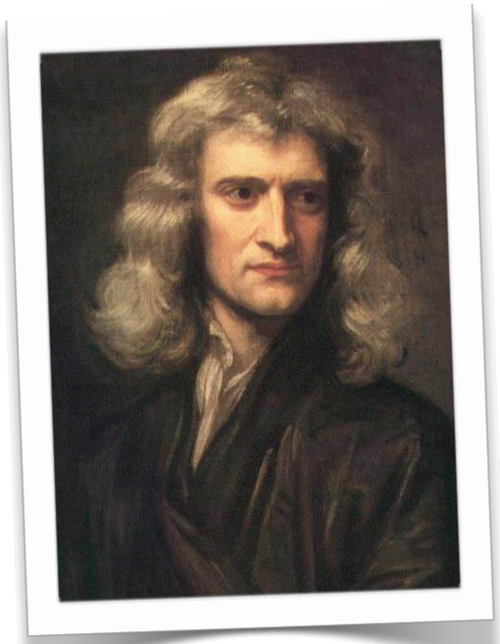
Light waves

- What is light?
- The electromagnetic spectrum
- Waves
- Wave equations
- Light as electromagnetic radiation
- Polarisation
- Colour
- Colour addition
- Colour subtraction
- Interference & structural colour

What is light?

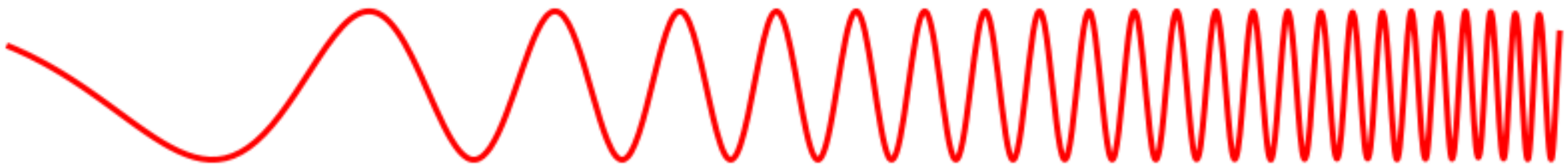
- The question of what is light was a matter of great debate during the 17th and 18th century.
- Sir Isaac Newton believed that light was a stream of particles.
- Christian Huygens proposed that light travelled as waves.
- In the end, it was found that light has both particle & wave properties.
- Light travels as a wave, but interacts with objects as a particle.



Huygen's Principle

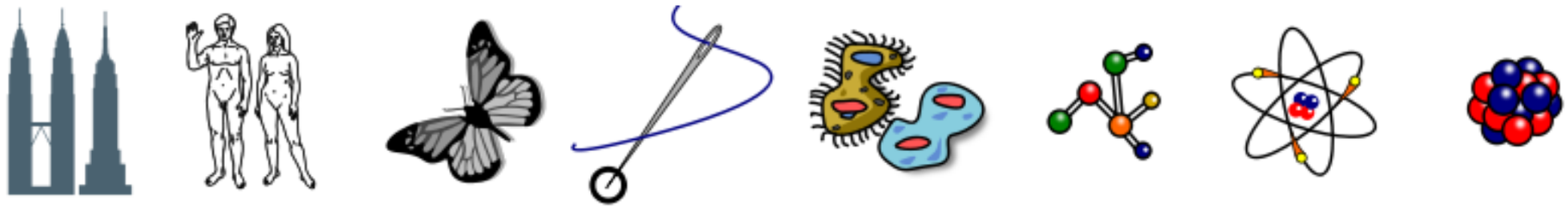
The electromagnetic spectrum

- 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.



Radiation Type	Radio	Microwave	Infrared	Visible	Ultraviolet	X-ray	Gamma ray
Wavelength (m)	10^{3}	10^{-2}	10^{-5}	0.5×10^{-6}	10^{-8}	10^{-10}	10^{-12}

