WAVES

- Waves have two important functions : carry energy.
  Carry information.

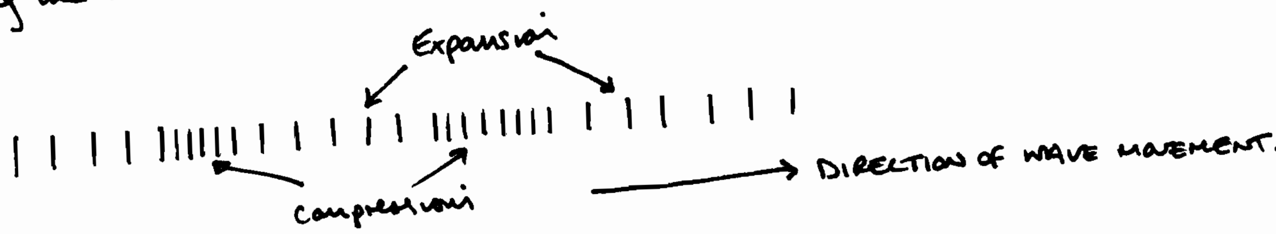
- Two types of wave :

□ **TRANSVERSE WAVE** - particles carrying the wave travel at ight angles to the direction of wave motion.

Can be :
REFLECTED
REFRACTED
DIFFRACTED

Examples: ripples in a pond, waves in ocean, Seismic S-waves (not P)

□ **LONGITUDINAL WAVES** - particles carrying the wave move back and forward along the direction of the wave. The particles oscillate about a fixed point.

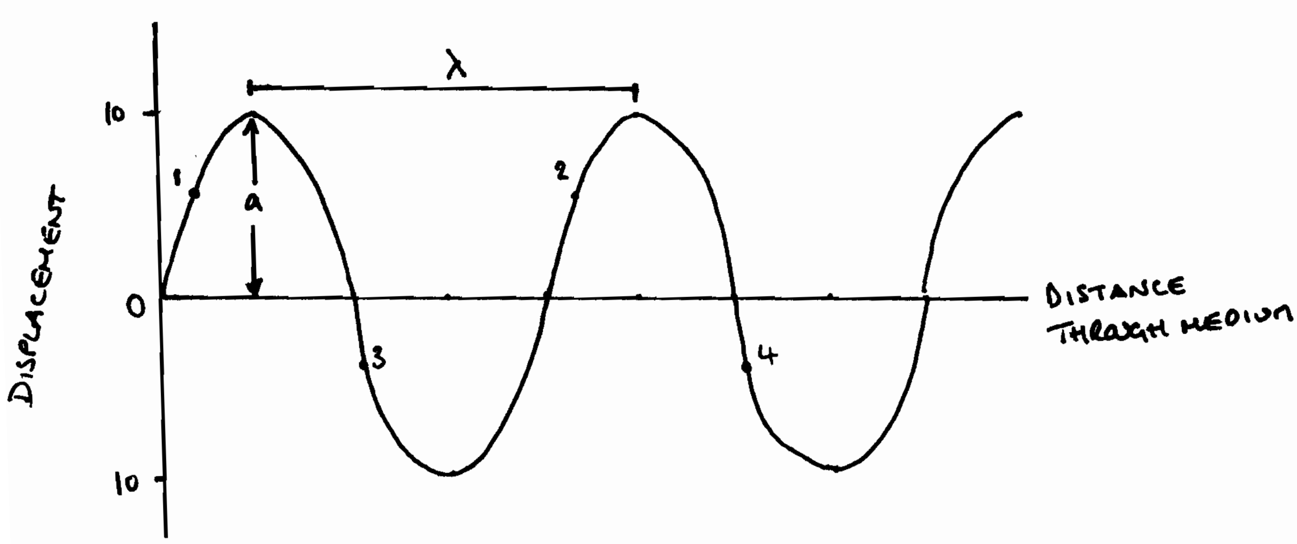


EXAMPLE : SOUND WAVES

IMPORTANT : WAVES TRANSFER ENERGY + INFORMATION WITHOUT TRANSFERRING MATTER

eg. water is the medium through which the wave energy is transfered.

KEY DEFINITIONS :



PHASE - Point 1+2 are in phase - both moving in the same direction with the same speed. 3+4 are also in phase. 1+3 are described as out of phase.

