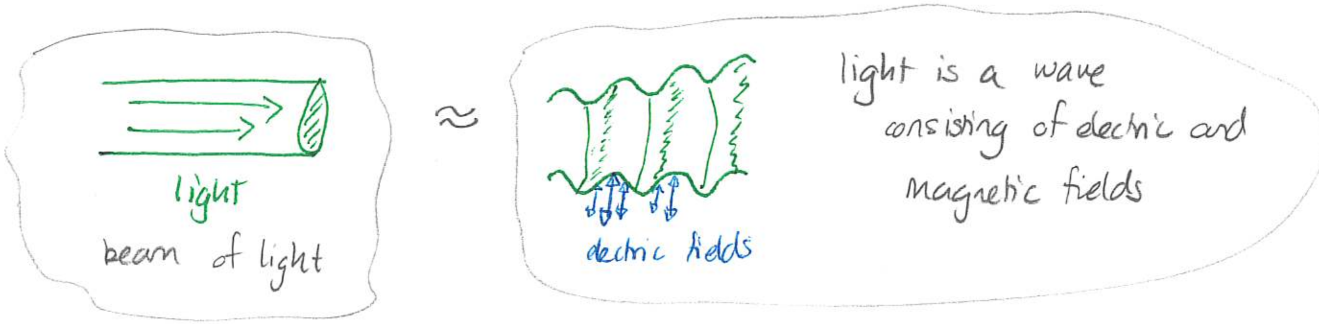
Fri: Read

Mon: HW by 5pm

Light as an electromagnetic wave

Experimental and theoretical evidence developed during the 19th century led to the conclusion



The usual rules for waves applied and, in this case, the speed of light in a vacuum is the same regardless of the wavelength or frequency

speed of light = wavelength × freq

3.0×10^8 m/s = wavelength × freq. ⇒ wavelength (m) = $\frac{3.0\times10^8 \text{ m/s}}{\text{frequency (Hz)}}$

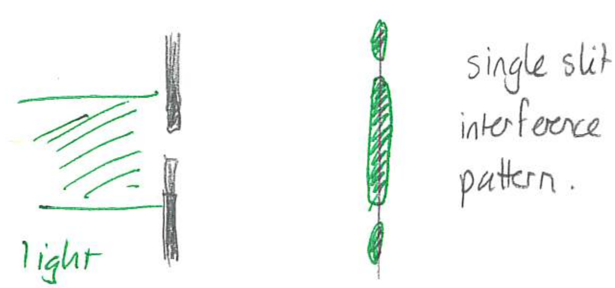
⇒ frequency (Hz) = $\frac{3.0\times10^8 \text{ m/s}}{\text{wavelength (m)}}$

Quiz 1 70% – 90%

Low intensity light

We can now ask whether the interference pattern produced depends on the intensity of the light incident on the arrangement of barriers and slits. We will illustrate and discuss this with a single slit.

DEMO: Laser and single slit



The wave picture of light again predicts a series of bright and dark spots and it can give the intensity very accurately at any location.

Slide: Single slit pattern

Slide: Single slit : varying intensity

Quizz -90%

In general we would observed that the basic pattern is unaffected by intensity – it will just vary in its brightness. However as the intensity becomes very low actual observations reveal stark discrepancies with wave predictions

DEMO: Show video from AJP article Aspden et al AJP 84, 671 (2016)

Such experiments reveal:

* light always arrives at the screen as individual entities
* the exact location of arrival is random and cannot be predicted with certainty
* as the particles accumulate they build up the interference pattern that is predicted using waves.