Approximate Scale of Wavelength



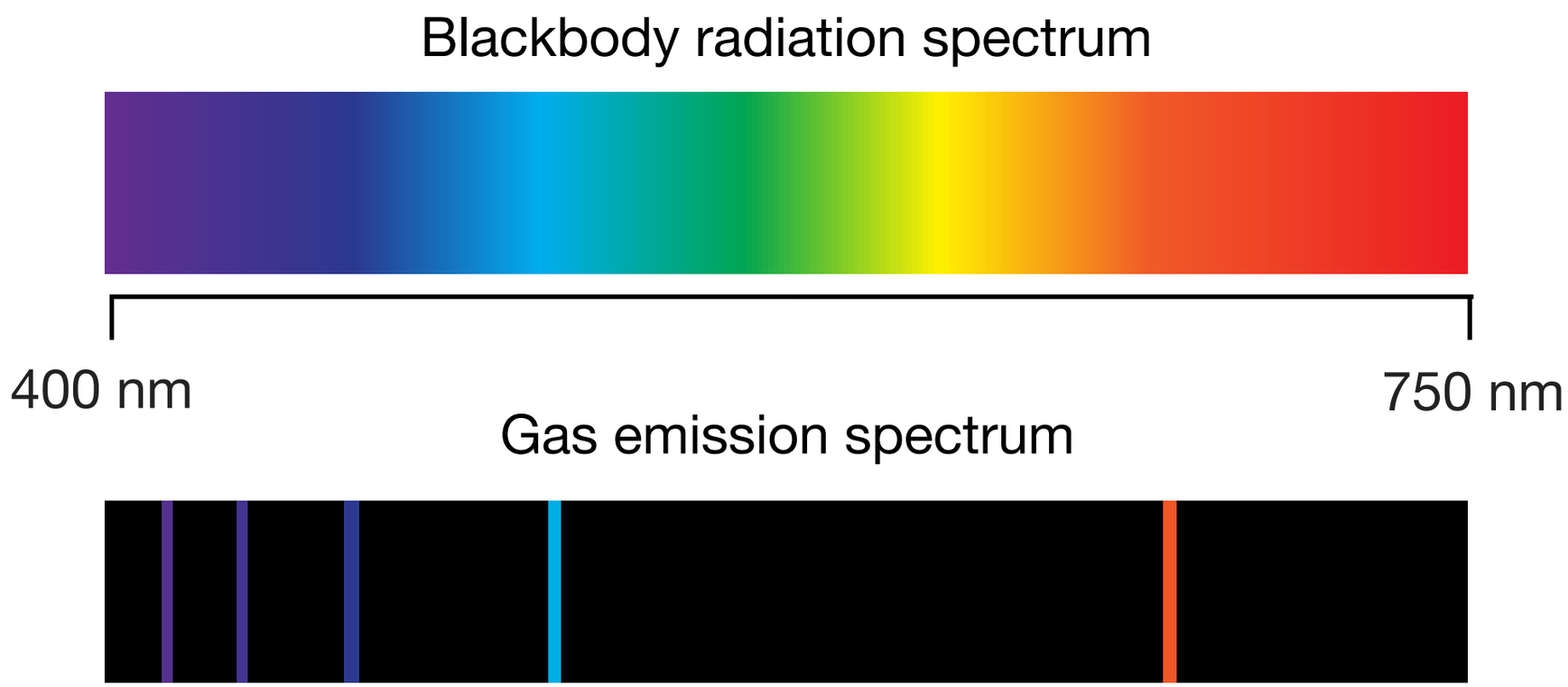
Buildings | Humans | Butterflies | Needle Point | Protozoans | Molecules | Atoms | Atomic Nuclei

Frequency (Hz)

10^{4} | 10^{8} | 10^{12} | 10^{15} | 10^{16} | 10^{18} | 10^{20}

The visible spectrum

- "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.

