

Lesson 36: de Broglie Wavelengths

In 1923 [Prince Louis de Broglie](#) proposed a new idea...

- Could things believed to be particles (like electrons and baseballs) sometimes act like waves?
 - All the stuff discovered so far has shown that what appeared to be waves (EMR) sometimes acted like a particle, so de Broglie just wanted to know if particles could act like waves.
- Nobody really took de Broglie seriously until Einstein read his paper and agreed with his ideas.



*Illustration 1:
Louis de
Broglie*

de Broglie suggested combining a couple of formulas, one of them a particle type, the other a wave type.

$$\begin{array}{ccc} p = mv & & p = \frac{h}{\lambda} \\ \swarrow & & \swarrow \\ & mv = \frac{h}{\lambda} & \\ & \lambda = \frac{h}{mv} & \end{array}$$

λ = wavelength (m)
 h = Planck's Constant (always 6.63×10^{-34})
 m = mass (kg)
 v = velocity (m/s)

This formula allows us to calculate the de Broglie Wavelength of a moving particle.

- For an object to have a wavelength, it must be moving.
- Day to day objects that are around us have wavelengths so small that we can never hope to measure them.

Example 1: Determine the de Broglie wavelength of a 0.20kg ball moving at 15m/s.

$$\begin{aligned} \lambda &= \frac{h}{mv} \\ \lambda &= \frac{6.63 \times 10^{-34}}{0.20(15)} \\ \lambda &= 2.2 \times 10^{-34} \text{ m} \end{aligned}$$

Warning!

Many people make the mistake of calculating the energy of the moving particle using kinetic energy, then using $E = hc / \lambda$ to find the wavelength. You can NOT do this, as it assumes the mass stops, changing all its energy into a pulse of EMR.

Now the hard part... finding experimental data to support the theory.

- The problem was that no one had ever seen a particle diffract or interfere with another particle, which would be proof that the particle was acting like a wave.
- With wavelengths as small as the one we found in Example 1, it's impossible to see the wave properties.

- Remember from Young's Double Slit experiment that to be able to see the effects of diffraction and measure wavelength, you need slits or objects which are not much larger than the wavelengths being studied.
- It is impossible to build a diffraction grating as small as 10^{-34}m . That's smaller than the orbits of electrons around a nucleus!
- But notice where mass is in the formula... with a really small mass (like an electron), the wavelength gets bigger!
 - These might be measurable.

Example 2: Determine the wavelength of an electron accelerated by a 100V potential difference. First calculate the velocity of the electron using formulas you used in the electricity unit...

$$E_k = \frac{1}{2}mv^2 \quad E = qV$$

$$qV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$v = \sqrt{\frac{2(1.60\text{e-}19)(100)}{9.11\text{e-}31}}$$

$$v = 5.93\text{e}6 \text{ m/s}$$

Now use that velocity to calculate the wavelength...

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

$$\lambda = \frac{6.63\text{e-}34}{9.11\text{e-}31(5.93\text{e}6)}$$

$$\lambda = 1.23\text{e-}10 \text{ m}$$

Although this wavelength is very small, the spaces between the atoms of a crystal are about this size.

- [Davisson and Germer](#) shot electrons at a crystal sample of nickel in a vacuum tube and observed a diffraction pattern.
 - The spaces between the atoms of nickel are about the same size as the wavelength of the moving electrons, so they acted like the openings in a diffraction grating.
 - On the other side of the nickel the electrons (acting as waves interfering with each other) hit the phosphorescent coating on the tube and formed the glowing pattern as shown in *Illustration 2*.
 - Just like measuring values in Young's Double Slit experiment, we can make similar measurements here to find the wavelength.
- The value de Broglie predicted and Davisson-Germer's values were exactly the same.
- The conclusion: particles have wave properties!

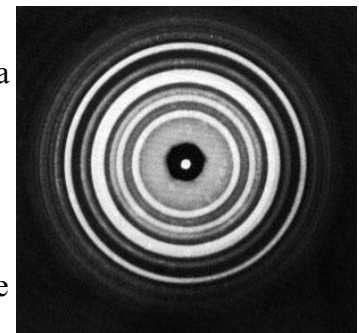


Illustration 2:
Interference pattern seen for electron diffraction.