WAVELENGTH - the shortest distance between two points which are in phase. Represented by λ.

AMPLITUDE - the greatest displacement of a wave from its undisturbed position. Represent by a on the diagram.

FREQUENCY - f, of a wave is the number of complete waves produced per second. Units are Hertz (Hz) which mean s^{-1}. 1 kHz = 1000 Hz.

TIME PERIOD or **PERIOD** - the time taken to produce one complete wave (ie. time of one wavelength).

- **Frequency and Time Period are related by the following eqn:**

$$\text{Frequency} = \frac{1}{\text{Time Period}} \quad \therefore \quad f = \frac{1}{T}$$

eg. If a complete wave takes 0·2s, what is the frequency.

$T = 0{\cdot}2s \quad \therefore \quad f = \frac{1}{0{\cdot}2} = \underline{\underline{5\,Hz}}$ ie. 5 complete waves are produced per second.

- **Wave Velocities**

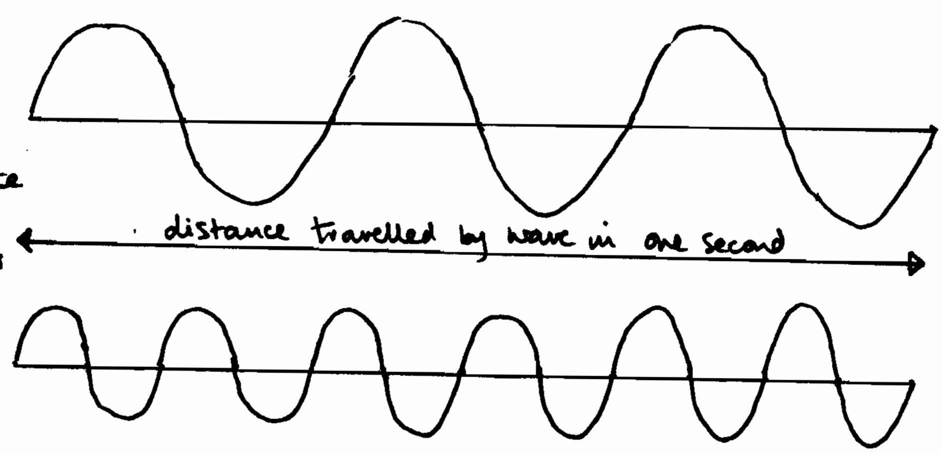
The velocity of a wave, v, is the distance travelled by a wave in one second.

The Wave Equation is: Velocity = frequency × wavelength

$$\underline{\underline{v = f\lambda}}$$

- For a particular slinky the velocity of waves down it will be the same for all wavelengths. High frequency waves will have a shorter wavelength ∴ v remains constant.

The speed of waves along a slinky is the same for all wavelengths
$f\uparrow$, $\lambda\downarrow$



$\lambda = 0{\cdot}4m$
$f = 3\,Hz$
$\therefore v = 3 \times 0{\cdot}4 = \underline{1{\cdot}2\,m/s}$

$\lambda = 0{\cdot}2m$
$f = 6\,Hz$
$v = 0{\cdot}2 \times 6 = \underline{1{\cdot}2\,m/s}$

• We see this again when we look at the electromagnetic spectrum – all E-M waves travel at 3×10^8 m/s in a vacuum, but their frequency + wavelength determine their properties.

DIFFRACTION

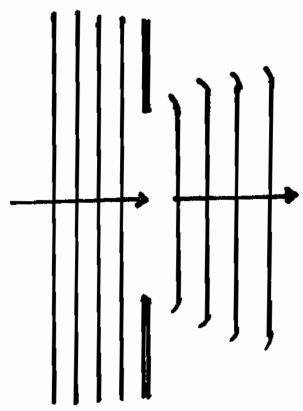
• When waves pass through a small hole, they spread out – DIFFRACTION.

• This can also occur when they pass an edge.

• The extent of the diffraction depends upon:

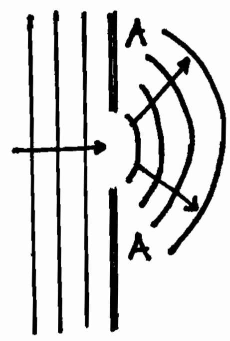
1. WAVELENGTH OF THE WAVES.
2. PHYSICAL DIMENSION OF THE GAP.

