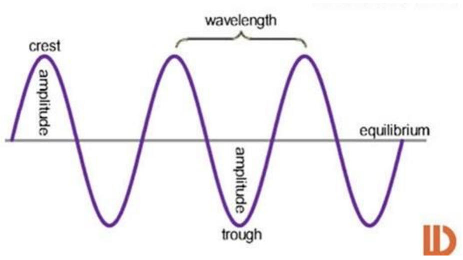
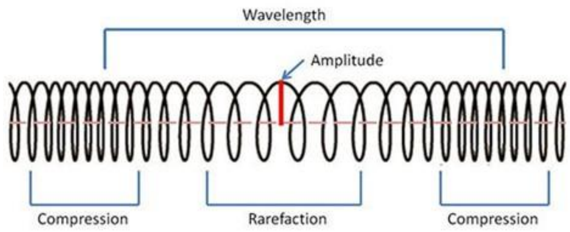
Topic 3 – Properties of waves, including light and sound

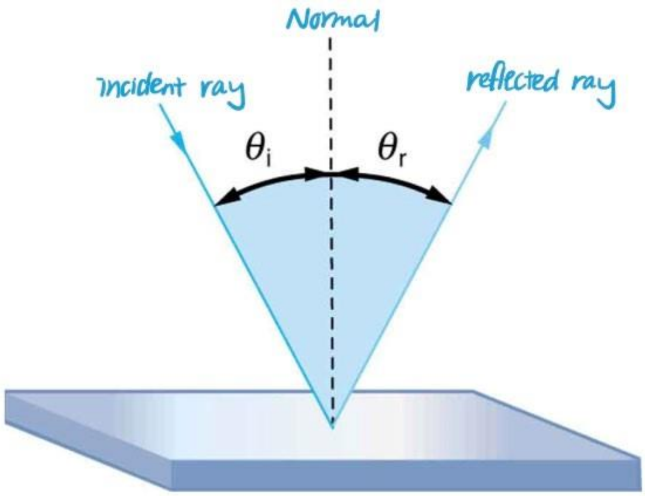
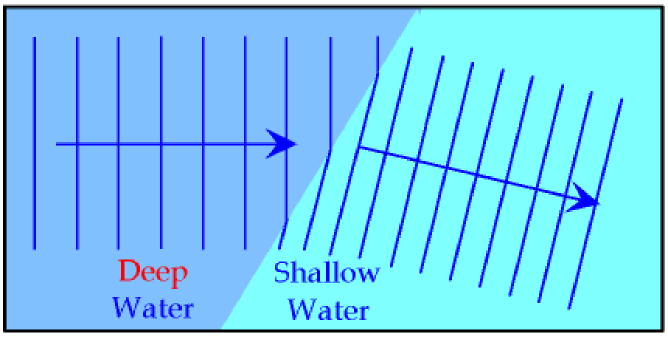
Table of Content

3.1 General wave properties

- Waves transfer energy without transferring matter
- Wave motion is illustrated by vibration in ropes, springs & water

Transverse waves	**Longitudinal wave**
	
Direction of travel perpendicular to direction of vibration	Direction of travel parallel to vibration/oscillation
Eg electromagnetic wave, S-wave, water wave	Eg sound wave, ultrasound wave, P-wave

Wavelength - distance between a pt on a wave to corresponding pt on next wave
Amplitude - max displacement of a pt from mid-position
Frequency - no of waves per sec
Speed - distance travelled by wave per unit time

Reflection	**Refraction**
	

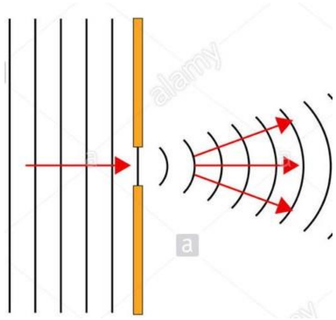
• ∠ of incidence = ∠ of reflection	• Shallow - slow & short λ • Can change speed & wavelength • Wave changes direction **Suggest a cause for the change in direction of the wave (1)** • Waves move faster in region B or slower in region A • If the waves slow down the waves will bunch together, causing the wavelength to decrease.
	The waves will also start to travel closer to the normal • If the waves speed up then they will spread out, causing the wavelength to increase. The waves will also turn slightly away from the normal

(d) The wave passes into water.

