Lecture 36

Next HW: Weds Dec 4

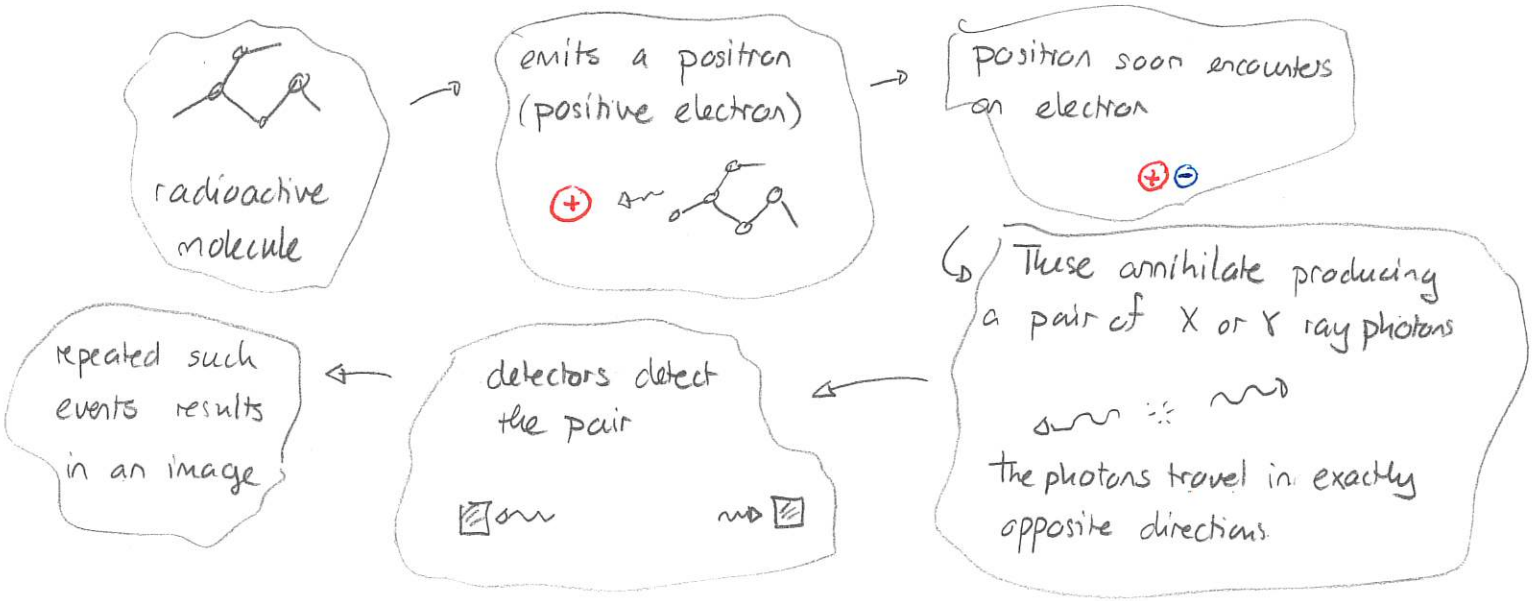
Weds: 12.4

Photon model of light

In the photon model of light, light consists of individual particles called photons. In physics this model is used:

1) to understand low-intensity light phenomena
2) to understand how light and matter (molecules/atoms) interact
3) for modern quantum theory information processing protocols.

One practical application is positron emission tomography. This is a medical imaging technique that uses radioactive tracer molecules injected into the body. The process is



DEMO: NIBIB PET Video

Models of Matter

Given that light can be describe in terms of:

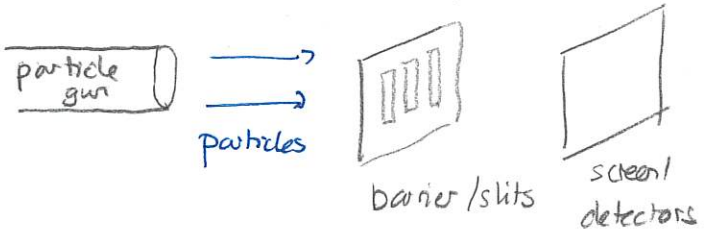
* waves AND
* particles,

we ask whether the same is true for particles? In order to show that particles have a wave nature, we would need to consider interference experiments for subatomic particles

Particle interference

We could imagine firing a stream of identical particles that have been prepared identically toward an arrangement of barriers and slits.

Consider the possibility of firing neutrons (that will not interact with each other) toward such barriers/slits and then an array of detectors.



Quiz1 ~ 80% say 3.