① Small wavelength, large gap:



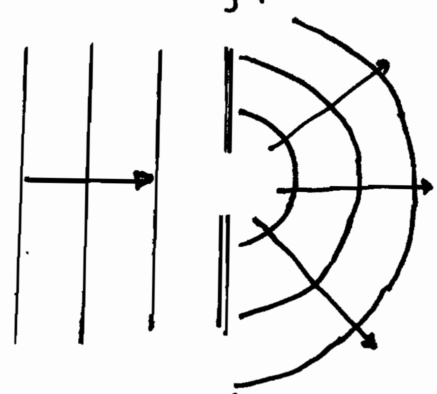
Note: wavelength same on both sides (bad drawing!).

② Small wavelength Smaller gap.



Gap ↓, tends to behave like point source.

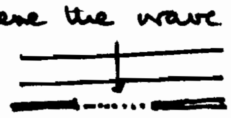
③ Large wavelength Small gap.



Large λ ⇒ waves spread out more. (More diffraction)

• As they size of gap decreases, the model tends towards a POINT SOURCE.

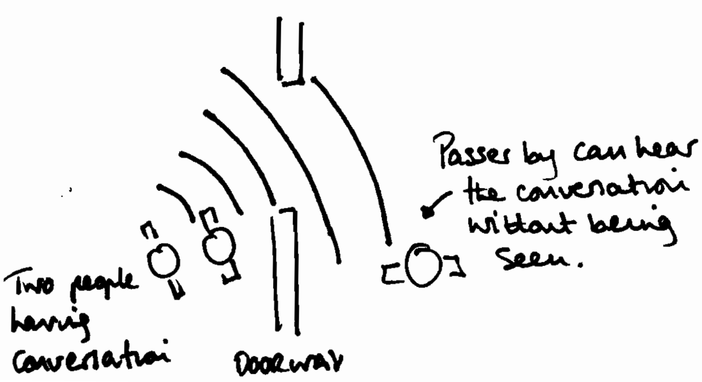
• Why are there no waves at points A on diagram 2. Effectively, imagine the gap as being many point sources lined up – the point sources create constructive interference where the wave is seen, and destructive in area A, ∴ no wave is seen.



↖ equivalent of many point sources

[Huygen's Principle: each point on a wavefront is a point source of wavelets. These wavelets superpose and interfere to form future wavefronts.]

• SOUND also DIFFRACTS – this tells us that sound must be carried by waves.



- LIGHT is carried by waves – why can we not see around corners?

  LIGHT has very small wavelength ∴ is hardly diffracted at all

  SOUND has very long wavelength ∴ can get large diffraction.

THE ELECTROMAGNETIC SPECTRUM

- Electromagnetic spectrum is made up of many different sorts of electromagnetic waves.
- In an electromagnetic wave, energy is carried by oscillating ELECTRIC and MAGNETIC FORCES. These forces are at right angles to the direction in which the wave travels.
- Electromagnetic waves are:
  - a type of transverse wave.
  - they travel at the speed of light (3×10^8 m/s) in a vacuum.
  - they are able to propagate through a vacuum, unlike sound waves which need a medium to pass through.
  - As all types travel at 3×10^8 m/s, it is their frequency + wavelength that define their properties.
  - can be reflected + refracted. Show diffraction + interference effects.

TYPES OF ELECTROMAGNETIC WAVES.

1. GAMMA RAYS
2. X RAYS
3. ULTRA VIOLET RAYS
4. VISIBLE LIGHT
5. INFRA RED
6. MICROWAVES
7. RADIOWAVES

HIGH FREQUENCY ↓ LOW FREQUENCY

SHORT WAVELENGTH ↓ LONG WAVELENGTH

Remember the wave eqn: $v = f\lambda$

Where $v = c$ = Speed of light @ $3 \times 10^8\ \text{ms}^{-1}$

∴ $c = f\lambda$ for electromagnetic wave questions.

