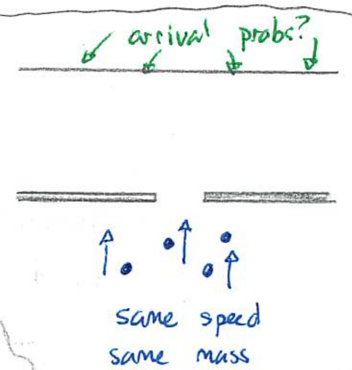
Fri: 13.6, 13.7

Weds Dec 4: HW by 5pm

Wave picture for particles

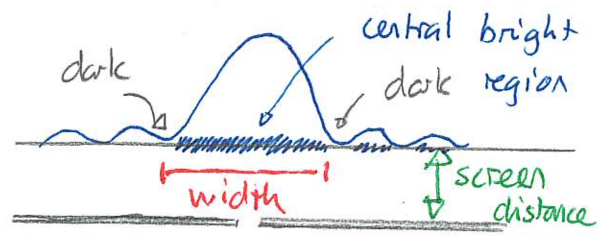
We saw that various single and double slit experiments with particles such as electrons, neutrons and molecules required a wave explanation for particle behavior. We now connect a wavelength to the particles. Consider a single slit

Physical Situation



→ Associate wave with particles

→ Use wave physics to determine how wave propagates. → predict intensity



Requires wavelength of associated wave:

$$\text{wavelength} = \frac{6.63\times10^{-34}\,\text{J s}}{\text{mass} \times \text{speed}}$$

→ wave physics predicts

$$\text{width central region} = \frac{2\times \text{wavelength} \times \text{screen distance}}{\text{width slit opening}}$$

Quiz 1 80%

Slide: Different width single slits

Demo: Zeilinger article – different single slit widths.

We can calculate wavelengths for various particle experiments.

For example:

1) Zeilinger experiment → particles are neutrons

→ mass 1.67×10^{-27} kg

→ speed 206 m/s (460 mph)

$$\text{wavelength} = \frac{6.63 \times 10^{-34}\,\text{J}\cdot\text{s}}{\text{mass} \times \text{speed}}$$

$$= \frac{6.63 \times 10^{-34}\,\text{J}\cdot\text{s}}{1.67 \times 10^{-27}\,\text{kg} \times 206\,\text{m/s}} = 1.93 \times 10^{-9}\,\text{m}$$

2) baseball → mass 0.140 kg

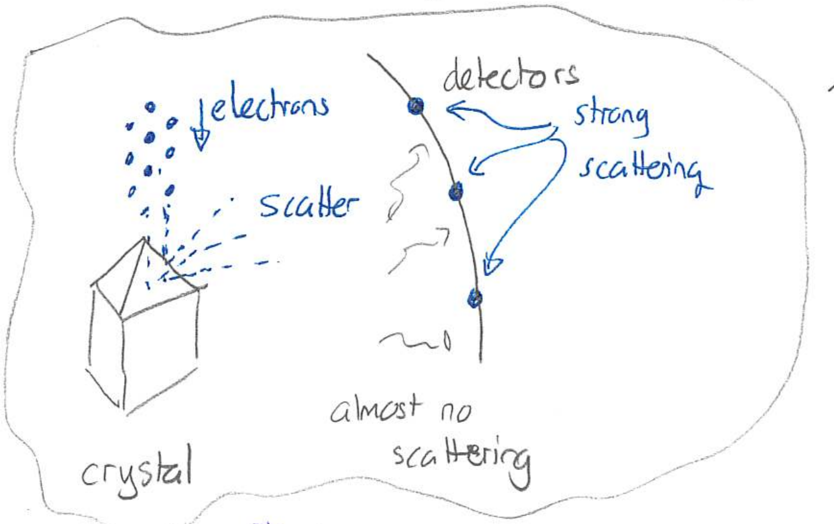
→ speed 45 m/s about 100 mph

$$\text{wavelength} = \frac{6.63 \times 10^{-34}\,\text{J}\cdot\text{s}}{0.140\,\text{kg} \times 45\,\text{m/s}} = 1.05 \times 10^{-34}\,\text{m}$$