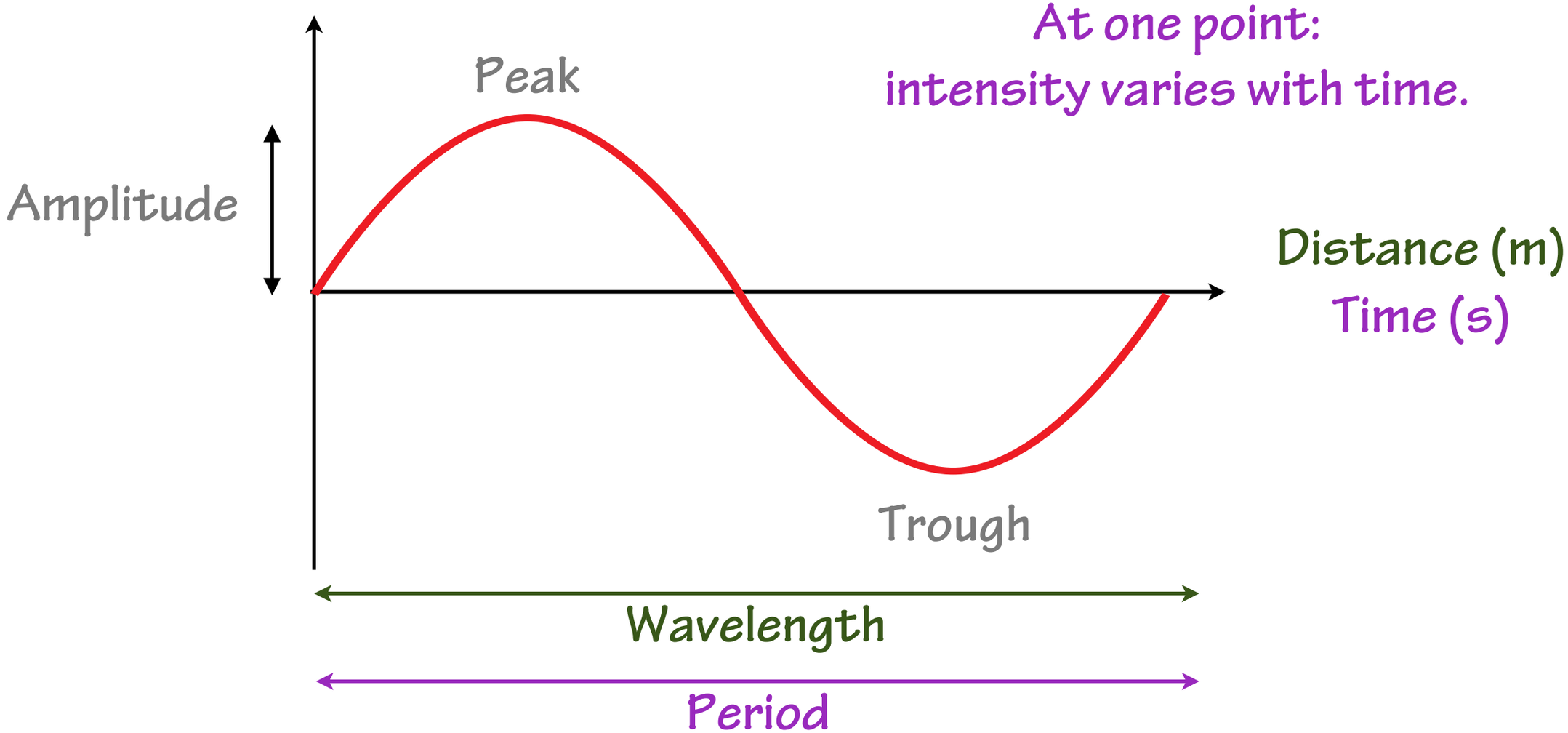


The wavelengths emitted are the same that are absorbed by the element.

Waves

A snapshot in time:
intensity varies with distance.

At one point:
intensity varies with time.



Wave equations

$$v = f\lambda$$

v = wave speed (m/s)
(dependent on material)

λ = wavelength (m)

f = frequency (Hz)

$$f = \frac{1}{T}$$

period (s)

