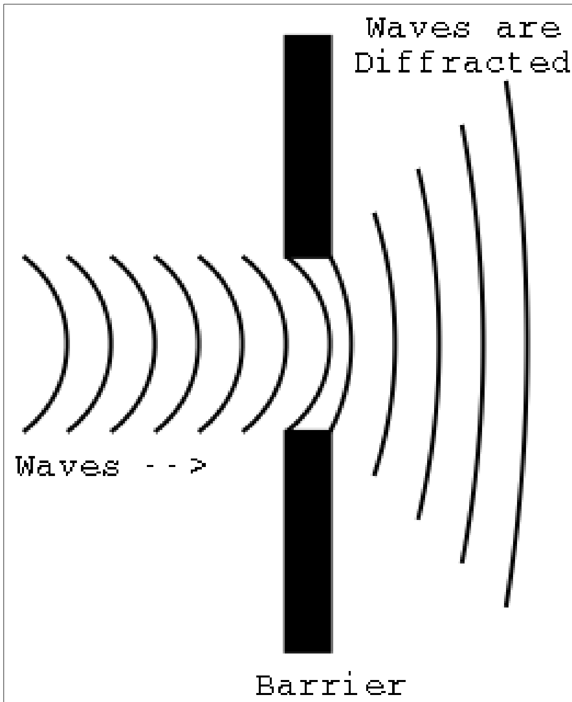
Introduction

To understand how **light** led scientists to discover much about the nature of the atom, we need to understand some basic concepts about light and review the basic terminology associated with light. If you've had a physics or physical science course, this material should be familiar to you. If not, you should get a basic understanding of how we "view" light out of this note pack.

Light: Wave or particle?

In the earlier days of science, physicists didn't have very good theories on the nature of light. They **did** have observations of natural phenomena to base their theories on, however. Initially, light was viewed as if it were a stream of small particles (photons). This explained a fair amount of light's properties, but didn't explain why light would **diffract** like a wave.



- Waves bend around small obstructions.
- You can observe this easily with water waves.
- Light diffracts too, but you need **small** obstructions, as the wavelength of light is much smaller than water waves.

Illustration 1 - Diffraction, a wave property

So, for a while, people believed that light was a wave and not made of particles. Much of the terminology we use to deal with light, in fact, is based on this notion that light is a wave. We speak of light in terms of its **frequency** and **wavelength**, two properties which we can define in terms of waves:

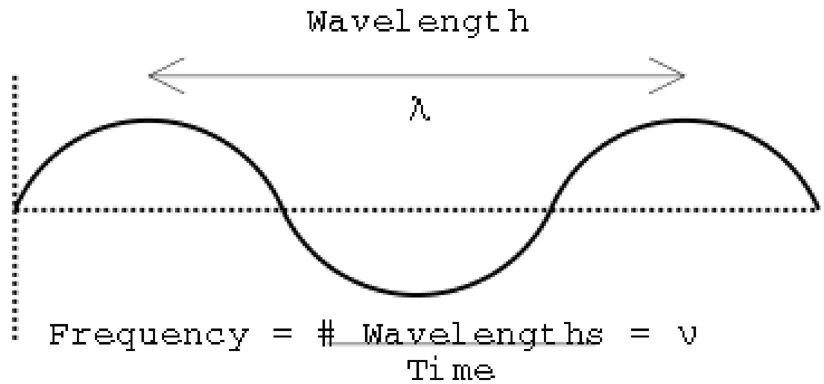


Illustration 2 - Defining the wavelength and frequency

The graphic illustrates the definitions of wavelength and frequency.

- **Wavelength**, abbreviated λ, is defined as the distance from the wave crest to wave crest (or wave trough to wave trough). It is a measure of the "size" of the wave. For light, wavelength is typically measured in the metric unit **nanometers**. [A nanometer is 10^{-9} m!]
- **Frequency**, abbreviated ν, is defined as the number of **wavelengths** that pass by in a given amount of time. The unit of frequency is the **Hertz**, which is defined as 1/s (reciprocal seconds). You might have often heard the term "cycles per second" - this is a different way of expressing the same thing.

Since light travels at a constant speed, we can **relate** the frequency and wavelength of light waves and convert easily between the two.

$$c=\lambda\times\nu$$

where c = $3.00\text{x}10^{8}$ m/s (the speed of light).

For example, *the wavelength of red light is 700. nm. What is the frequency of this light?*

Use $c=\lambda\times\nu$

c = $3.00\text{x}10^{8}$ m/s ν = ? (trying to find this) λ = 700. nm

Plugging in,

$$\nu=\frac{3.00\times10^{8}\ \text{m/s}}{7.00\times10^{-7}\ \text{m}}=4.28\times10^{14}\ \text{Hz}$$

But there are some properties that the wave theory of light just can't account for. Light can knock electrons off metal atoms, but only if the frequency of the light is high enough. It didn't matter how **much** light you shined at the metal - if the frequency was too low, nothing would happen. Einstein said this was because light was made of **packets of energy** (photons) whose energy content was proportional to their frequency.

To understand this concept, compare it to the example of throwing ping pong balls at the classroom wall. It doesn't really matter how many times you throw the ball at the wall (or even if you get the whole class to join in!), the wall isn't going to come down. But all it takes is one hit with a wrecking ball and the wall comes down. The wrecking ball has more energy than the ping pong ball - and enough energy to knock the wall down. Photons hitting a metal atom is a similar situation - all it takes is a single photon with a high enough frequency and you can knock off an electron, but any number of "ping pong balls" (photons with lower frequencies) won't be able to knock off the electron.

You can calculate the energy of a photon, if you like, by using a relationship Einstein developed.

$$E_{photon} = h \times \nu$$

where
E_{photon} = the energy of the photon in J
h = Planck's constant, 6.63×10^{-34} J-s

These energies will be important when we consider **atomic line spectra** of elements.

The modern notion of light is that it exhibits both wave and particle properties (so-called "wave-particle duality"). We will simply use the wave terms like frequency and wavelength when discussing light and use Einstein's relationship to discuss the **energy content** of light.

<u>Summary</u>

This note pack quickly covered the basic things about light that you need to know to understand the way the structure of the atom was discovered - terminology (wavelength, frequency, the speed of light) as well as how to relate light to energy.