DeBroglie Waves

Physics II: Modern Physics

College of the Atlantic

The energy of a photon is given by

$$E = h\nu \, . \tag{1}$$

The momentum p of a photon is given by

$$p = E/c \, . \tag{2}$$

(This result is from special relativity and follows from an analogy to the momentum carried by classical waves.) And, wavelength and frequency of light are related by

$$c = \lambda\nu \, . \tag{3}$$

Combining these equations, one obtains

$$p = \frac{h}{\lambda} \, . \tag{4}$$

This equation applies to photons.

DeBroglie postulated that just as a wave can behave like a particle, so a particle can behave like a wave. The wavelength of a "matter wave" is given, by analogy to Eq. (4):

$$\lambda = \frac{h}{p} \, . \tag{5}$$

This wavelength is often referred to as the deBroglie wavelength. Shortly after deBroglie's hypothesis, a number of experiments were done demonstrating that electrons behave like waves, and that the wavelength of these waves is indeed given by Eq. (5).

When calculating the deBroglie wavelength of objects, the following facts and definitions are often useful. The non-relativistic momentum of an object of mass m moving at a speed v is given by

$$p = mv \, , \tag{6}$$

and its kinetic energy is given by

$$K = \frac{1}{2}mv^2 \, . \tag{7}$$

Equations (6) and (7) can be combined to directly relate p and K:

$$p = \sqrt{2mK} \, . \tag{8}$$

Finally, a few masses, expressed in handy "hc"-units:

$$\text{mass of electron} = 0.511\text{MeV} \tag{9}$$

$$\text{mass of proton} = 938.3\text{MeV} \tag{10}$$

$$\text{mass of neutron} = 939.6\text{MeV} \tag{11}$$