Speed of light: $c = 3.00 \times 10^8$ m/s

Wave equations

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

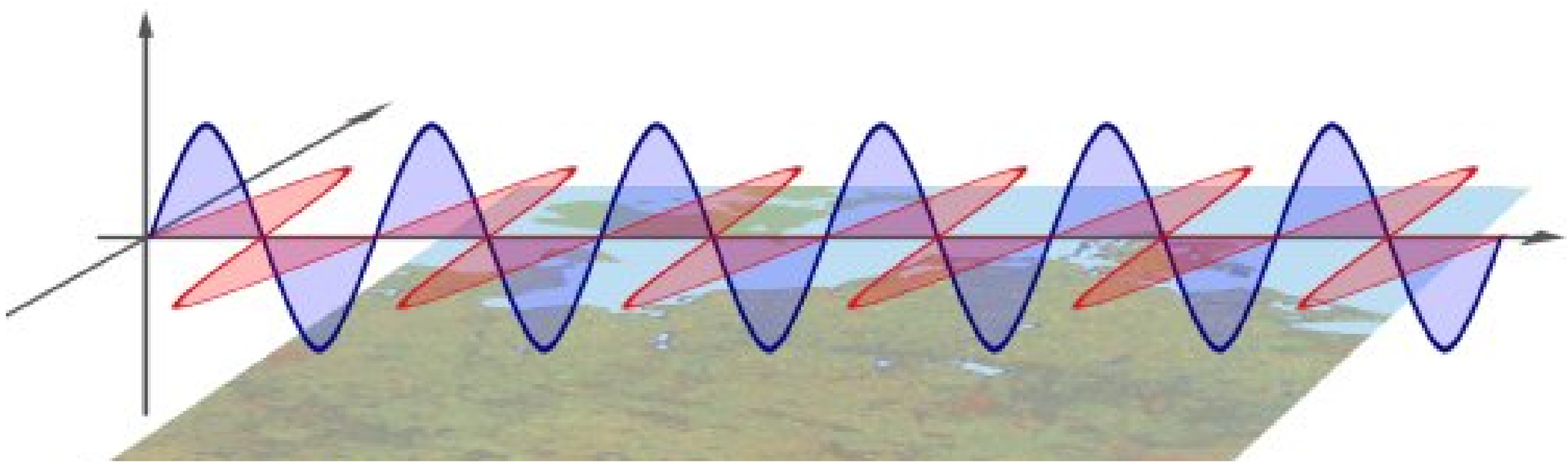
$$v = f\lambda \longrightarrow \lambda = \frac{v}{f}$$