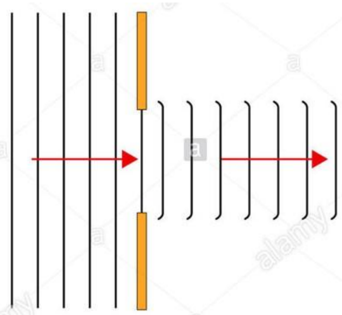
State and explain any change in the pattern of wavefronts shown in Fig. 6.1.

Speed in water is faster than air so waves speeds up then they will spread out, causing the wavelength to increase.

Diffraction



↓ gap
↑ wavelength
↑ diffraction

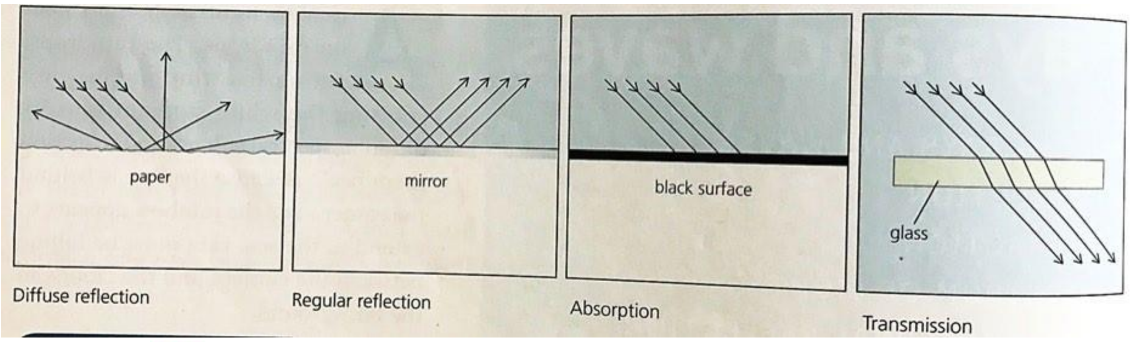


↑ gap
↓ wavelength
↓ diffraction

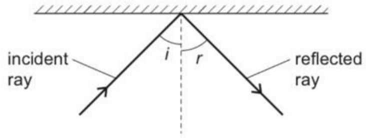
3.2 Light

3.2.1 Reflection of light

- Image in a **mirror** is virtual, upright, laterally inverted, same size as object reflected
- **Luminous objects** - make their own light (eg sun)
- **Non-luminous objects** - don't make own light

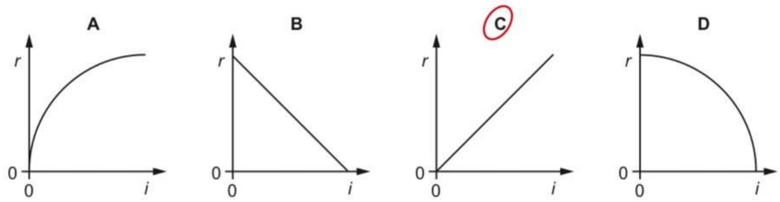


23 A ray of light is incident on a plane mirror. A student measures the angle of incidence *i* and the angle of reflection *r*.



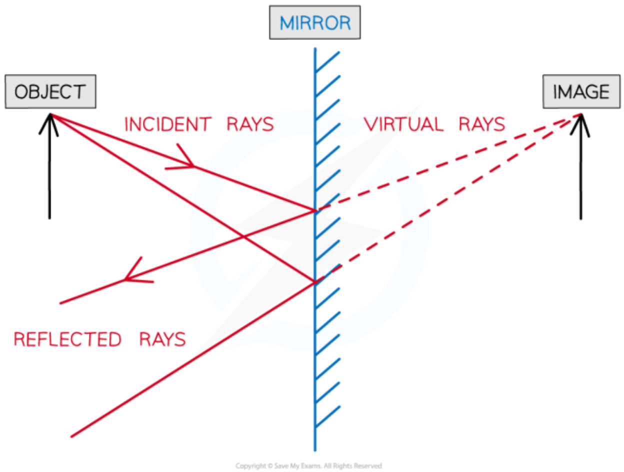
The student varies the angle of incidence and then plots a graph of *r* against *i*.

What does the graph look like?