If the neutrons behaved like particles they would mostly arrive opposite the slits, with very few arriving in the "shadow" of the barrier

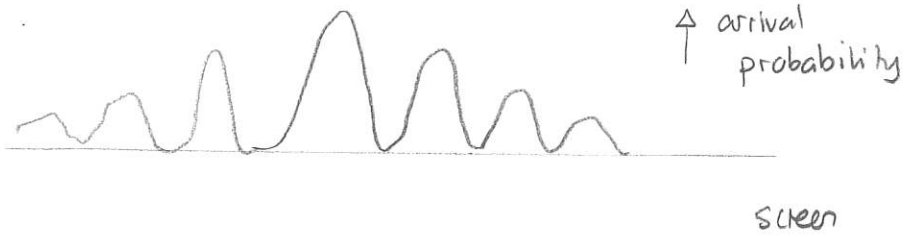
DEMO: PhET Quantum Wave Interference → Single Particle

→ neutrons
→ double slits
→ fire several and observe.

Experiments like these have been done:

1) electrons: DEMO: IMM electron experiment
2) neutrons: Zeilinger RMP 60, 1067 (1988)
3) biomolecules: Hackermuller: PRL 91 090408 (2003)

These experiments show probability distributions for arrival of particles that resemble those for photons

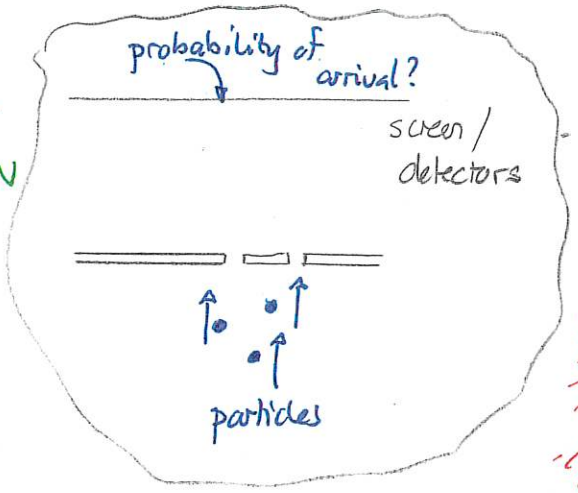


DEMO: Slide Particles Passing through double slits

Wave description for particles

Quantum theory offers a wave description that can explain this.

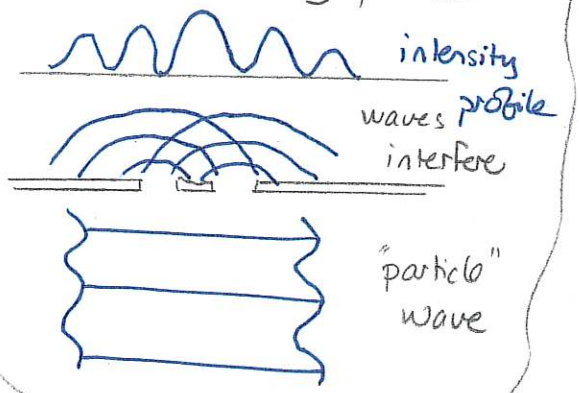
PHYSICAL SITUATION



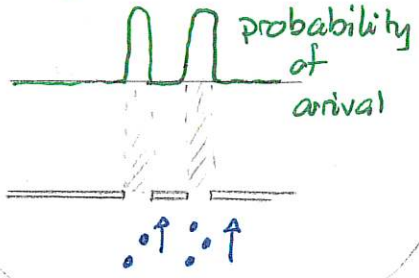
QUANTUM MATHEMATICAL DESCRIPTION

Associate a wave with the particles - requires wavelength

Use techniques from physics of waves, interference of waves, ... to predict an intensity profile



CLASSICAL DESCRIPTION



THE TWO MODELS GIVE DIFFERENT PREDICTIONS

Wave picture gives probability of arrival ≡ intensity profile

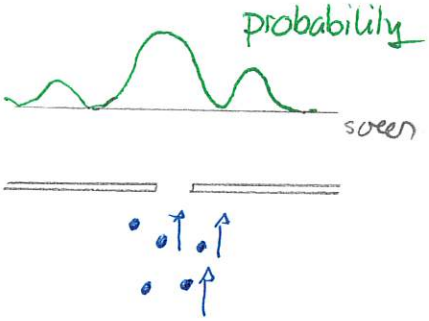
Actual experiments agree with predictions from the WAVE MODEL

DEMO : Double Slit Slide.

DEMO: Bernet PRA 62 023606 Argon Interference / Diffraction

Quiz 2 ~~60%~~ 60% - 70%

Single Slit Diffraction



We can fire particles at a barrier containing a single slit.

DEMO: Slide Particles Through Single Slit

Quiz 3 90%

Quiz 4 most say 2.

We will answer the question about the spread of arrival by appealing to the wave theory of light.