$$\lambda = \frac{3.00\times10^{8}\,m/s}{95.3\times10^{6}\,Hz}$$

$$\lambda = 3.15m$$

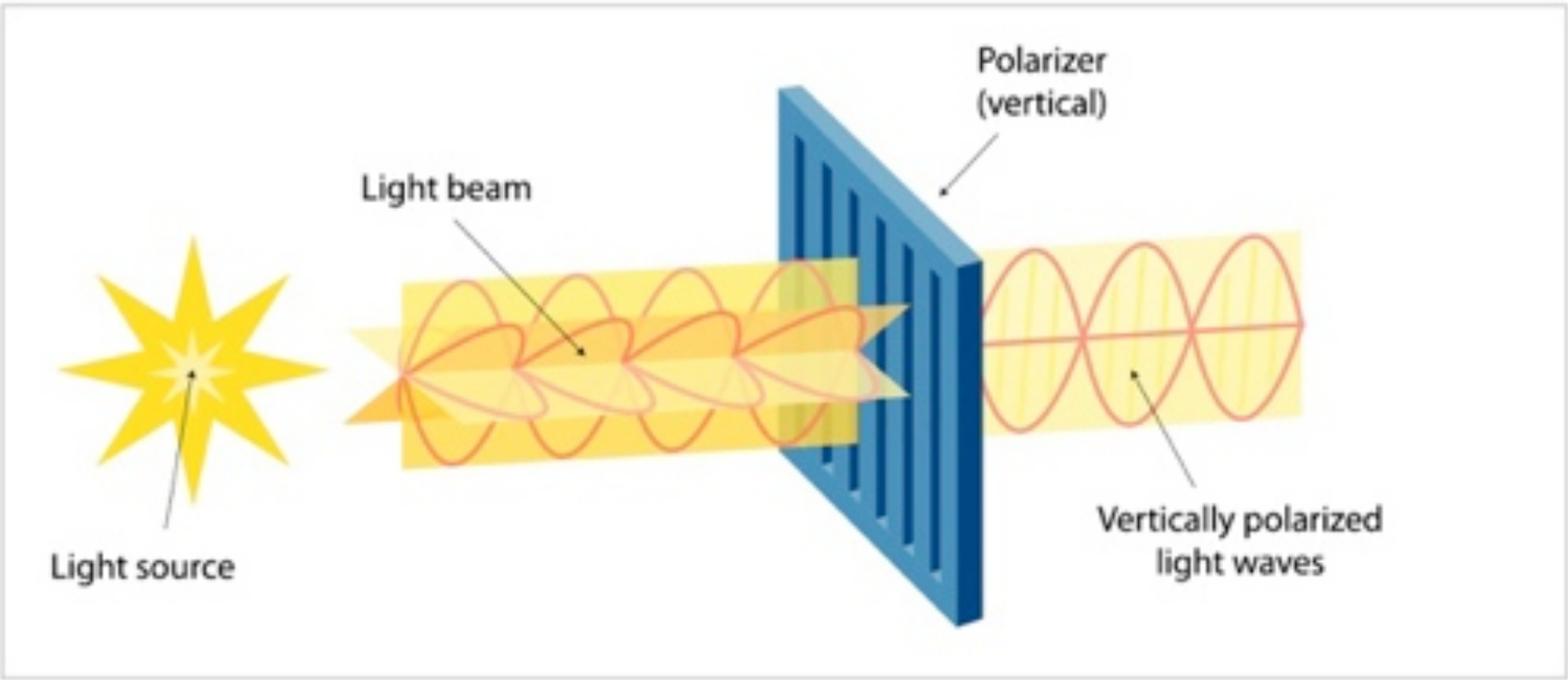
Light as electromagnetic radiation

- 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.



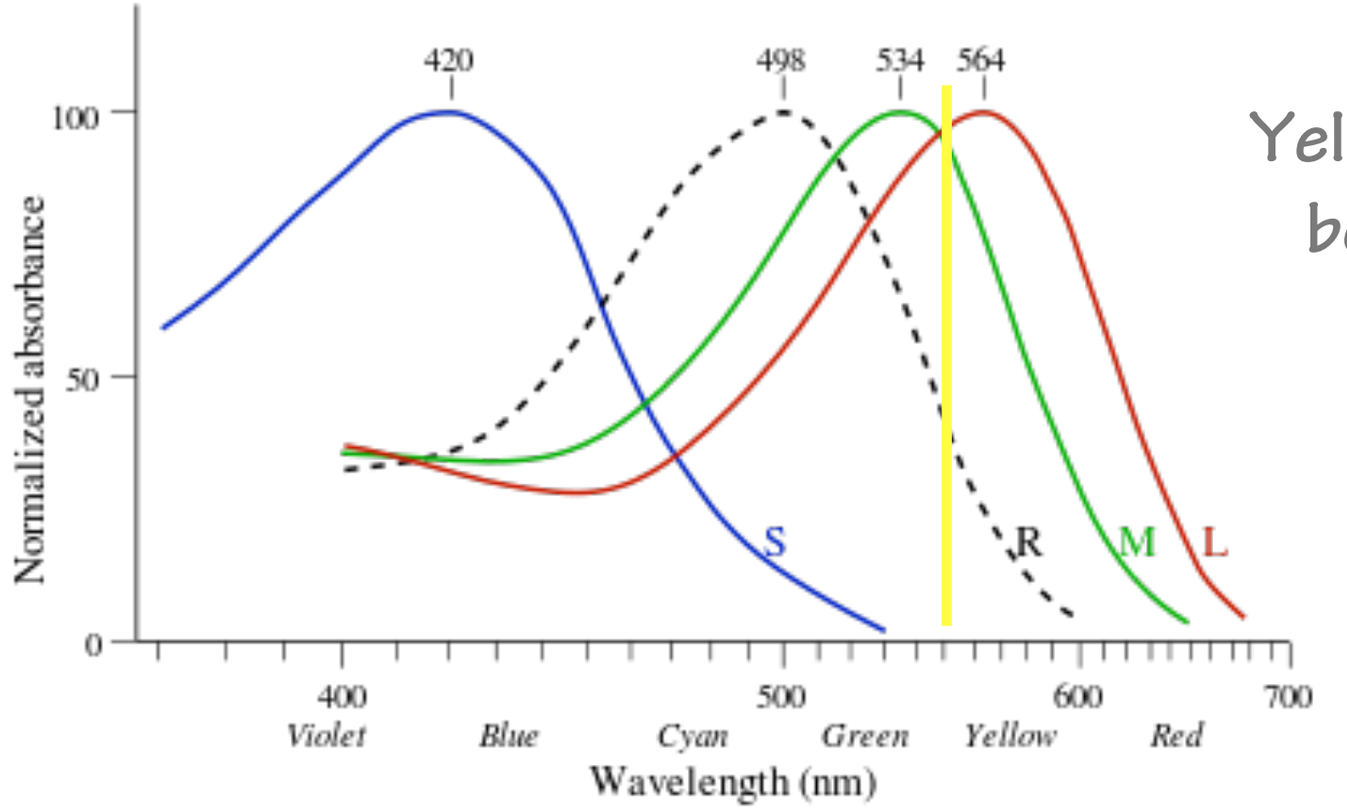
Polarisation

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.

