Light waves

- What is light?
- The electromagnetic spectrum
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The question of what is light was a matter of great debate during the 17th and 18th century.

Sir Isaac Newton believed that light was a stream of particles.

Christian Huygens proposed that light travelled as waves.

In the end, it was found that light has both particle & wave properties.

Light travels as a wave, but interacts with objects as a particle.
We now know that light is a form of **electromagnetic radiation**. It is produced as electrons give off bursts of energy (**photons**). Higher energy radiation has a shorter wavelength, higher frequency.
• “Black-body” light sources emit a full spectrum of light.
• Other sources such as heated gases emit only certain wavelengths.
• If the light passes through the gas, those same wavelengths will be absorbed.

The wavelengths emitted are the same that are absorbed by the element.
A snapshot in time: intensity varies with distance.

At one point: intensity varies with time.

Waves

Amplitude

Distance (m)

Time (s)

Wavelength

Period

Peak

Trough
Wave equations

\[ \nu = f \lambda \]

- \( \nu = \text{wave speed (m/s)} \)
- \( f = \text{frequency (Hz)} \)
- \( \lambda = \text{wavelength (m)} \)
- Speed of light: \( c = 3.00 \times 10^8 \, \text{m/s} \)
Wave equations

- A radio station has the frequency 95.3 MHz
- What is the wavelength of the radio waves?

\[ v = f \lambda \quad \rightarrow \quad \lambda = \frac{v}{f} \]

\[ \lambda = \frac{3.00 \times 10^8 \text{ m/s}}{95.3 \times 10^6 \text{ Hz}} \]

\[ \lambda = 3.15 \text{ m} \]
Light as electromagnetic radiation

• Light is a part of the **electromagnetic spectrum** (radio waves → gamma radiation).

• Visible light is violet (~400nm) → red (~750nm).

• Electromagnetic radiation is a **transverse wave** with perpendicular alternating electrical and magnetic fields.

• Electromagnetic radiation is **polarised**. The oscillations occur in defined planes.
Polarisation

• The electric & magnetic fields of electromagnetic radiation each have an orientation.

• Polaroid filters have a crystal structure that allows through only one orientation of electromagnetic waves.

• Two polaroid filters at right angles will block all light.
Polarisation

Uses of polaroid filters:

• Polaroid glasses reduce water glare. (Water glare is horizontally polarised.)

• Modern 3D cinemas use polarisation to create 3D images. Two offset images in different polarisation are projected - each eye is covered by a differently polarised lens.

• Light from stressed material surfaces will be polarised.
Our eyes have colour sensitive cone cells.

There are different receptors for red, green & blue wavelengths.

Red, green & blue are the primary colours of light.

Spectral wavelengths trigger all three colour receptors; the same combination of RGB will look the same to our eyes.

Yellow light triggers both red & green receptors.
Colour addition

- Red, green & blue are the primary additive colours of light.
- Other colours are made by combining light of these colours.

\[
\begin{align*}
\text{red} + \text{green} & = \text{yellow} \\
\text{green} + \text{blue} & = \text{cyan} \\
\text{blue} + \text{red} & = \text{magenta} \\
\text{red} + \text{blue} + \text{green} & = \text{white}
\end{align*}
\]
Colour subtraction

- Coloured paints or filters selectively remove colours.
- Some wavelengths will be absorbed; others will be reflected / transmitted.

- **Magenta, cyan & yellow** are the primary subtractive colours.

### Diagram:

- **Magenta filter**
- **Cyan filter**
- **Yellow filter**

- **White light**
- **Magenta light**
- **Blue light**
- **No light**
Colour subtraction

- Magenta, cyan & yellow are the primary colours of paint & ink.
- Other colours of pigments are made by combining inks of these colours.

\[
\begin{align*}
\text{yellow} + \text{cyan} &= \text{green} \\
\text{yellow} + \text{magenta} &= \text{red} \\
\text{cyan} + \text{magenta} &= \text{blue} \\
\text{cyan} + \text{magenta} + \text{yellow} &= \text{black}
\end{align*}
\]
Interference & structural colour

• Colour absorption is not the only way that colours are seen.

• The colours in oil slick come from the interference of light waves travelling microscopically further (half a wavelength) to reflect off the bottom and cancel out particular wavelengths.

• Cancelling out red wavelengths gives a blue / green (cyan) colour.

• This also happens on the surface of many insect shells.