Phys 100 2023

Lecture 36

Fri: HW by 5pm

Mon: (After break) Read. 12.4

Models of matter

We will eventually consider how light in the form of individual photons interacts with matter (atoms, molecules). In this picture the light consists of discrete objects and can deliver energy in discrete quantities. We aim for a comparable picture of matter. We had:

Light → Classical model: waves

→ Quantum model: photons (particles)

We consider possibilities for matter such as molecules, atoms, electrons,...

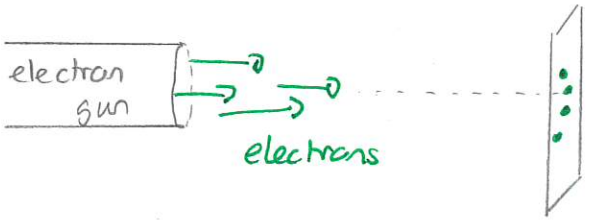
Matter → Classical model: particles

→ **Wave model?**

Would a wave model be relevant for particles? To demonstrate this we would aim to demonstrate interference for particles. Specifically we consider interference of subatomic particles

Particle interference

We can construct devices which fire electrons toward some detector/screen



Provided that the beam is wide enough we could explain the electron behavior in terms of small particles that follow a particular trajectory.

What if we insert a barrier/slit arrangement between the electron gun and the screen? To remove the possibility of electric interactions we modify the situation to consider neutrons.

Quiz 1 70%

If the neutrons behaved like particles then none would appear in the "shadow" of the barrier. On the other hand, what if the neutrons behaved like waves?

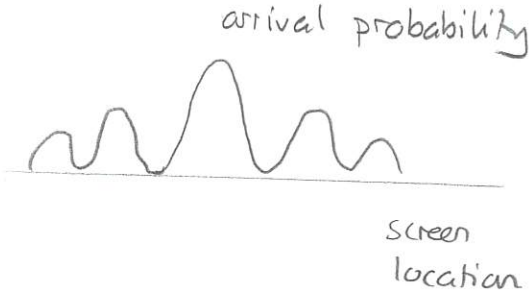
DEMO: PhET Quantum Wave Interference.

* Single Particles Tab
* Select neutrons
* Select double slits

Experiments like this have been done:

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

These experiments show probability distributions that resemble those of photons in interference experiments.

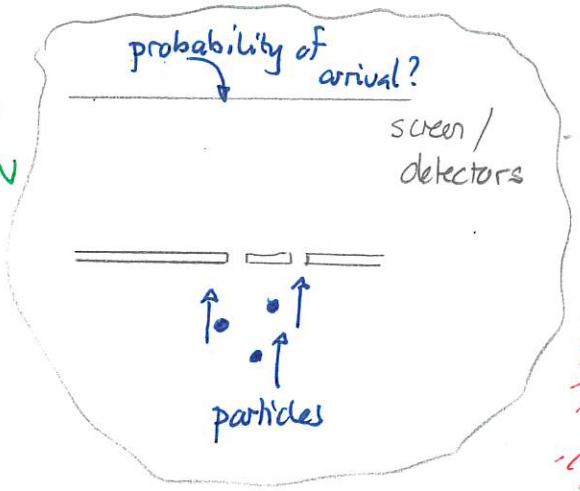


Single/Double probability/slits.

Wave description for particles:

Quantum theory offers a wave description that can explain this.

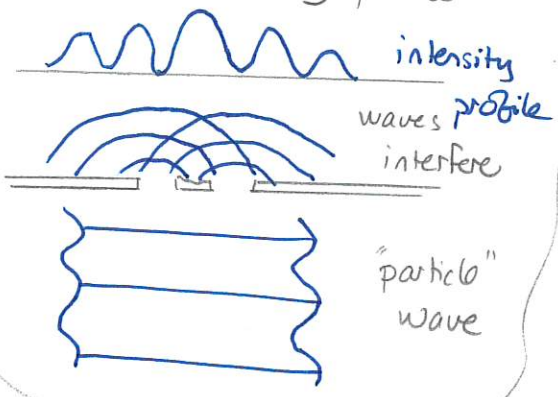
PHYSICAL SITUATION



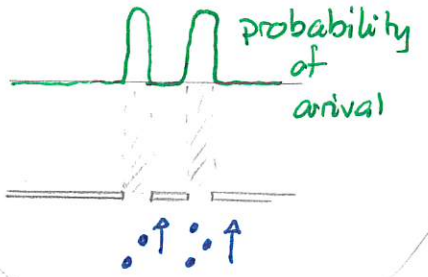
QUANTUM MATHEMATICAL DESCRIPTION

Associate a wave with the particles - requires wavelength

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

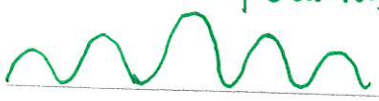


CLASSICAL DESCRIPTION



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.

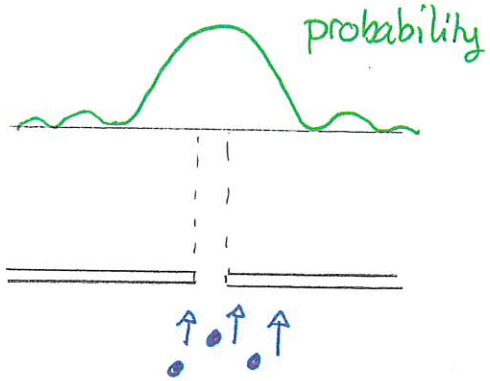
DEMO: Bornet PRA 62 023606 Argon Interference / Diffraction

Quiz 2 80%

Single slits

Similar situations arise when particles pass through single slits. Again, rather than passing as particles through the opening they tend to spread.

This is true for light waves and the intensity profile can be calculated. This gives the illustrated probability distribution.

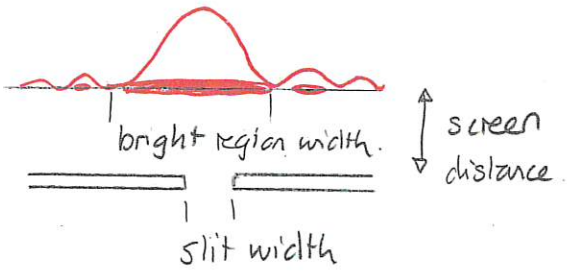


Demo: Probability for a single slit

& Quiz 3 80%

Quiz 4 very few

In order to answer the last question we need some results from the theory of light. For light passing through a single slit, there is a "central bright region". We can measure the width of this and ask how this depends on the wavelength and the slit width. The result is:



bright region width = 2 × wavelength × screen distance / slit width

Demo: Laser light + slits

Single Slit Slides

Demo: Zeilinger paper – two slots single slits