Home Problem Set #1 Due: September 22 (Mon), 2014

1. Answer the following questions related to the wave-particle duality.

(a) When an electron (mass m) is moving with the velocity of υ, what is the wave length of electron wave suggested by de Broglie?

(b) Find the de Broglie wavelength of a He atom having thermal energy at T = 300 K.

(c) Represent the linear momentum p and kinetic energy E of the electron with wave number k , mass m, and Plank constant h.

2. Answer the following questions.

(a) What should be the energy of an electron so that the associated electron waves have a wavelength of 600nm?

(b) Find the phase and group velocities of this de Broglie wave in (a).

(c) What is the energy of a light quantum (photon) which has a wavelength of 600nm? Compare the energy with the electron wave energy calculated in (a) and discuss the difference.

3. If one were to ask, “what is the location of an electron if we know that it is moving with a specific velocity?”, would this be a meaningful question? Would you prefer to believe that electrons actually have specific positions and velocities simultaneously but the world is such that we can’t know them, or that electrons are entities such that thinking in terms of simultaneous position and velocity is an inappropriate thing to do?

4. Derive $\Psi_1 + \Psi_2 = \Psi = 2\cos(\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x)\cdot\sin[(k+\frac{\Delta k}{2})x - (\omega+\frac{\Delta\omega}{2})t]$

by adding $\Psi_1 = \sin[kx - \omega t]$ and $\Psi_2 = \sin[(k+\Delta k)x - (\omega+\Delta\omega)t]$

5. Answer the following questions.

(a) Why is the wave nature of matter not more apparent to us in our daily observation?

(b) Can the de Bloglie wavelength of a particle be smaller than a linear dimension of the particle? Larger? Is there necessarily any relation between such quantities?

(c) Is the frequency of a de Broglie wave given by E/h? Is the velocity given by υ? Is the velocity equal to c? Explain

6. Justify that the wave formula for a simple harmonic wave traveling in the x direction can be expressed by $y = A\sin(kx - \omega t)$

7. Derive the following Heisenburg's uncertainty principle using the wave properties of particles, $\Delta p \Delta x \geq \hbar/2$

Where, Δx = the uncertainty in the position of a particle

Δp = the uncertainty in its linear momentum

(Hint, refer to Concepts of Modern Physics, Ed. Arthur Beiser or other books)