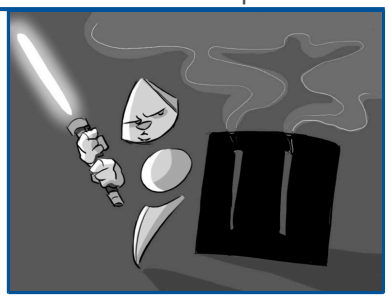


# Light waves

*So what now? Is light a wave or a particle? And what about light rays? The answer is as simple as it might be confusing: light 'is' neither a wave nor a particle. Light waves, photons (light particles) and light rays are just models we employ to describe and predict the behaviour of light. For many applications, like the construction of a simple telescope or camera, the ray-optic model will be precise enough. If it has to be more accurate, and especially if we work with light on a very small scale (as in the experiments you just did), the wave model will be necessary. And if we examine the interaction of light with matter at the atomic level, we have to take into account that it comes in discrete energy packets, namely photons, which behave like particles.*

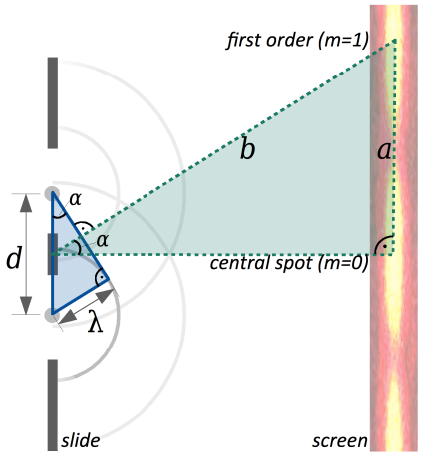
## Facts to remember

- Light can diffract and interfere with itself, just like water or sound waves.
- The smaller a structure is compared to the wavelength, the stronger the light diffracts on it. Since the wave-length of visible light is very small (about one hundred times less than the width of a hair), the slits have to be very small too.
- The diffraction of longer wavelengths (e.g. red) is stronger than that of shorter ones (e.g. blue) on the same structure. Diffraction can therefore be used to measure light's wavelengths precisely.
- For a double slit experiment in which the screen is far from the slits ($b \gg d$), the distance $a$ of the $m^{th}$ diffraction order to the central spot (the position of the beam without the slit mask) depends on:
  $\lambda$: the wavelength of light
  $d$: the distance between the centre-points of the two slits; and
  $b$: the distance between the slits and the $m^{th}$ diffraction order on the screen.
  as follows:

$$m \frac{\lambda}{d} = \frac{a_m}{b_m}$$

Since the ratio $a_m/b_m$ is nothing else but $\sin(\alpha_m)$, this equation is the same as the often used

$$m\,\lambda = d\,\sin(\alpha_m)$$




## The double slit: 200 years of research, still making progress...

When Thomas Young was performing his double slit experiment in 1803, he built on observations that the Italian Francesco M. Grimaldi had already conducted in 1665. But instead of ending the discussion on the particle or wave nature of light, the experiment raised so many new questions that it keeps researchers busy, even today.

In 1923, Louis de Broglie came up with the idea that if light can behave both as a particle and as a wave, then other particles might behave like waves too? He even calculated their wavelength: for instance, an electron would have a wavelength of around 5 pm, 100 000 times smaller than that of green light. Thirty-seven years later, Clauss Jönsson managed to measure a beautiful diffraction pattern of electrons that he sent through a tiny double slit. Since then, the experiment has been repeated with larger and larger objects, like protons, atoms and even molecules. The larger the object, the smaller the wavelength and the harder it is to conduct the experiment. Today, researchers work on the interference of viruses, which are gigantic compared to the size of an electron.

What is really disturbing about the double-slit experiment is the result of sending only one photon (or electron) at a time through the slits. Special detectors can measure the precise location on the screen where the photon arrives. If you repeat the experiment multiple times and record one photon after the other, you will find that they become distributed on the screen in the same diffraction pattern as in your experiments today. But what does each single photon interfere with, itself? If so, how can it pass through both slits at the same time? Or how does it know where the other photons went that passed the slit before it? These questions still puzzle scientists today; maybe you can find an answer to them?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