Phys 100 2024

Lecture 31

Mon: HW 5pm

Weds: Read 12.2

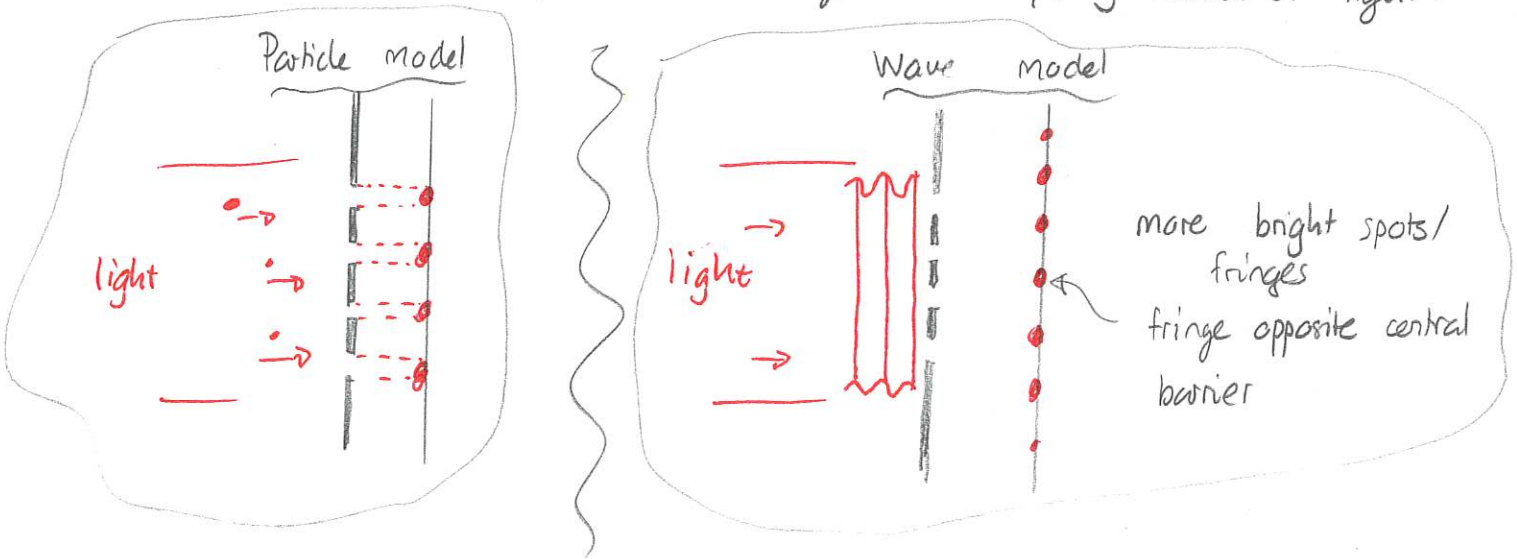
Wave nature of light

When light, of the correct type, passes through arrangements of slits in barriers it produces patterns that are not just shadows and bright areas corresponding to the slit arrangement.

DEMO: Laser and slit arrangement

* double slit
* ~~three slits~~ few slits ⇝ central max should have five bright
* diffraction grating
* square, hexagonal

We can attempt to explain these using two competing models of light



The wave model always predicts correctly and this leads us to conclude

Light can be described as a wave

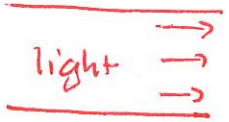
DEMO: Slide – Overlapping Waves from a Double Slit

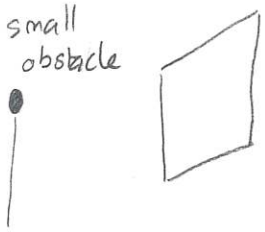
Quiz 1

The patterns that are produced as a result of interference of waves are called interference patterns. Such interference patterns were first produced by Thomas Young in 1801. A complete mathematical theory for this was developed by Augustin-Jean Fresnel in the early 1800s. This theory:

1) did not describe what the waves consisted of – what the medium was or what was moving to create the waves.
2) was able to describe the interference pattern that could be produced by any arrangement of barriers and openings.

A striking example was that of light incident on a small circular disk





Quiz 2

DEMO: Poisson spot

This question was first address by Siméon Poisson in 1818. He used Fresnel's model to predict that there should be a bright spot immediately behind the center of the disk. This was observed by Arago in 1818. This settled the debate about the nature of light.

