Tues: Discussion /quiz

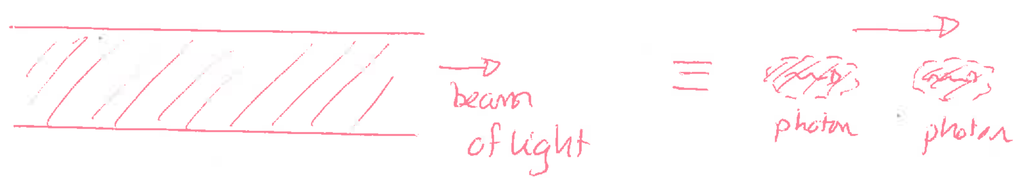
Supp Ex 123, 124, 125

Ch 28 Q 11, 12

Ch 28 Prob 20, 24, 25

Photons

Light can be viewed as providing energy in discrete packages. These are called photons and in many respects behave as particles. We can view a beam of light as a stream of photons



The crucial properties of photons are:

1) a photon cannot be split or subdivided. Two photons will not combine into a single photon

2) the energy of a photon is

$$E_{photon} = hf = h c/\lambda \qquad h = 6.6 \times 10^{-34}\ J \cdot s$$

(Planck's constant)

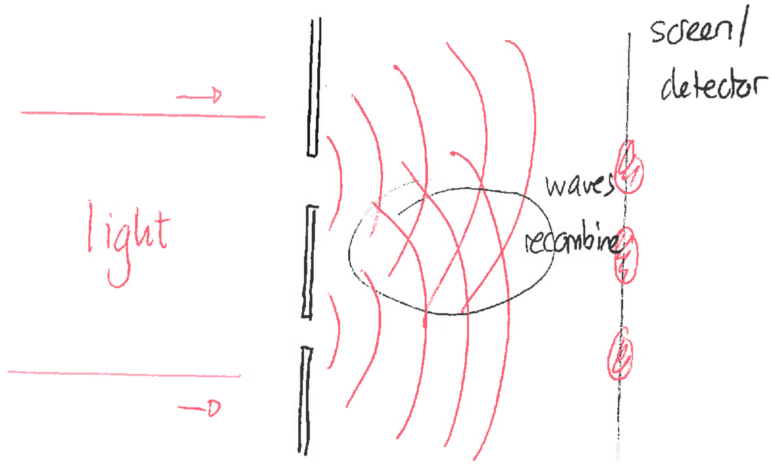
3) when interacting with an atom/molecule or matter a photon is either scattered or else is completely absorbed. The atom/molecule must has the ability to absorb this quantity of energy.

Warm Up 1

Photons and Interference

The classical wave model of light is very successful at describing interference and diffraction. These always involving splitting and recombining a wave.

But the photon model does not allow for photons to be split and nor to be recombined into a single photon.



slits split wave into two parts

Can the photon model describe the production of these interference patterns?

Perhaps a photon could choose to pass through either the upper slit or the lower slit. We might then separate the photons into those that pass through upper slit and those that pass through the lower slit. Each subset of photons would then produce its own intensity pattern on the screen. But the sum of the resulting patterns is not the same as the pattern produced when both slits are open. How can we describe the pattern?

We consider low intensity light so that there is only one photon present at any time. What would we observe?

Demo: PhET Quantum Wave Interference

1) No barriers - a) high intensity → check fade, observe screen
   b) low intensity (single particles) → uncheck fade → check Hits

2) Double slit a) High Intensity tab → check fade → observe pattern
   b) Single Particles → observe pattern building up

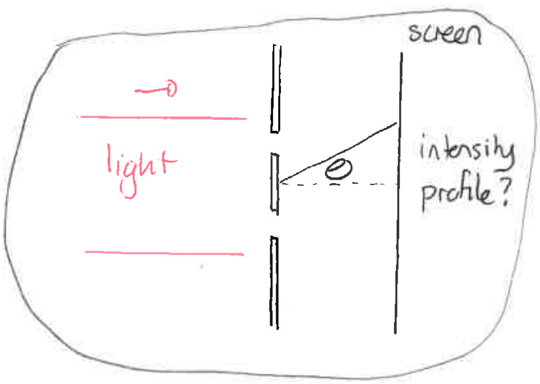
We observe a typical fundamental feature of quantum physics, which is that there is an inherent randomness to physical events. Specifically for optical interference experiments.