Virtual Image & Ray Diagram

- Light from the object hits the mirror, reflecting from it (*i*=*r*)
- To an observer, the reflected ray appears to have come from the right-hand side of the mirror
- The reflected ray can be traced back in this directions, forming a **virtual ray**
- This can be repeated for another ray travelling in a slightly different direction
- An image of the object will appear where these two virtual rays cross
- The type of image formed in the mirror is called a **virtual image**



- A virtual image is formed by the divergence of rays from the image, and cannot be projected onto a piece of paper (because the rays don't actually go through the image)

3.2.2 Refraction of light

Refraction: bending when light travels from one medium to another due to change in speed of ray of light

Critical angle: ∠ of incidence when ∠ of refraction = 90° **Explain why image of coin is a virtual image?**

- It cannot be formed on a screen

$ssssssssss\ oooo\ llllllhtt\ llii\ aallaa = 3 \times 10^8/ss$

- When light enters a glass block, it slows down, causing it to change direction. • When it leaves the block it speeds up again, changing direction once more

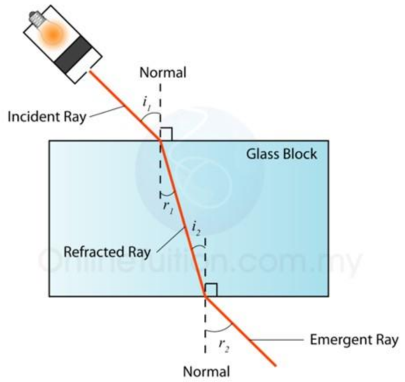
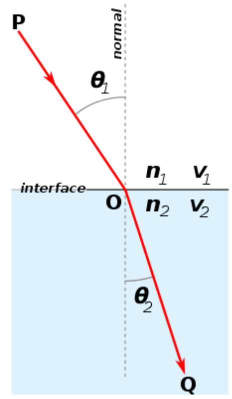


Diagram showing the refraction of light as it passes through a rectangular block

- As the light **enters** the block it bends **towards** the normal line (**Remember: Enters Towards**)
- When it **leaves** the block it bends **away** from the normal line (**Remember: Leaves Away**)

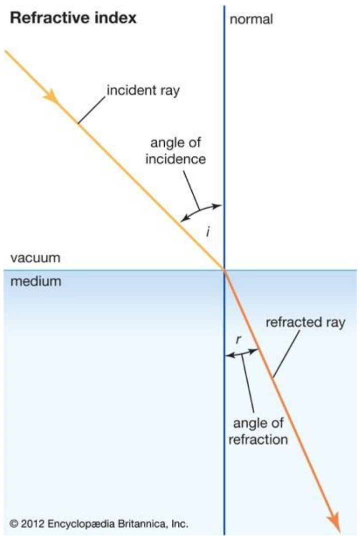
Snell's law



$$ii_1sslliiθθ_1 = ii_2sslliiθθ_2$$

$$ii = \frac{\sin ll}{\sin aa}$$

Refractive index



$$ii = \frac{1}{cc} \frac{ssssssssss\ oooo\ lllllhtt\ llii\ vvaaccccvvvv}{ssssssssss\ oooo\ lllllhtt\ llii\ vvaattssaallaall}\ ooaa \quad \sin$$

$$RRssoollssccttllvvss\ lliissssii\ oooo\ lllllvvllss = 1.5$$

Explain why the quantity refractive index does not have a unit (1)

- Refractive index is a ratio of 2 similar quantities

(ii) When a ray of white light is incident on the prism, dispersion produces a continuous spectrum of coloured light.

State how the speed of light in glass depends on its frequency. Explain how this is shown by the dispersion of white light in the prism.

statement ..... Larger the frequency, smaller the speed of light in glass

explanation ..... Violent has larger frequency, smaller speed & larger refractive index

..... [3]

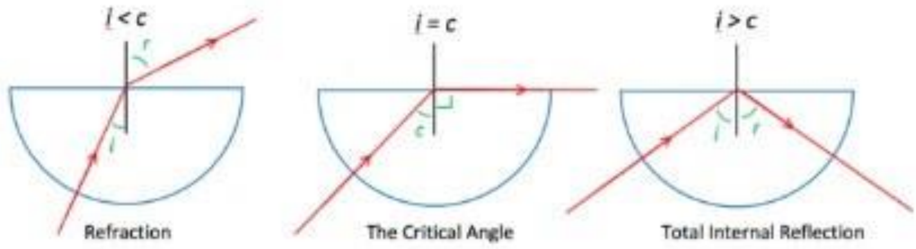
Total internal reflection

- When light is moving from a denser medium towards a less dense one, most of the light is refracted, but a small amount of it can be internally reflected.

