PHYSICAL SCIENCE

LIGHT – WAVES

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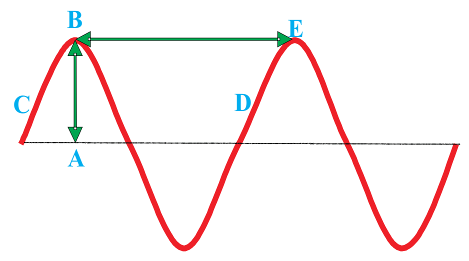
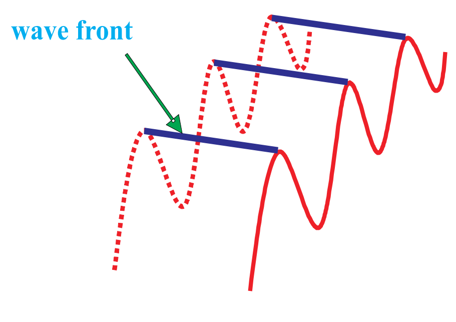
Burnwood Secondary

Electro Magnetic Radiation

Definitions

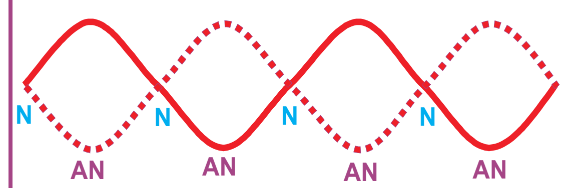
- **points in phase** (B and E) (and D) : points in a wave that have the same displacement and are moving in the same direction.
- **wavelength** (BE) and (CD) : distance between 2 successive points in a phase
- **amplitude** (AB) : maximum distance a point moves from it's rest position
- **frequency** : number of complete vibrations that occur in one second (unit : Hz)
- **period** : time taken for one complete vibration to occur (Symbol : T)
- **wave front** : line joining points in the same phase eg: a line joining all the points on a crest of a wave
- **velocity** : rate of change of displacement
- **transverse wave** : disturbance at right angles to direction of propagation
- **longitudinal wave** : disturbance in the direction of propagation





Standing Waves

Standing waves are really an example of interference.



Standing waves are produced when two waves interfere which :
- have the same amplitude
- and wavelength
- and are traveling in opposite directions.

A stationary wave pattern is produced. Standing waves tend to store energy.

N = **nodes** : points of zero disturbance , destructive interference

AN = **antinodes** : points of maximum disturbance , constructive interference

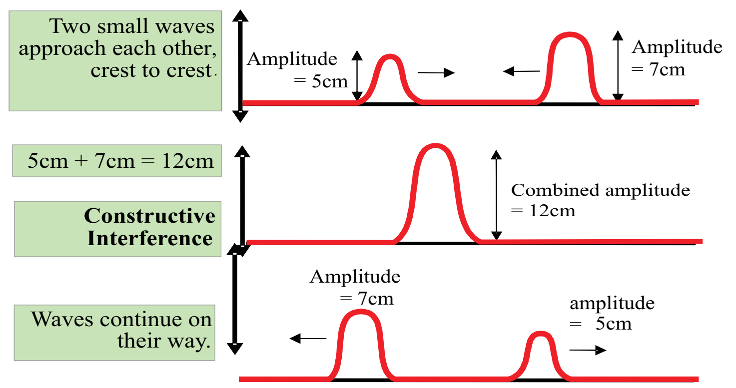
Principle of Superposition of Waves

(predicts displacements when two waves meet)

