Problem Set 4: De Broglies Relations, Fourier Superpositions and Borns Interpretation

1. **Calculating de Broglie Wavelengths of Particles**

   (a) Calculate the de Broglie wavelength of an electron moving with a speed of 10^5 m/s and also that of an electron moving with a speed of 0.99×10^8 m/s. Be careful in your choice of formulae in the second case as it is relativistic.

   (b) To observe small objects, one measures the diffraction of particles whose de Broglie wavelength is comparable to objects size (or features). Find the kinetic energy in electron volts required for electrons to resolve (a) a large organic molecule of size 10 nm, (b) atomic features of size 10 nm and (c) a nucleus of size 10 fm. Repeat these calculations using alpha particles in place of electrons.

   (c) An electron and a photon both have kinetic energy equal to 50 keV . Are their de Broglie wavelengths equal? What are the values of the wavelengths for each?

   (d) Calculate the de Broglie wavelength of a proton that has been accelerated through a potential difference of 10 MV , if it started from rest.

2. **Light in a Loop**

   Suppose you have an optic fiber wound in a loop of length L. You shoot some light into the loop and it goes round and around in the loop for eternity. Using the idea of continuous wave that we used to explain Bohr quantization of atom (via de Broglie waves), find out what wavelength photons can be sustained inside this loop of optic fiber.

3. **Quantum Effects Magnified**

   For the purpose of this problem, consider you live in a parallel universe where Planks constant is $\hbar = 10$ Js. You find a very light but strong string of length $\ell = 1$ m, and tie a ball of mass $m = 2$ kg to one end and start rotating this mass in a circle above your head at a constant speed v, by holding the other end of the rope and providing it whatever force is necessary to keep it moving in the circle with speed v.

   (a) What would be the De-Broglie wave associated with the moving ball?

(b) What would be the minimum speed that this ball must have when moving in the circle? Recall that the magnitude of the momentum of the ball will be constant when moving with the constant speed, $p = mv$.

(c) If you want to increase its speed, by what minimum amount you must do it?

(d) The ball only has kinetic energy given by $E = \frac{1}{2}mv^2$. What is the energy of the ball in "ground state" and in the "First excited state"?

Ignore the existential questions regarding how your arm (or the rope) will work in such a magnified quantum world.