Reese Ch. 26, Part B2

(Sect. 15 = pp. 1235-1239)

- Light: Particles vs. Waves (1704 to 1923)
- Louis de Broglie's hypothesis that wave-particle duality extends to electrons. (1924)
- Experimental confirmation
  - C. Davisson and L. Germer in US (1927)
  - G. P. Thomson in England
- Technological connection: electron microscope

Particle-Wave Duality of Light: I

- In his influential book **Opticks** (1704), Isaac Newton gave his support to the idea that light consists of corpuscles.
- However, the interference pattern found in the double-slit experiment (1801) of Thomas Young provided strong evidence that light is a wave.
- Maxwell's electromagnetic theory tied together electricity, magnetism, and optics and seemingly sealed the case for waves.

Particle-Wave Duality of Light: II

- However, Planck's analysis of the blackbody spectrum (1901) and especially Einstein's explanation of the photoelectric effect (1905) evidently require a particle aspect.
- Compton's experiments and analysis on the scattering of x-rays from electrons (1923) revealed the photon as possessing a momentum appropriate to its energy.

De Broglie's Hypothesis (1924)

- In his doctoral thesis, Louis de Broglie constructed an explanation for the wave-particle duality of light in terms of a model according to which photons have a (tiny but nonzero) mass. (Nowadays, physicists are pretty sure that the photon's mass is strictly zero.)
- De Broglie then hypothesized that electrons also have a wave-particle duality that had not yet been discovered. Specifically, he proposed that an equation known to be correct for light also gives the "de Broglie wavelength" for electrons:

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

Experimental Confirmation: I

- In 1925, Clinton Davisson and Lester Germer, working at Bell Telephone Laboratories, were studying the scattering of electrons from a polycrystalline nickel surface when they had an accident that oxidized the nickel target.
- In the process of reclaiming a clean surface, they produced larger crystals and that changed the scattering behavior that they observed. Although they had not previously heard of de Broglie's hypothesis, by 1927 they had recognized that the strong maxima and minima in the scattering data was due to the diffraction of electron waves.

Experimental Confirmation: II

- In 1927 and 1928, George P. Thomson (son of J. J. Thomson) published results on the scattering of higher-energy electrons (kinetic energies 10-40 keV) as they passed through thin microcrystalline foils.
- Thomson used the de Broglie wavelength equation to make a detailed analysis of the diffraction patterns.
- Since then, experiments have shown that de Broglie's equation applies to protons, neutrons, and even neutral atoms. Wave-particle duality is apparently a universal characteristic of matter.

Electron Microscope

- In 1931, Ernst Ruska discovered that a magnetic coil can be used to focus a beam of electrons. He constructed the first crude electron microscope; he achieved a magnification of 400x.
- Since then, electron microscopes have been greatly improved. Any microscope's resolution is limited to details roughly equal to or greater than the wavelength of the waves, but now electron beams of an appropriate energy (several thousand volts) can be used to reveal detail MUCH smaller than the limit of an optical microscope.