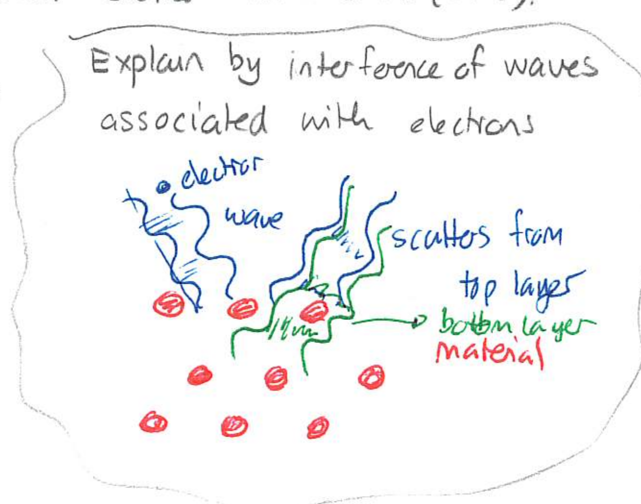
In order to demonstrate interference effects we need a barrier/slit with an opening roughly the size of the wavelength. This is barely possible for neutrons but not feasible for a baseball.

Electron scattering

The earliest evidence for the wave nature of particles came from electrons scattered off crystals, first done by Davisson + Germer in the US (1926).



DEMO: NIH images



DEMO: Wikipedia Electron Microscope images

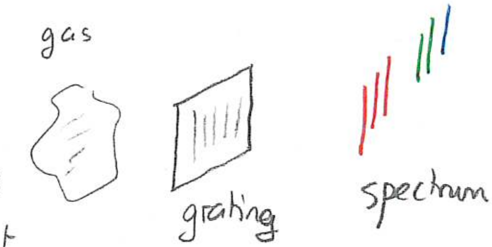
Atomic spectra

Atoms and molecules, can, under the right circumstances emit and absorb electromagnetic radiation such as light. The emitted light can be broken into constituent colors, each with a very specific wavelength. The resulting pattern is called the emission spectrum

DEMO: Discharge tube + spectrum glasses.

Observed facts are:

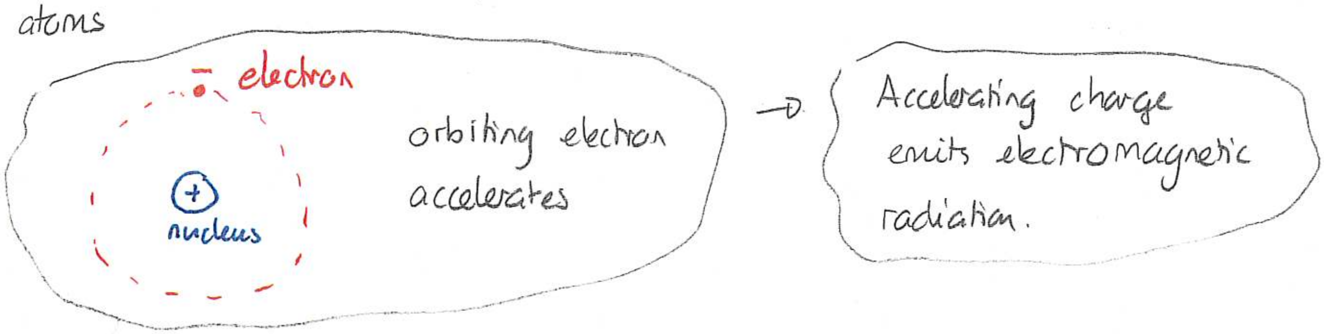
1) the emission spectrum only depends on the type of molecule/atom
2) the emission spectra of different types of atoms and molecules are distinct
3) the emission spectrum can be used to identify the atom/molecule



end

Explanations for emission spectra

Classical physics could use electromagnetic interactions between the positive nucleus and negative electrons to try to explain emission by atoms



However, it cannot get the details correct.

Quantum physics, developed in the 1920s, uses a very different framework. The details can be worked out exactly for the hydrogen atom and correctly predict the hydrogen spectrum.