BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION MO2022)

CLASS: **IMSC** **SEMESTER : V**
BRANCH: **PHYSICS** **SESSION : MO /2022**

SUBJECT: PH301 QUANTUM MECHANICS AND APPLICATIONS

TIME: **03 HOURS** **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates

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Q.1(a) What do you understand by Wave-particle duality? [2]

Q.1(b) Calculate the wavelength associated with an electron subjected to a potential difference of 1.25 kV? [3]

Q.1(c) A wave function $\psi(x) = A_n Sin\frac{2n\pi x}{L}$ in the region $0 \le x \le L$. Find the value of A_n using normalization condition? [5]

Q.2(a) Write down the time independent and time-dependent Schrodinger equation? [2]

Q.2(b) For a rectangular potential barrier of width a and height V_o, show that the transmission co-efficient for (E> Vo) can be expressed as $T = \frac{4p_1^2 p_2^2}{(p_1^2 - p_2^2)^2 \sin^2(p_2 a/\hbar) + 4p_1^2 p_2^2}$. [3]

Q.2(c) Calculate the probability of transmission of a-particle through the rectangular barrier indicated below: V_o= 2 eV, E= 1 eV and barrier width =1 Å, mass of a-article = 6.4×10^{-27} kg [5]

(use $T = \frac{-4p_1^2 p_2^2 \sec h^2(ip_2 a/\hbar)}{(p_1^2 + p_2^2)^2 \tanh^2(ip_2 a/\hbar) - 4p_1^2 p_2^2}$

and apply approximation for the thick barrier $ip_2 a >> \hbar$)

Q.3(a) What do you understand by zero-point energy of a quantum oscillator? [2]

Q.3(b) For a particle in a box show that allowed values of total energy are given by [3]

$$E = E_x + E_y + E_z = \frac{\hbar^2}{2m}\left[\frac{n_x^2}{l_x^2} + \frac{n_y^2}{l_y^2} + \frac{n_z^2}{l_z^2}\right]$$

Q.3(c) Calculate the energy difference between the ground state and the first excited state for an electron in one dimensional rigid box of length 10^{-10} m (mass of electron = 9.1×10^{-31} Kg and h= 6.626×10^{-34} Joule-sec. [5]

Q.4(a) What do you understand by de-Broglie waves? [2]

Q.4(b) For the radial part of Hydrogen atom given by [3]

$$\frac{\partial^2 R}{\partial r^2} + \frac{2}{r}\frac{\partial R}{\partial r} + \left[\frac{-l(l+1)}{r^2} + \frac{2\mu}{\hbar^2}\{E - V(r)\}\right]R = 0$$

Setup the recursion relation

$$a_{k+1} = \frac{k+l+1-\lambda}{(k+1)(2l+k+2)}a_k$$

Use substitutions $\alpha^2 = -\frac{2\mu E}{\hbar^2}$ *and* $\lambda = \frac{\mu Z e^2}{\hbar^2 \alpha}$

Q.4(c) Show that energy Eigen-values are given by [5]

$$E_n = -\frac{\mu Z^2 e^4}{2\hbar^2 n^2}$$

Q.5(a) What do you understand by spin angular momentum of an electron? [2]

Q.5(b) Define magnetic moment of an atom and Lande's g-factor? [3]

Q.5(c) Mathematically show that magnetic dipole moment and orbital angular momentum of an electron are related by $\mu_l = -\frac{e}{2m}p_l$. Numerically calculate the value of Bohr-magneton. [5]