- However, if the angle of the light is great enough then instead of being refracted, ALL of the light is reflected

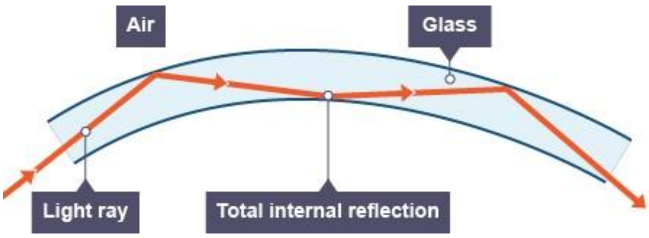
Conditions for total internal reflection

- More dense to less dense (most of the light is refracted, but a small a
- ∠ of incidence greater than critical ∠



Optical Fibres

- long thin rod of glass surrounded by cladding which uses total internal reflection to transfer information by light, even when bent
- Allow high-spped transmission of data on internet
- Use in medicine (endoscopes, inside-body flexible cameras) and communications (high speed data transfer)



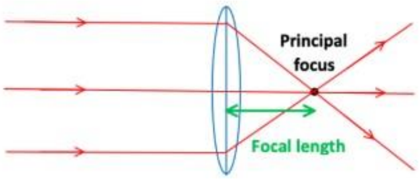
Describe use of optical fibres in medicine

Light travels down optic fibres into or out of body to examine internal organ eg endoscopes

3.2.3 Thin converging lens

Principal focus

- When parallel rays of light (travelling parallel to the principal axis) pass through a lens, they are brought to a focus at a point known as the principal focus