The nature of an interference pattern depends on

1) the arrangement of slits and barriers e.g.
   * number and shape of openings
   * spacing and size of openings
2) the wavelength of the incident light

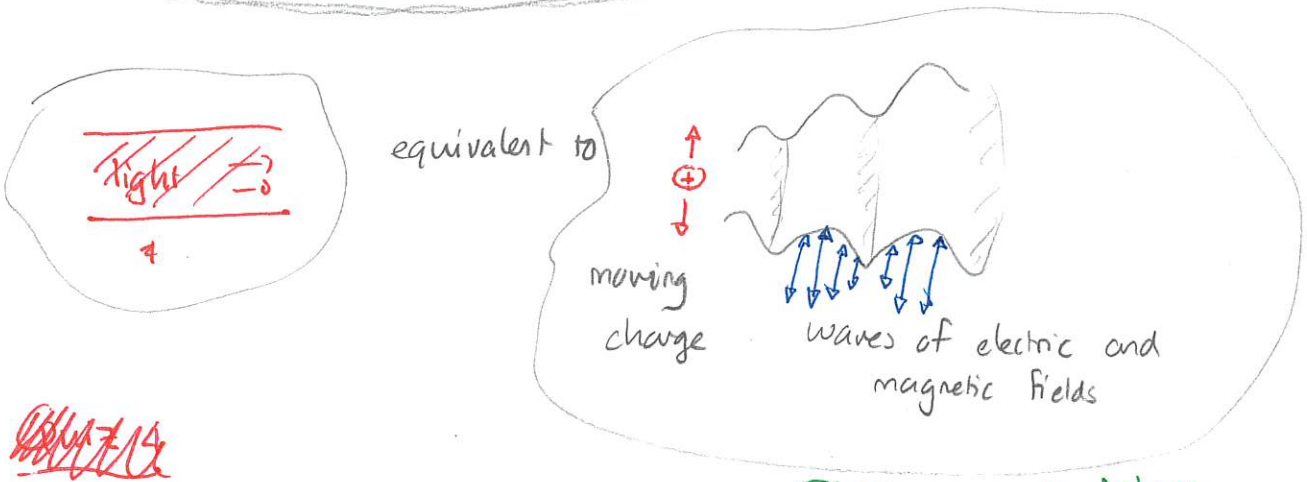
DEMO: Slide Overlapping Waves

We use these to:

1) determine wavelengths of light e.g. from stars, materials, ...
2) determine shape and size of obstacles

Then by the late 1800s, the dominant model for light was.

Light is an electromagnetic wave



Electromagnetic Wave

There exists an entire range of electromagnetic waves. These are characterized by their wavelengths or frequencies. But in a vacuum, the speeds of all types of electromagnetic waves are identical. Then we can relate their wavelength and frequency using

$$\text{speed} = \text{wavelength} \times \text{frequency} \Rightarrow 3.0\times10^{8}\,\text{m/s} = \text{wavelength} \times \text{frequency}$$

$$\text{frequency} = \frac{\text{speed}}{\text{wavelength}} \Rightarrow \text{frequency} = \frac{3.0\times10^{8}\,\text{m/s}}{\text{wavelength}}$$

$$\text{wavelength} = \frac{\text{speed}}{\text{frequency}} \Rightarrow \text{wavelength} = \frac{3.0\times10^{8}\,\text{m/s}}{\text{frequency}}$$

Quiz 4

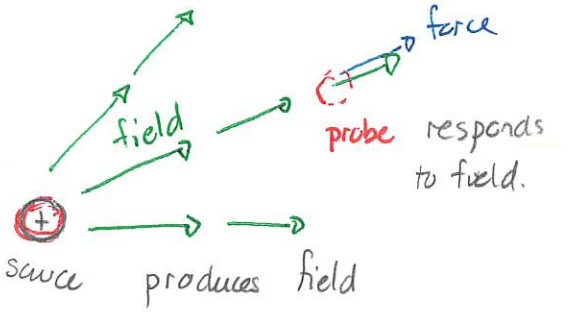
DEMO: Wikipedia EM Spectrum

The production, propagation and detection of electromagnetic waves depends on their wavelength. For example

1) cellphone $\approx$ wavelength $\approx$ 6 -> 12cm ~> produced + detected using electronics
2) light $\approx$ wavelength - 350 - 700 nm ~> produced + detected at atomic level

Electromagnetic Waves.

It remained to determine the exact type of wave that comprised light waves. The answer emerged after the complete theory of electricity and magnetism was developed by James Maxwell in the 1860s. The theory describes interactions between charged particles in terms of electric and magnetic fields.



DEMO: PhET Charges and fields

* Show fields produced by charges
* Show probe response to field

DEMO: PhET Electric Field Hockey

DEMO: Magnet Board

DEMO: PhET Magnets and Electromagnets

* Show magnet + compass
* " DC + compass
* " AC + compass

Quiz 3

Electric fields can exist in regions of space where there are no charges and even where there is a vacuum. this is also true for magnetic fields. Electromagnetic theory gives (first shown by Maxwell)

Waves of electric and magnetic fields can exist in a vacuum

→ These waves travel at the speed of light $c = 3.0 \times 10^8 m/s$

→ These waves can be produced by accelerating charged particles.

DEMO: PhET ~~Eteel~~ Radio Waves

* produce waves