deBroglie Matter Waves – 12.5

1923 deBroglie was a graduate student in Paris,France and had the idea that since many ideas in physics were reversible (EMR – fluctuating magnetic/electric waves), then if light can behave light a particle and have momentum, then maybe ordinary particles exhibit a wave-like nature.

Compton's formula re-arranged is $\lambda = h/p$ and $p = mv$

So… $\lambda = h/mv$

This was so radical, the university withheld his graduation for a year. Einstein himself eventually supported deBroglie and he graduated in 1924.

deBroglie was awarded the Nobel Prize in 1929.

Consider: 1) magnitude of the matter wave of a 100 g ball moving at 20 m/s.

$\lambda = h/mv = 6.63 \times 10^{-34} / 0.1 \times 20 = 3.3 \times 10^{-34}$ m

This is a ridiculously small wavelength!

2) magnitude of the matter wave of an electron accelerated through 50 V?

$\lambda = h/mv$ $m = 9.11 \times 10^{-31}$ kg

$v = ?$ Ek gained = Ee lost

$\frac{1}{2} mv^2 = qV$ $q = 1.6 \times 10^{-19}$ C

$v = 4.2 \times 10^6$ m/s

$\lambda = h/mv = 6.63 \times 10^{-34} / 9.11 \times 10^{-31} \times 4.2 \times 10^6$

$\lambda = 1.7 \times 10^{-10}$ m

That's no so far out. Visible light is in nanometers (10^{-9})

So….wave nature of larger objects are so small, we don't see the effects.

Experimental Confirmation - 1927 (3 yrs later) Davisson, Germer (USA) and Thomson (Scotland) set out to show the wave properties of matter. The matter was electrons. Independently, they show a beam of electrons at a nickel crystal. They rotated the crystal and at a certain angle, they saw maximum diffraction and a pattern that resembled Young's double slit! So… electrons (a piece of matter with mass) displayed diffraction and interference (wave properties). The regular atomic structure of the nickel crystal acted as the double slits.

Diffractions happens when the opening is smaller than λ or the wave is going around an object than is smaller than λ. We don't see 10^{-34} much! But electrons can be diffracted by small objects and we have electron microscopes.

Light microscope limit – 1500 x

Electron microscope limit – 300,000 x !!

Problems to Try

1. Calculate the deBroglie wavelength of each of the following:
   a) 2.0 kg ball thrown at 15 m/s **[2.2 x 10^{-35} m]**
   b) proton accelerated to 1.3 x 105 m/s, mass of proton = 1.7 x 10-27 kg. [**3.0 x 10^{-12} m]**
   c) an electron moving at 5.0 x 104 m/s **[1.5 x 10^{-8} m]**

   from Fundamentals of Physics p. 714

2. In some scattering experiments, the speed of the particles is tuned so that their deBroglie wavelength has a specific value. If a wavelength of 0.117 nm is required, how fast must a neutron be travelling to achieve this wavelength?
   #37 p. 628 in our text. **[3371 m/s]**