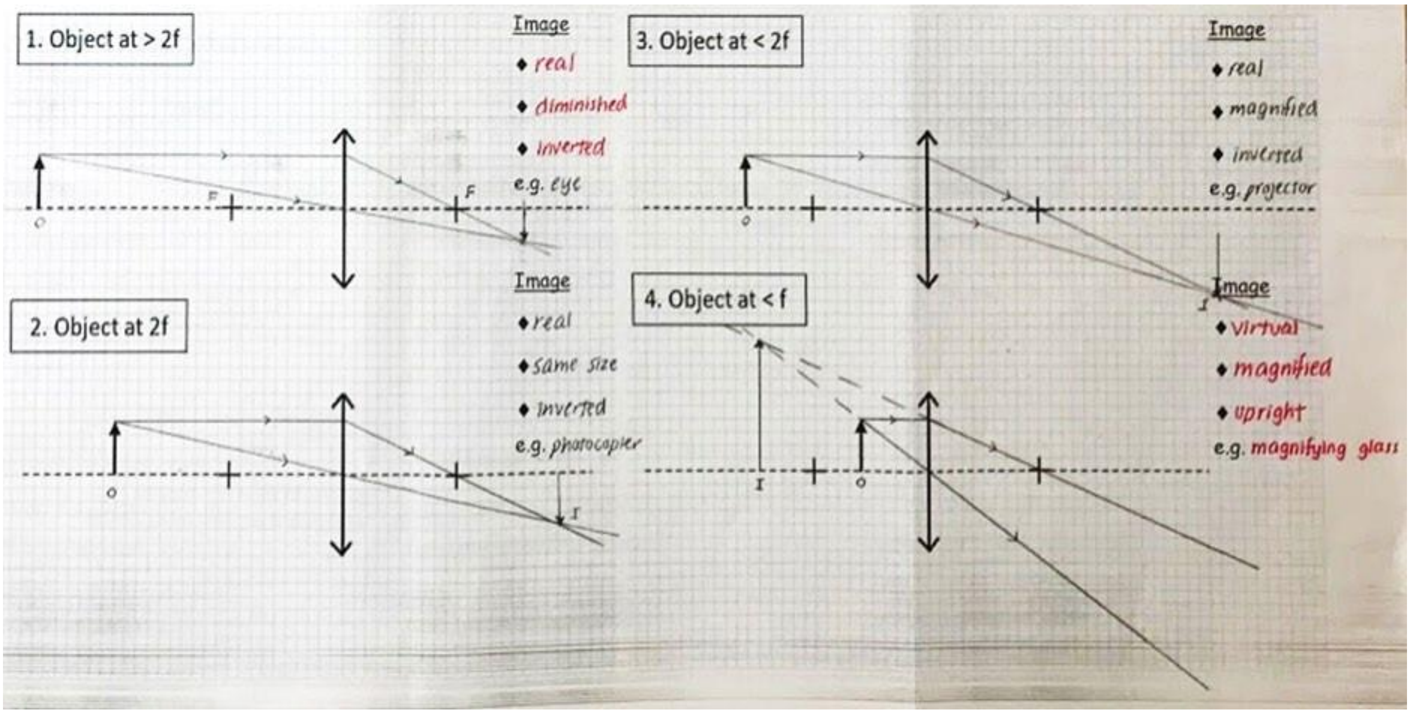


Focal length

- Distance of the principal focus from the lens
- Depends on how curved the lens is

Real image - image can be caught on a screen

Virtual image - behind the lens



(c) A converging lens is used as a magnifying glass.
The focal length of the lens is 10 cm.

(i) Describe the position of the object in relation to the lens.

Object closer to lens than one focal length

.... [1]

(ii) Describe the position of the image in relation to the lens and the object.

Image further from lens than object

.... [1]

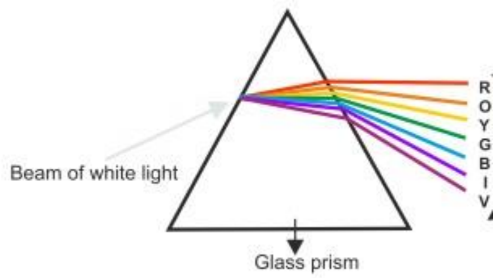
(iii) Give three properties of the image formed by a magnifying glass.

Virtual, magnified, upright

....

3.2.4 Dispersion of light

Monochromatic - single frequency of light



- When white light is passed through a glass prism, it splits up into its constituent colours coz different colours travel at different speeds in glass, so they refract by different amounts
- Longer the wavelength, less the light refracts (Red)

3.3 Electromagnetic spectrum

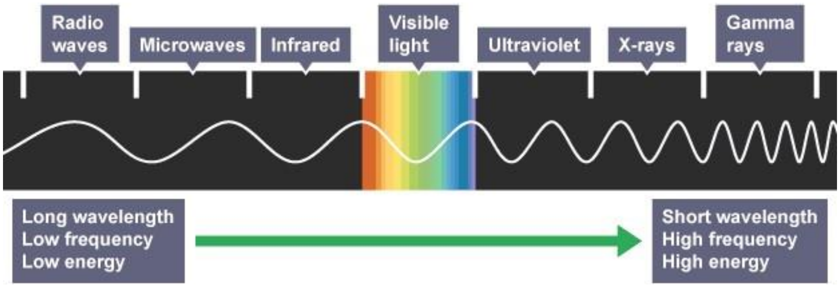
Properties

- Transverse waves
- Do not need a medium
- Travel at 3×10^8 m/s in a vacuum
- All obey

vvsslloocclltttvv = ooaassllvvssiiccvv × wwaavvssllssiiilltth

vv =

ooff



(**R**oman **M**an **I**nvented **V**ery **U**nusual **X**-ray **G**uns)

	Uses	Safety awareness / precautions
Radio waves	• Radio & TV communication	(Not tested)
Microwaves	• Satellite communication • In microwave ovens	Internal heating of body cells
Infra-red radiation	• Remote controllers Thermal • imaging	(Not tested)
Visible light	• Fibre optics Eyes • (seeing)	(Not tested)
Ultraviolet	• Suntan beds • Detecting forgeries	(Not tested)
X-rays	• Medical imaging • Security imaging	• Cause mutation of body cells leading to cancer • Take at low dosage • Don't allow other ppl in the room when X-ray being taken
Gamma rays	• Cancer treatment • Sterilizing medical equipment	(Not tested)

