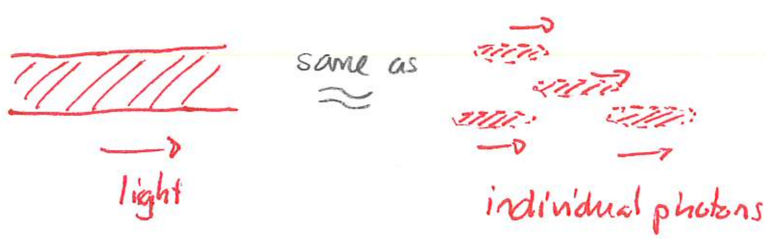
Mon: HW by 5pm, Read
Group exercise

Weds: Review

Fri: Test 3 Covers Waves, Light Lectures 28-35
HW 8, 9

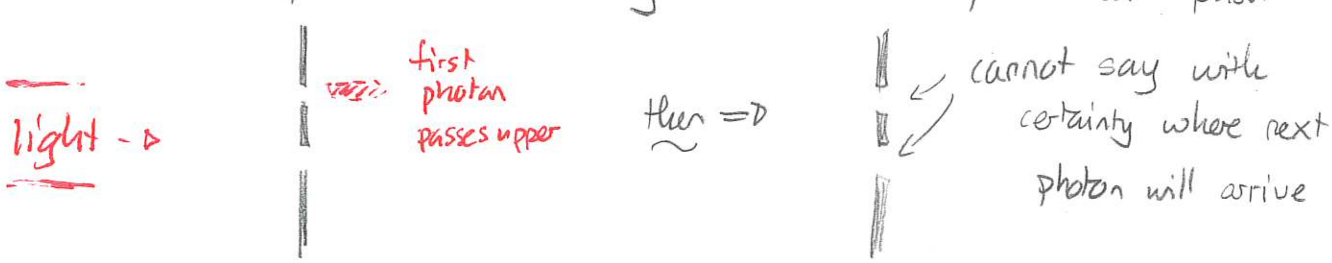
Photon model of light

In the photon model of light, light effectively consists of particles, called photons. The model provides properties of photons:



1) any single photon cannot be split into more than one photon
2) two or more photons cannot combine to form one photon
3) when a photon is detected, it appears in a single detector or at a single location.
4) photons are massless
5) photons travel at the speed of light (in a vacuum $c = 3.0 \times 10^8$ m/s).

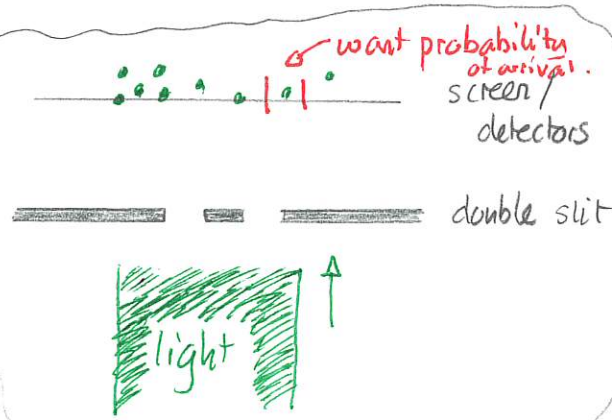
Additionally, it is impossible to predict in general where photons will arrive or be detected. Thus if light consisting of photons is incident on a double slit, we cannot predict with certainty where the next photon will pass.



Predicting photon arrival probabilities

Fortunately a general theory in physics, quantum theory allows us to predict the probabilities with which photons will arrive at various locations. F.r

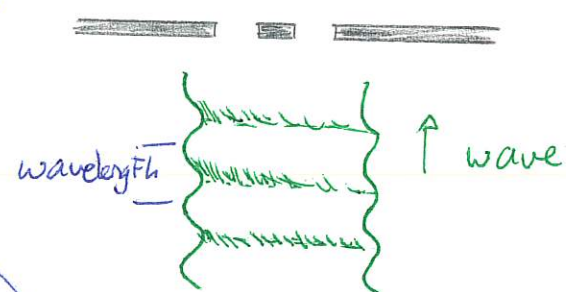
The scheme is illustrated for an interference experiment



