger equation for Hydrogen atom problem. Separate this into CM and relative co-ordinates. Obtain the radial and angular differential equations from the differential equation of the particle with reduced mass. Write down the solutions of angular part (spherical harmonies) after analying the corresponding differential equations. How does the radial equation provide the energy ? 1+3+4+2

9. Derive the expression of spin-orbit interaction energy $\Delta E_{L_1S} = \frac{R_\infty \alpha^2 z^4 hc}{2n^3 l(l+\frac{1}{2})(l+1)}\left[j(j+10 - l(l+1) - s(s+1)\right]$ obtain the term shift expression and determine the same for hydrogen like atom (single electron). 5+3+2

Physical Constants :

$m_e = 9.11 \times 10^{-31} kg$

$m_p = 1.6726 \times 10^{-27} kg$

$\hbar = 1.055 \times 10^{-34} Js$

$C = 3 \times 10^8 m/s$