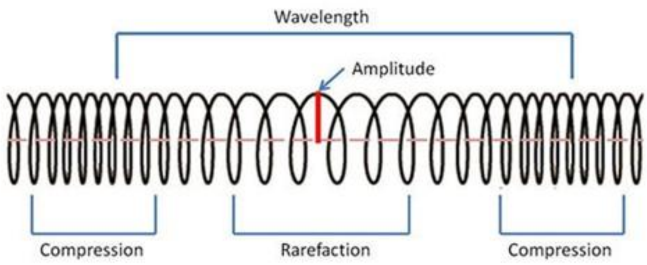
Ionizing radiation

- Electrons have enough energy to break away from atoms to produce ions Eg Ultraviolent, X-rays, gamma rays

3.4 Sound

Properties

- Longitudinal wave



- **Wavelength** - distance between compression / rarefaction

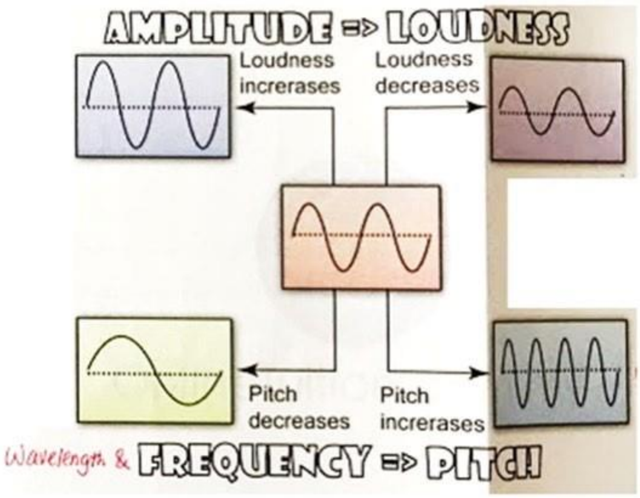
Rarefaction	Region of • Low pressure • Molecules far apart
Compression	• High pressure • Molecules closer

- Medium is needed to transmit sound waves

Air	350 m/s
Water	1500 m/s
Solid	5000 m/s

- Light travels faster than sound

- **Human range of audibility** - 20Hz to 20000Hz
- **Ultrasound**: sound with frequent above audible by humans (20000Hz)



Echo

- Occur when sounds reflected when hit flat, hard surface (eg wall)

$$ssssssssss = \frac{2 \times ssllssttaaiiccss}{ttllvvss}$$

$$ss = \frac{2ss}{tt}$$

Experiment

1. One student stands on one side, the other student extend the measuring tape to 100m & stand on the other end.
2. One student fire pistol at one end.
3. The student on the other end start stopwatch when see smoke & stop stopwatch when hear sound.
4. Calculate speed of sound by speed $= \frac{\text{distance}}{\text{time}}$

(c) The loudness of the sound increases at the same pitch.

State and explain any change there would be in the pattern of wavefronts shown in Fig. 6.1.

Increase in loudness will cause the amplitude to increase but wavelength will not be affected. The increase in pitch will cause wavefront to be closer at compression & further at rarefaction.

(ii) The wave travels from the rock into the air.

State and explain whether the wave will be audible to a healthy human ear.

statement Frequency doesn't change in different medium

explanation Yes. Because the human range of audibility is 20Hz to 20000Hz

Fig. 4.1 shows a loudspeaker that is producing a sound wave in air of frequency 15000 Hz.

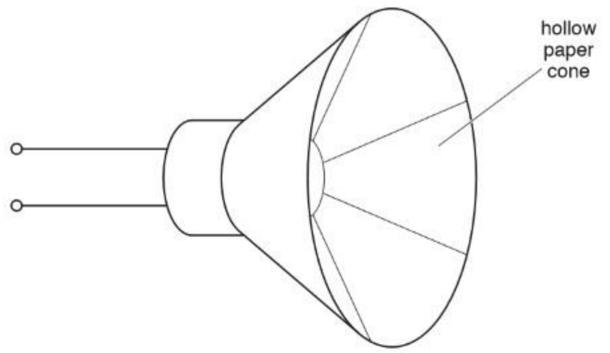


Fig. 4.1

(a) Describe how the cone of the loudspeaker produces this sound.

The cone vibrates, air vibrates, longitudinal wave transfer energy, producing rarefaction and compression, vibrating at 15000Hz.