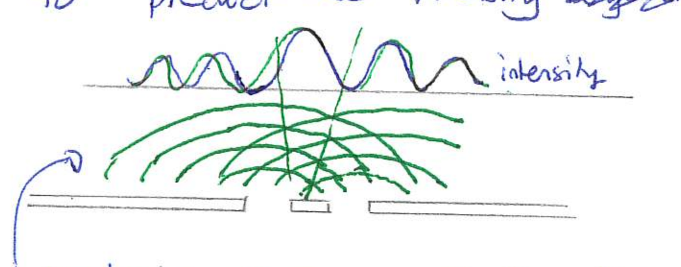
To calculate

Associate a wave with the light. This has

* a wavelength
* a frequency
* intensity



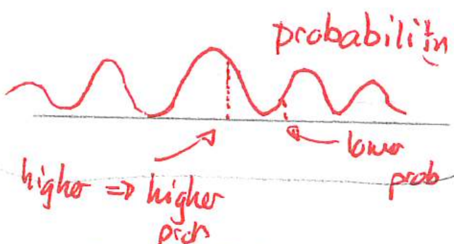
Use (classical) physics of waves to predict the intensity ~~beyond~~



Overlapping waves ~ constructive / destructive interference ~ profile

MATHEMATICAL MODEL

The probability of arrival at the screen is determined using a probability graph which has the same form as the intensity profile from the wave picture.



Slide 1 Double Slit prob

Slide 2 - Single Slit prob

Quiz 1 95%

Quiz 2

Photon numbers and photon energy

The probability only tells us how likely the arrival of a photon will be but not how many there will be.

Quiz 3

The number detected is

> number detected = total number available × probability of detection

So we would need to know the total number of photons available. The way to compute this will involve.

> Determine total energy in available light.

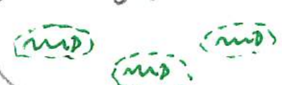
> Determine energy of a single photon.

→

$$\text{Number of photons} = \frac{\text{total energy in light}}{\text{energy one photon}}$$

This means that we need a rule for the energy of a single photon. The original rule was first proposed by Einstein in 1905. The scheme is.

> For light of exactly one wavelength (or one frequency)



→

> Every single photon has exactly the same energy as each of the others of the same frequency

→

> The energy of one photon (for light with frequency f) is
>
> $$\underbrace{\text{energy}}_{\text{in Joules}} = h \times \underbrace{\text{frequency}}_{\text{in Hertz}} \qquad E = hf$$
>
> where
>
> $h = 6.63 \times 10^{-34}$ J.s
>
> is Planck's constant

Quiz 4

In order to get from wavelength to photon energy we need

given wavelength, λ → frequency = $\frac{3.0\times10^8 \text{ m/s}}{\text{wavelength}}$

$f = c/\lambda$

→ Photon energy = h × frequency

$E_{photon} = hf$

Quiz 5

1 Photon numbers

A particular (red) light source produces light with wavelength $600\,\text{nm} = 6.00 \times 10^{-7}\,\text{m}$.

a) Determine the energy of each photon of this light.

b) Suppose that a beam of light contains exactly 700000 of these photons. What is the total energy in the beam?

c) Suppose that a beam of this light has energy $3.5 \times 10^{-3}\,\text{J} = 0.0035\,\text{J}$. Determine the number of photons in this beam.

A different (blue) light source produces light with wavelength $450\,\text{nm} = 4.50 \times 10^{-7}\,\text{m}$.

d) Suppose that a beam of this light has energy $3.5 \times 10^{-3}\,\text{J} = 0.0035\,\text{J}$. Will it contain more, fewer, or the same number of photons as the beam of red light with the same energy? Explain your answer.

Answer: a) $\text{frequency} = \dfrac{3.0\times10^{8}\,\text{m/s}}{\text{wavelength}} = \dfrac{3.0\times10^{8}\,\text{m/s}}{6.00\times10^{-7}\,\text{m}} = 5.0\times10^{14}\,\text{Hz}$

$\text{energy} = 6.63\times10^{-34}\,\text{J}\cdot\text{s} \times 5.0\times10^{14}\,\text{Hz} = 3.3\times10^{-19}\,\text{J}$.

b) $\text{total energy} = 700\,000 \times 3.3\times10^{-19}\,\text{J} = 2.3\times10^{-13}\,\text{J}$

c) $\text{number} = \dfrac{\text{total energy}}{\text{energy per photon}} = \dfrac{3.5\times10^{-3}\,\text{J}}{3.3\times10^{-19}\,\text{J}} = 1.1\times10^{16}$

d) The wavelength is smaller ⇒ frequency larger

⇒ energy per photon larger

⇒ need fewer photons for same total energy.