Colour

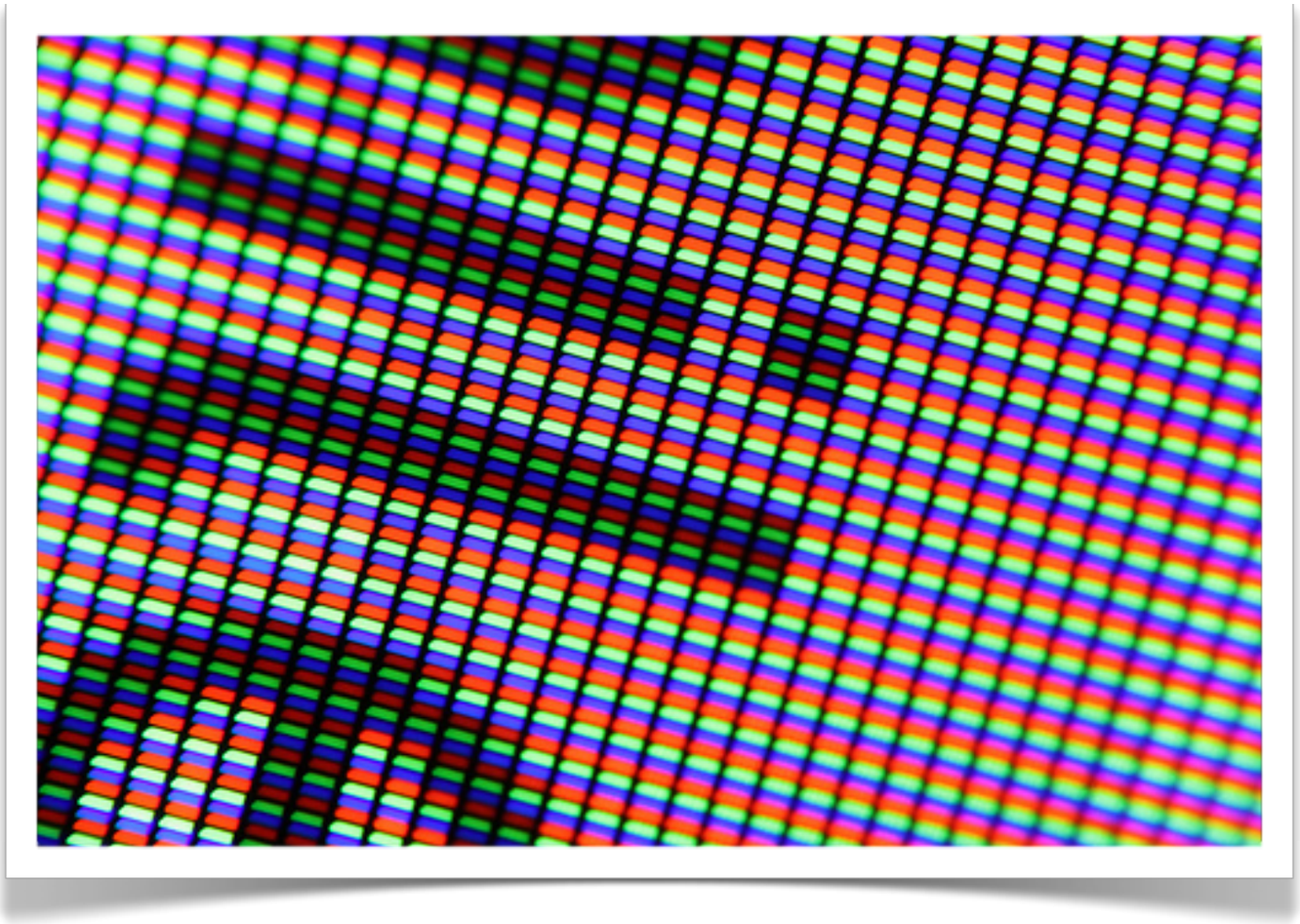
- Our eyes have colour sensitive **cone** cells.
- There are different receptors for red, green & blue wavelengths.
- **Red**, **green** & **blue** are the primary colours of light.
- Spectral wavelengths trigger all three colour receptors; the same combination of RGB will look the same to our eyes.