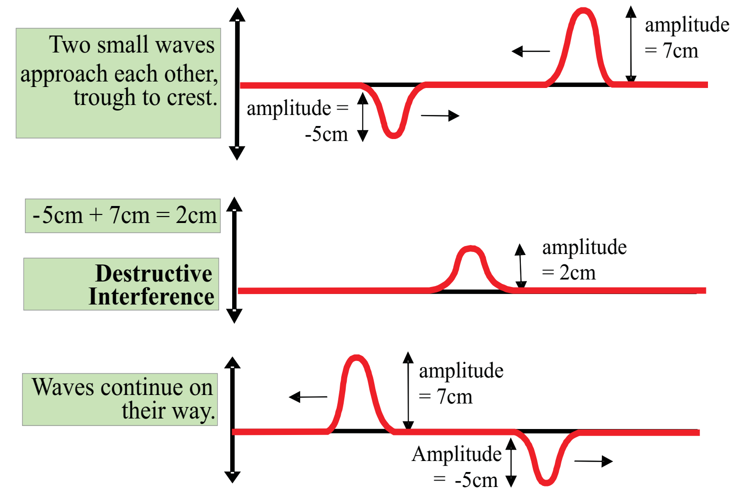
When two waves in the same medium meet, the instantaneous displacement of the medium at any point is given by the algebraic sum of the displacements of the individual waves.

The phenomenon of waves meeting is called **INTERFERENCE**

Constructive Interference



Destructive Intereference

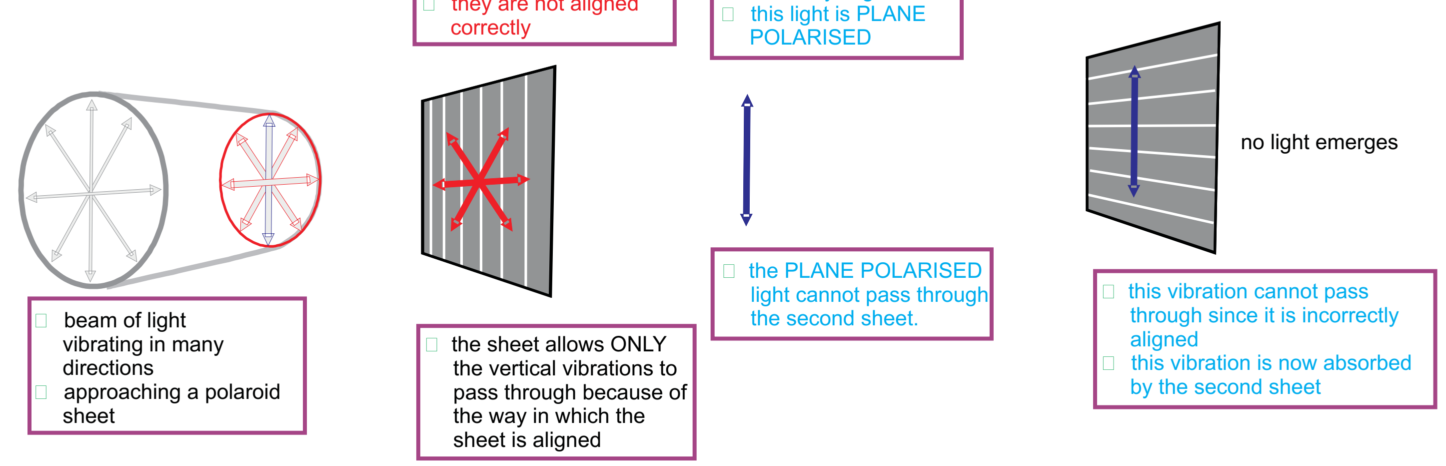


Polarization

When a wave is made to vibrate in one plane only it is said to be plane polarized.
Since light can be polarized, light is transverse in nature

It is important to note that
- **polarization** shows that light is **transverse**, but NOT necessarily a wave.
- **diffraction** and **interference** shows light to be a **wave** but NOT necessarily transverse

Collectively, light is proven to be a **transverse wave**.



Colour of Light

- speed of light is $3 \times 10^8 ms^{-1}$ in a vacuum maximum speed symbol c
- $c = f\lambda$
- speed of light is lesser in a material medium
- all **colours (frequencies)** have **the same speed** in a **vacuum**
- in a **material medium**, different colours have **different speeds (refraction** confirms this)
  - violet light is refracted more than red light (but diffracted less than red)
  - violet light travels slower than red light
- when light travels from **one medium** to **another**
  - the **speed** and **wavelength changes**
  - the **frequency** remains **constant**
- thus a **light** wave is better **described** by it's **frequency** rather than by it's colour
- SUMMARY - Light waves of all frequencies
  - have the same speed in a vacuum
  - but different speeds in a material medium

Objects do not possess colour, but rather **the ability to absorb**, **reflect** or **transmit** certain frequencies of light.
- opaque objects selective reflection
- transparent objects selective transmission

White objects **reflect** all colours.
Black objects **absorbs** all colours.
Colourless transparent objects **transmits** all colours.

