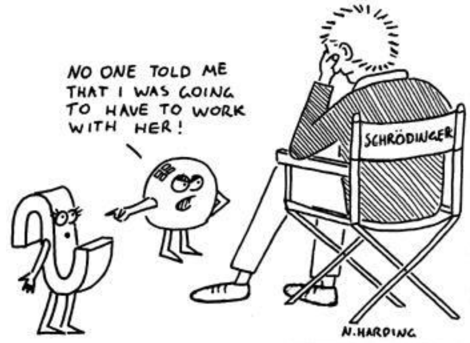
# Wave-Particle Duality

This concept states simply that all particles (not just light) exhibit properties of both waves and particles. This means that all matter or particles that are moving have wave properties that can be associated with it. This duality is one of the foundations of quantum mechanics (quantum physics and chemistry)




## Photon Momentum

Although light has no rest mass it does have relativistic momentum. This means, as is observed in the photoelectric effect, that a photon of light can behave like a particle and has an associated momentum. Einstein showed that the momentum of a photon can be determined by the following equation:

$$p = \frac{E}{c}$$

## De Broglie Wavelength

In 1924 Loius-Victor de Broglie drew a very stunning and controversial conclusion. He stated that since light can have properties of both a wave and a particle; it must follow that particles should have both wave and particle characteristics. Using the momentum equation for light derived by Einstein above; de Broglie was able to write a formula for the **associated wavelength of a particle** that has a defined momentum. This is now known as the **de Broglie wavelength:**

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

**Q:** Can you derive this formula using Einstein's momentum equation above, $E = hf$ and $c = f\lambda$?

## DeBroglie Confirmed!

De Broglie's formula was confirmed three years later when electrons were observed to diffract according to wave properties and later it was shown that passing electrons through a thin metal sheet produced the predicted interference patterns that waves show (essentially the particle version of the Young's double slit experiment).

## Questions

1. Determine the momentum of photons with a wavelength of $700\ nm$. Compare this value to the momentum of a marble (m=10g) rolling at 1m/s. Using this result explain why you do not feel the "collision" of light photons on your body or why photons of light do not hit and move objects as one would expect.

2. Determine the deBroglie wavelength of a baseball ($m = 1.5kg$) moving at 90 km/h. Would you be able to observe this wave? Would the ball diffract through a door with a 1.5 m opening? Explain.

3. Determine the de Broglie wavelength of an electron ($m = 9.11 \times 10^{-31} kg$) moving at 0.8c.

4. In order to "see" the wavelength of the baseball in question 2, what would you have to do to the speed of the ball? Is this feasible?

5. What would the consequences be if the value of Planck's Constant, $h$, were a lot bigger (e.g. $6.63 \times 10^{-1}$ or bigger)?