DEMO: PhET Quantum Wave Inteference

⇒ High Intensity → Double Slit * width 25%
* Sep ~~25%~~ 50%
* vertical position

→ Display → time average intensity.
→ hits

⇒ Single Particle → single photon
→ auto repeat

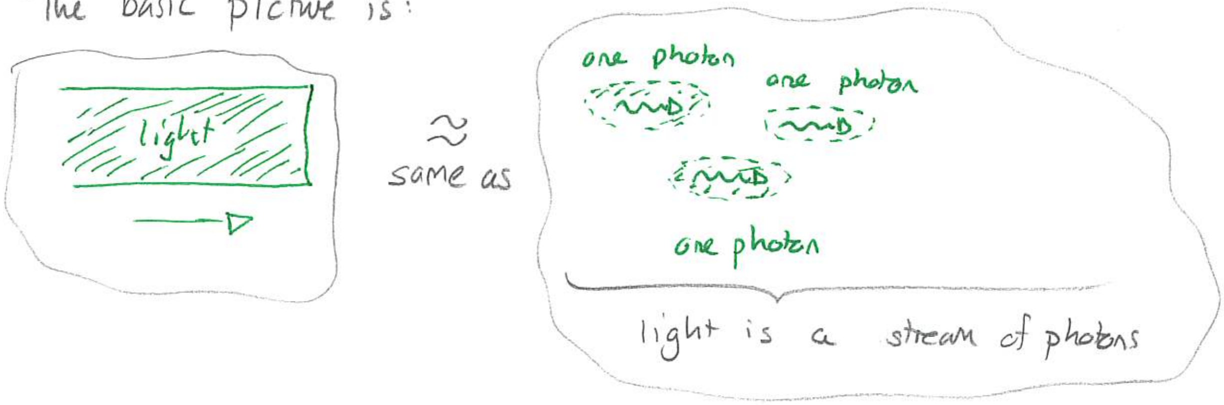
The wave model does not predict this. We need a new model that considers light as individual entities but also eventually predicts the interference pattern in agreement with wave physics.

Photon model of light

The model that describes this low-intensity light behavior uses:

Photons ~ individual particles of light

The basic picture is:



The model assumes the following properties for photons:

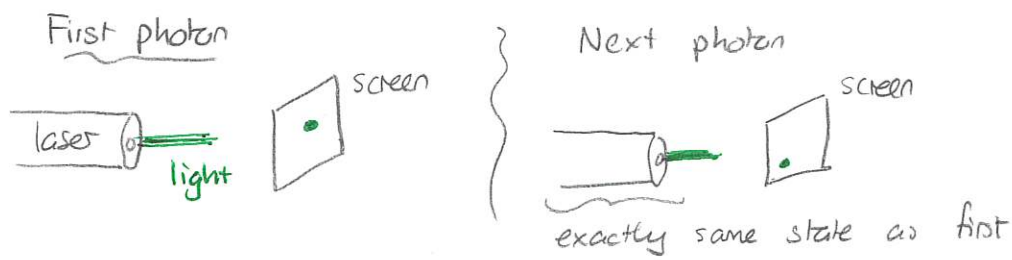
1) any photon is indivisible ⇒ a photon cannot be split into two or more photons
2) photons do not combine ⇒ two or more photons do not combine to make one.
3) when a photon is detected – it appears at a single location and ceases to exist
4) photons are massless
5) a photon occupies an extended range in the direction in which it propagates
6) in a vacuum a photon propagates at the speed of light.

Quiz 2 90%

The model does not attempt to predict with certainty where any photon will arrive

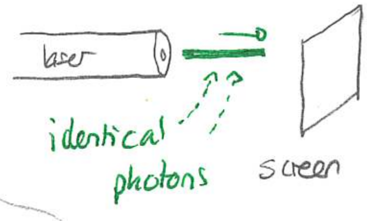
Quiz 4

So we have



The physical theory that describes this is quantum theory. In this situation it says:

Prepare photons in *exactly* the *same* way

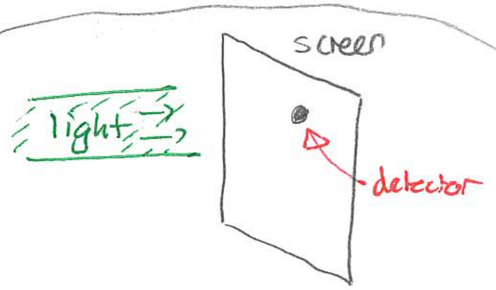


→ It is *impossible* to *predict* where any particular photon will arrive *with certainty*

→ It is possible to predict the probability with which a photon will arrive at various locations

Probabilities

Probability is a mathematical method for describing how likely any occurence might be. In the context of photons, we could imagine a small detector at a screen



suppose that the light provides a known (total) number of photons

→ Count the number of particles that arrive at the detector

→ Probability of arrival

$$= \frac{\text{number that arrive}}{\text{number that could arrive}}$$

Quiz 5 80%

Quiz 6 80%

There is a theory, quantum theory, that will allow one to predict these probabilities very accurately.