Primary Colours :
- Red
- Blue
- Green

Secondary Colours :
- Turquoise (Blue + Green)
- Magenta (Blue + Red)
- Yellow (Green + Red)

White Light
- Blue + Green + Red = White

Complementary Colours
- Any **two colours** which **together** produce **White light** are called **complementary colours**

Diffraction

- ability of waves to travel around corners and obstacles in their path
- true for both transverse and longitudinal waves
- amount of diffraction increases with increasing wavelength therefore amount diffraction can be used to analyse wavelengths
- narrower gaps produce larger diffraction
- diffraction does not affect
  - frequency (period)
  - wavelength
  - speed

diff $^{\lambda}/_{w}$

Huygens Principle : Explanation for Diffraction
Each point on a wave front can be considered to be a center of disturbance for a new source of waves

Light - Single Slit Experiment

DIFFRACTION

red light is shone through a thin slit and it spreads out to form a pattern on the screen.

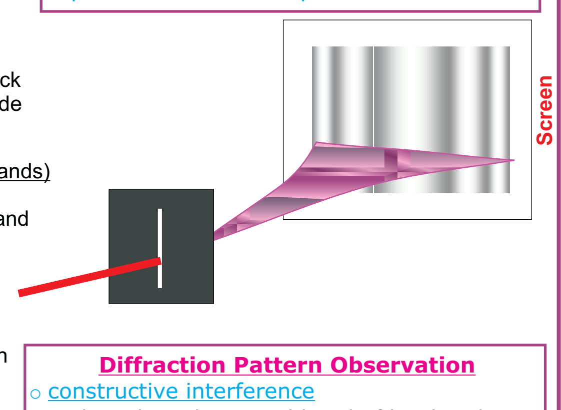
White light (black and white bands)
- each central band of bright white light
- flanked by alternate bands of spectral colour fringes and black Fringes
  - in each colour fringe red appears on the outside (longest wavelength greatest diffraction)

Red Light (monochromatic single frequency) (red and black bands)
- fringes are more distinct
- broad central band of red light (red has a large wavelength and Is diffracted a lot)

Blue Light (monochromatic) (blue and black bands)
- fringes are distinct
- broad central band of blue light
- less spaced than for red light (blue has a smaller wavelength And Is diffracted lesser)

A narrower slit produces greater diffraction

Diffraction of light confirms that light has a wave nature.
- Diffraction does **NOT** indicate whether light is transverse or Longitudinal.



Diffraction Pattern Observation
- constructive interference
  - broad single central band of bright white light
- destructive interference
  - flanked by alternate bands of spectral colour fringes and black bands

Light - Double Slit Experiment

INTERFERENCE PATTERNS

COHERENT source of light required
- two sources of light which maintain the same phase relationship with each other

Use ONE light source, but make two slits on a blackened glass slide. The two beams which emerge would be coherent since they originate from the same source.

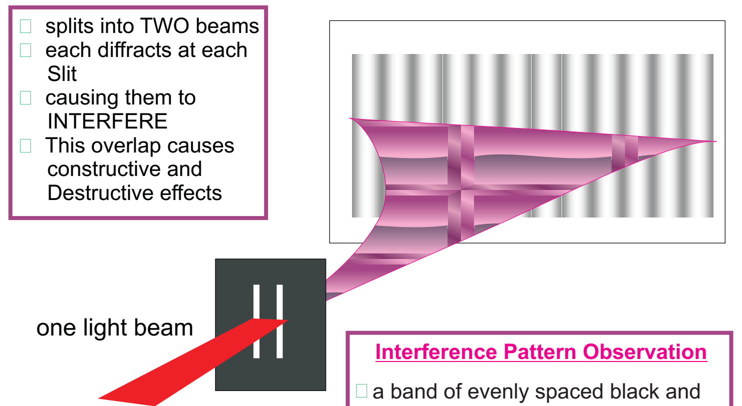
White Light
- diffraction occurs at each slit
- results in overlapping of waves
- hence constructive and destructive interference occurs
- a band of evenly spaced black and white lines are seen
  - black lines destructive interference (nodes)
  - white lines constructive interference (antinodes)

Red Light
- red and black lines are observed
- lines are more distinct

Blue Light
- blue and black lines are observed
- lines are closer than in the case of red (red has a larger wavelength)

Interference shows that light has a wave nature.
- Interference does NOT indicate whether light is transverse or longitudinal.