> If the photons are all produced identically and pass through the same equipment they will typically arrive at randomly varying locations.

Quantum physics does not offer a method for predicting the outcome of any single event. However, it can predict the probabilities with which various events occur. In the case of optical experiments

> Quantum physics can predict the probability with which photons will arrive at various detectors / locations.

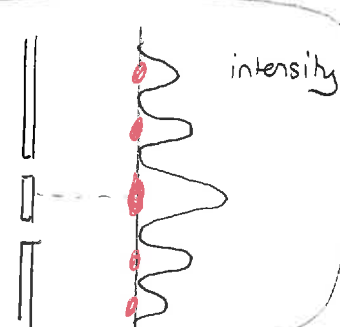
The way that quantum physics does this is by associating a wave with each photon and using the wave to predict the probability with which it will arrive in various locations. The scheme is:



physical situation

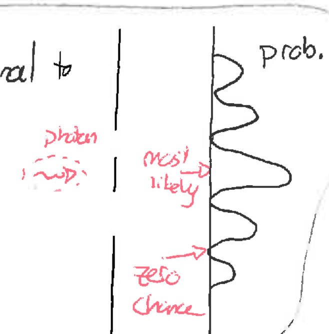
→

Associate a wave with light. Wave predicts:
- max at $d\sin\theta_m = m\lambda$
- intensities elsewhere



↙

The intensity profile is proportional to the probability with which photon will arrive at various locations



Quiz 1 - 100%

Note that even for ordinary light sources with moderately low power (e.g. 1mW laser) the rate at which photons arrive at the screen is so large that their granular nature is not apparent.

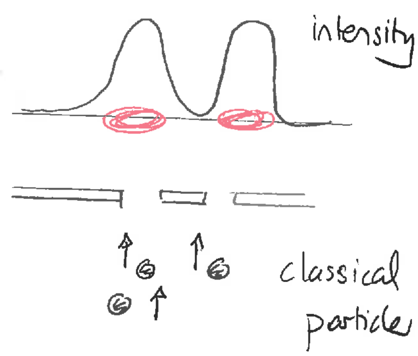
Particles and Interference

The same sort of interference expeiments can be done with particles such as neutrons, electrons, protons, small molecules

Demo: PhET Quantum Matter Waves
- single particles (neutrons)
- double slit

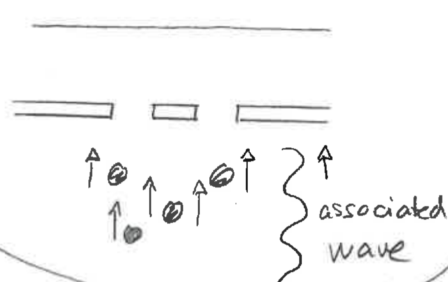
Demo: IMM electron interference - explanation link

The particles do not behave as classical hard balls. However quantum physics can do this via the following scheme.

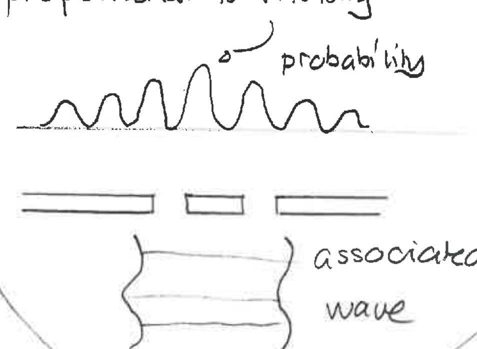


Quantum physics

- associate wave with particles.



→ use wave interference to predict probability which is proportional to intensity



Quiz 2 ← move location A

In order to predict the intensity via a wave one needs a wavelength. In quantum physics this is given by the de Broglie relationship

> Consider a material particle with mass m moving with speed v. There is a wave associated with this particle with wavelength
>
> $$\lambda = \frac{h}{mv}$$
>
> This wave is used to predict the probability with which the particle can be found at various locations

Warm Up 2

Example: An electron moves with speed 3.0×10^6 m/s
Detemine the electron wavelength

Answer:

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

$$\Rightarrow \lambda = \frac{6.6 \times 10^{-34} \text{ J.s}}{9.11 \times 10^{-31} \text{ kg} \times 3.0 \times 10^6 \text{ m/s}}$$

$$= 2.4 \times 10^{-10} \text{ m}.$$