Chapter 30  Quantum Physics

Chapter Outline

30-1  Blackbody Radiation and Planck’s Hypothesis of Quantized Energy
30-2  Photons and the Photoelectric Effect
30-3  The Mass and Momentum of a Photon
30-5  The de Broglie Hypothesis and Wave-Particle Duality
30-6  The Heisenberg Uncertainty Principle.
In 1923, a French graduate student Louis de Broglie, proposed a famous hypothesis (late Nobel Prize Winner):

1) Except for the wave behavior, light can have particle-like behavior, like a electron.

2) Then he further proposed, that the photon law $p = \frac{h}{\lambda}$ (the relationship of wavelength and momentum), can also apply to a particle:

De Broglie Wavelength

$$\lambda = \frac{h}{p}$$

SI unit: m

Note: the greater a particle’s momentum, the smaller its de Broglie wavelength.
How the de Broglie wavelength make sense?

1) For macroscopic object: Too small to be observed.

A 0.13-kg apple moving with a speed of 5.0 m/s: 
p=mv, substituting into \( \lambda = \frac{h}{p} \), we have \( \lambda = 1.0 \times 10^{-33} \text{ m} \).

The wavelength is smaller than the diameter of an atom by a factor of \( 10^{23} \)!

2) For microscopic object: compare to its size

In contrast, an electron has a kinetic energy 10.0 eV (a typical value).

\( K = \frac{mv^2}{2} = \frac{p^2}{(2m)} \), so we can find p.

Then \( \lambda = 3.88 \times 10^{-10} \text{ m} = 3.88 \text{ Å} \). This is comparable to the size of an atom!
Active Example 30-2

How fast is an electron moving if its de Broglie wavelength is $3.50 \times 10^{-7}$ m?
Solution:

1) $\lambda = \frac{h}{p} = \frac{h}{mv}$

2) $V = \frac{h}{m} \lambda = \frac{(6.63 \times 10^{-34} \text{ J.s})}{[(9.11 \times 10^{-31} \text{ kg})(3.50 \times 10^{-7} \text{ m})]}$
   
   $= 2080 \text{ m/s}$