CH-103 Tutorial-1

1. In photoelectric effect phenomenon, how do the following parameters vary with increasing frequency of incident radiation: (a) Photocurrent and (b) Kinetic energy of photoelectrons.

2. With what speed must an electron travel in order to have a de Broglie wavelength of 0.1 nm? Through what potential difference must the electron be accelerated to give it this velocity?

3. If the position of speck of dust mass 1 micro gram is known within 10^{-3} mm, what is the indeterminacy in its momentum and velocity?

4. If an electron in a hydrogen atom is confined to a region of size 53 picometer (pm) from the nucleus, what is the indeterminacy in its momentum and velocity?

5. Consider the eigenvalue equation $C^2\Psi = \Psi$ where C is a quantum mechanical operator, and Ψ is an eigenfunction. What are the possible eigenvalues of the operator C?

6. The eigenvalue equation is given as $\hat{A}\Psi = a\Psi$ Suggest eigenfunctions for the following operators

(i) $\frac{d}{dx}$ **(ii)** $\frac{d^2}{dx^2}$ **(iii)** $\int dx$ **(iv)** $-i\hbar\frac{\partial}{\partial q}$ **(v)** $\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}$

7. Under what conditions will a linear combination of two or more eigenfunctions also be an eigenfunction of an operator $\hat{A}$?

8. Which of the following CAN NOT be a valid wavefunction? Graphical arguments are welcome.

(i) ($\frac{1}{x}\sin x$ **(ii)** $x\sin x$ **(iii)** $Ae^{-\alpha x^2}$

9.Calculate the wavelength of light absorbed to bring out the transition from n = 1 and n = 2 for an electron in a one dimensional box of length of 1.0 nm.

10. For the particle in a box given in the above question, what is the probability of finding the electron between (i) x = 0.49 and 0.51, (ii) x = 0 and 0.020 and (ii) x=0.24 and 0.26 (x in nm) for both n=1 and n=2. Rationalize your answers.

11. Consider a particle in a 3-D box with $L_x=L_y=L_z$. How many *distinct* transitions can be possible (*i.e. may be observed*) in the system if you only consider n_i=1,2,3 (for i=x,y,z)?

CH-103 Tutorial -2

1. The wavefuctions of a particle in a 1D box are orthonormal to each other, i.e. $<\psi_i|\psi_j> = \delta_{ij}$ (Kroneker delta) Verify this for i = 2, j = 1, 2. Given $\sin\theta\sin\varphi = \frac{\cos(\theta-\varphi)-\cos(\theta+\varphi)}{2}$

2. The Schrodinger equation for a particle of mass m constrained to move on a circle of radius a is given by $-\frac{\hbar^2}{2I}\frac{d^2\psi(\theta)}{d^2\theta} = E_n\psi(\theta)$**, where $I=ma^2$ is the moment of inertia and ⍰ is the angle that describes the position of the particle on the circular ring. Suggest acceptable solution, permissible values of the quantum number n and obtain the expression for the eigenvalue E_n using appropriate boundary condition.**

3. Separate out the motions of the center of mass (M) and reduced mass (μ) for two particle system.

4. Why do we need spherical coordinates for the hydrogen atom problem and not for a particle in a box problem?

5. Obtain the formula for the volume element in spherical polar coordinates?

6. Assuming the ground state wave function for hydrogen atom to be $\Psi(r,\theta,\phi) = N\exp\left(\frac{-r}{a_0}\right)$ **find the normalization constant N. Use** $\int x^n \cdot e^{-ax} dx = n!/a^{n+1}$

7. From the wave function of 1s orbital, account for the fact that the probability of finding the electron is the same anywhere on the surface of a sphere of radius r (where r is the distance of electron from the nucleus). $\Psi_{1s} = \sqrt{\frac{1}{\pi}} \cdot \left(\frac{Z}{a_0}\right)^{3/2} \cdot \exp\left(\frac{-Z \cdot r}{a_0}\right)$