- splits into TWO beams
- each diffracts at each Slit
- causing them to INTERFERE
- This overlap causes constructive and Destructive effects



Interference Pattern Observation
- a band of evenly spaced black and white lines are seen
- black lines ⇨ Destructive interference (nodes)
- White lines ⇨ Constructive interference (antinodes)

Electromagnetic Waves Basic Properties

1. Electromagnetic waves originate from accelerating charges.
2. They consist of electric and magnetic fields at right angles to each other.
3. They can travel through a vacuum.
4. can be diffracted (wave)
5. display interference (wave)
6. can be polarized (transverse)
7. Their speed through a vacuum is $3 \times 10^8 ms^{-1}$.

Common Abbreviations

- **Radar:** radio detection and ranging
- **FM:** frequency modulation
- **AM:** amplitude modulation
- **UV:** Ultra-Violet
- **IR:** Infra-Red
- **UHF:** Ultra High Frequency
- **VHF:** Very High Frequency
- **HF:** High Frequency

1 angstrom = 1.0×10^{-10} meters

μ : micro
eg. 7m = 7×10^{-6}m

n : nano
eg 5nm = 5×10^{-9}m

Common Units of Frequency

Kilohertz
kHz: 10^3 Hz
eg. 5MHz = 5×10^3Hz

Megahertz
MHz: 10^6Hz
eg. 8MHz = 8×10^6Hz

Gigahertz
GHz: 10^9Hz
eg. 4GHz = 4×10^9Hz

Terahertz
THz: 10^{12}Hz
eg. 7THz = 7×10^{12}Hz

Spectrum

spectrum pattern which results when a beam of light is dispersed into component colours (frequencies)

Types of Spectra
There are two main types :
Emission Spectra and Absorption Spectra

SPECTRA → Emission spectra (→ Continuous spectra, Line Emission spectra); Absorption spectra

Emission Spectra
produced by a source of white light

Two types
- continuous spectra
  - produced by hot glowing solids, liquids
  - or by glowing gases under high pressure
  - all colours merge into one another
- line emission spectra
  - produced by gases and vapours under low or normal pressures that are stimulated to emit light by heat or electrical discharge
  - a series of individual lines of colour separated by dark spaces

Absorption Spectra
(line absorption spectra)
produced when white light is passed through the cool non-luminous vapours of an element
- black lines are seen in the continuous spectrum
  - the non-luminous vapours absorbs those frequencies of light, hence the black lines

NAME	Energy	Frequency	Refraction	Wavelength	Diffraction
Gamma Rays ($f \approx 10^{20}$ to 10^{24}Hz) ➢ emitted by radio-active elements ➢ very penetrative ➢ very dangerous	high	high	high	low	low
X-Rays ($f \approx 10^{15}$ to 10^{19}Hz) ➢ high penetrative power ➢ used in medicine ➢ photographs bones ➢ harmful if used in excess					
Ultra-Violet ($f \approx 10^{15}$ to 10^{17}Hz) ➢ Harmful					
Visible Light ($f \approx 10^{14}$ Hz) ➢ normal light ○ violet ○ indigo ○ blue ○ green ○ yellow ○ orange ○ red					
Infra-Red ($f \approx 10^{12}$ to 10^{14}Hz) ➢ heat waves					
Microwave Radar ($f \approx 10^{11}$) ➢ cooking (microwave ovens) ➢ transmission of data over long distances					
Radio Waves ($f \approx 10^{0}$ to 10^{11}Hz) ➢ TV ➢ FM ➢ Short Wave ➢ AM ➢ Long Wave	low	low	low	high	high