The Wave Nature of Matter

key concepts:

- In 1924, de Broglie postulated that **matter**, just like **light**, can have both **wave** and **particle** properties.
- **Electrons** produce an **interference** pattern when passed through a crystal.
- Electrons are **standing waves** with **quantized energy levels**.

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

$$\text{wavelength} = \frac{\text{Planck's constant}}{\text{momentum}}$$

$$\rho = m v$$

mass velocity

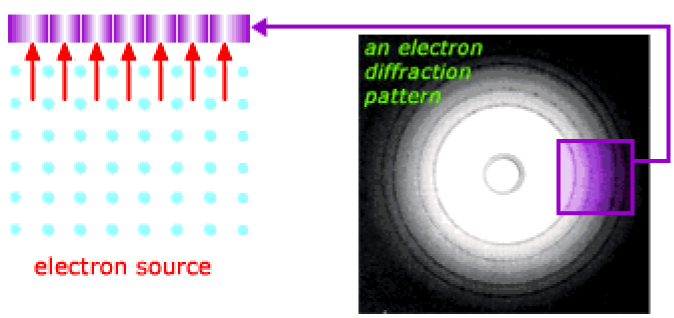
In 1924, de Broglie postulated that matter, just like light, can have both wave and particle properties.

Specifically, de Broglie calculated that the **wavelength (λ)** of a particle is equal to **Planck's constant (h)** divided by the **momentum (ρ)** of the particle. Momentum is equal to **mass** multiplied by **velocity**. When two particles with the same mass travel at different velocities, the slower particle has a longer wavelength. When two particles with different masses travel at the same velocity, the larger particle has a smaller wavelength.

$$\lambda = \frac{6.63 \times 10^{-34}\ \text{kg} \bullet \text{m}^2 / \text{s}}{9.109 \times 10^{-31}\ \text{kg} \times 1 \times 10^{6}\ \text{m/s}}$$

$$\lambda = 7.3 \times 10^{-10}\ \text{m}$$

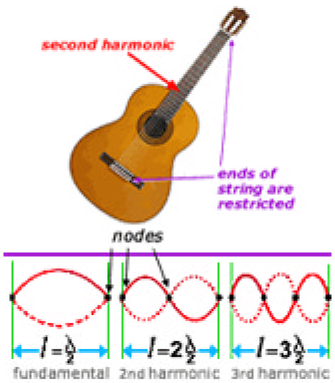
Using this formula, the **de Broglie wavelength** of an electron traveling at 1.0 x 10^{6} m/s can be calculated. Planck's constant is 6.63 x 10^{-34} kg•m^2, and the mass of an electron is 9.109 x 10^{-31} kg. Plugging in these values yields a wavelength of 7.3 x 10^{-10} m. This is on the order of the size of an **atom**.

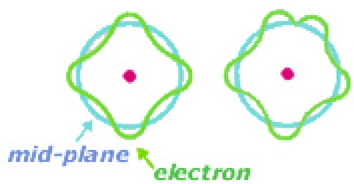


In 1927, Davisson and Germer proved that particles (specifically electrons) have wave properties.

When waves are passed through small slits, an interference pattern is formed. Davisson and Germer passed electrons through a crystal, and found an interference pattern. The wave nature of the electron was exactly as de Broglie had predicted.

The Wave Nature of Matter





A standing wave vibrates in a fixed region. Standing waves (such as guitar strings) can only have certain **frequencies** (the **fundamental**, second harmonic, third harmonic, etc). The frequencies are therefore quantized.

Electrons are standing waves. If the wave reinforces itself (such as in the example on the left), that energy level is permitted. However, if the wave does not reinforce itself (such as the example on the right), that energy level is not permitted.

The energy of the electron is quantized because of the wave properties associated with it.