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.



red + green = yellow

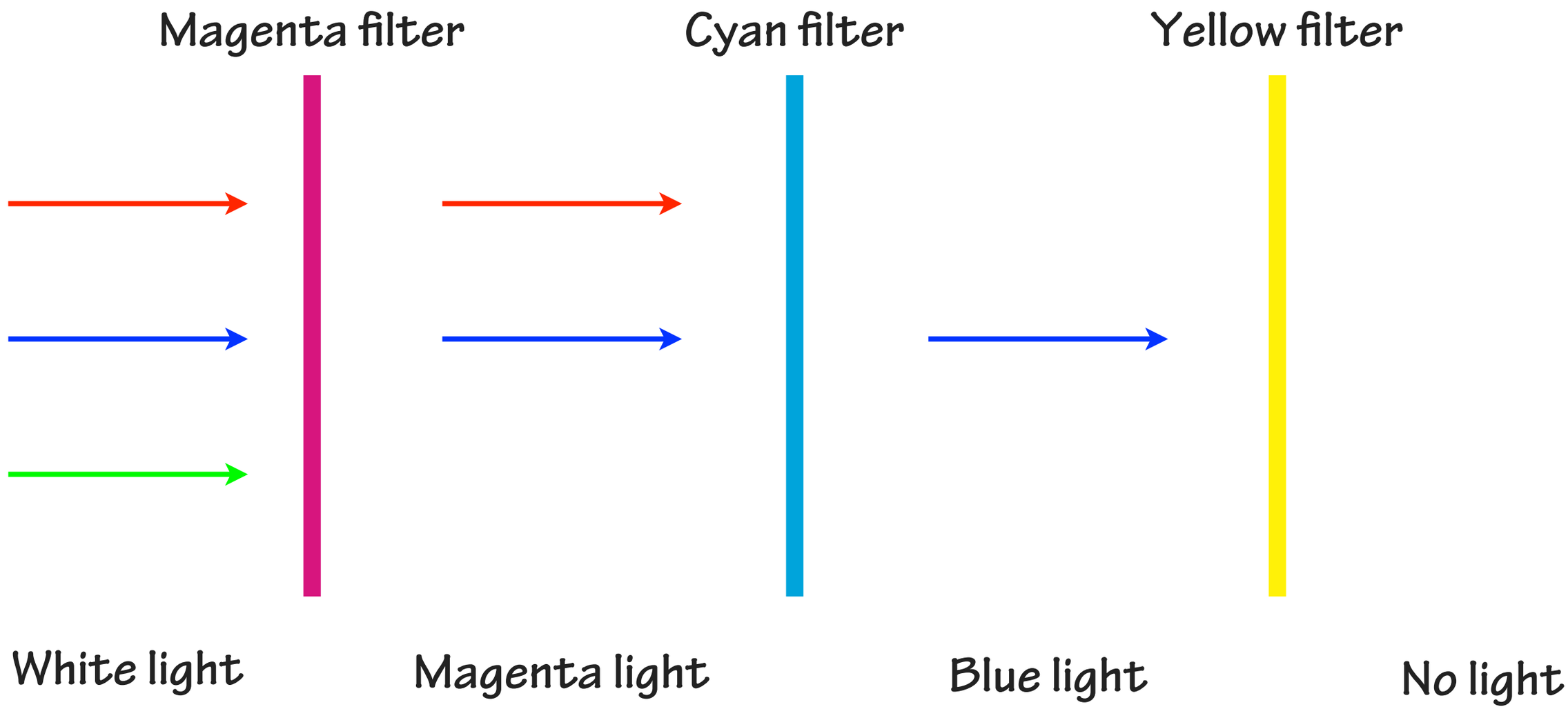
green + blue = cyan

blue + red = magenta

red + blue + green = white

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.



Colour subtraction

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

yellow + cyan = green

yellow + magenta = red

cyan + magenta = blue

cyan + magenta + yellow = black

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 of 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.