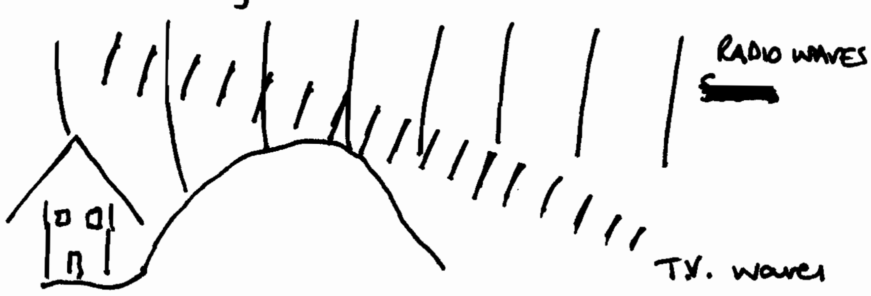
- Uses of electromagnetic waves:

  - Radiowaves - broadcasting + communications
  - Microwaves - cooking, satellite transmissions.
  - Infra-Red - Heaters + night vision equipment ($10^{-4} \rightarrow 10^{-6}$ m)
  - Visible light - optical fibres + photography (Red light $\lambda = 7 \times 10^{-7}$ m, Violet $\lambda = 4 \times 10^{-7}$ m)
  - Ultra Violet Light - fluorescent lamps. UV emitted from even hotter object than those that emit IR eg. 4000°C + for UV (SUN). ($\lambda = 10^{-8} \rightarrow 10^{-9}$ m)
  - X-Rays - observing the internal structure of objects and materials. Medical applications ($\lambda = 10^{-10}$ m)
  - Gamma Rays - Sterilising food + medical equipment

- Exposure to some electromagnetic waves can have a negative impact on the human body:
  - Microwaves: cause internal heating of body tissue.
  - Infra-red: prolonged exposure causes skin burn.
  - Ultra Violet: damage to surface cells and blindness (think sunglasses: UVA + UVB protection)
  - Gamma Rays: cancer, mutation of cells.

REMEMBER WAVELENGTH WILL EFFECT PROPERTIES OF THE WAVE.

eg. Radio Waves - long and medium wavelengths.
TV - Short wave lengths

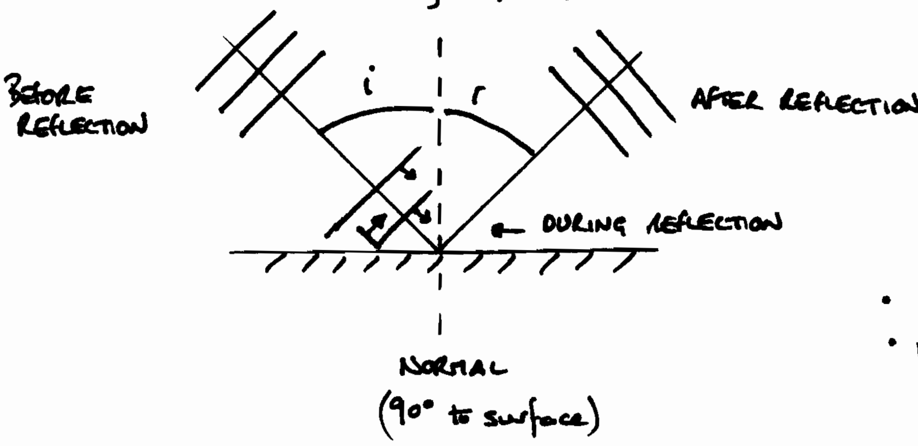


Radiowaves diffract around the hill providing good signal to house.
TV waves do not diffract well due to short wave length ∴ poor signal.

REFLECTION OF WAVES

1. Reflection of waves off a plane surface:

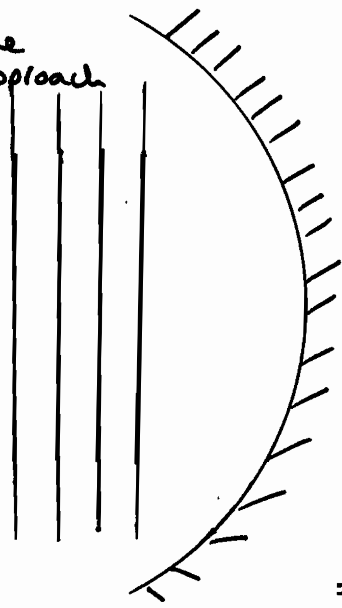
Angle of Incidence i = Angle of reflection r



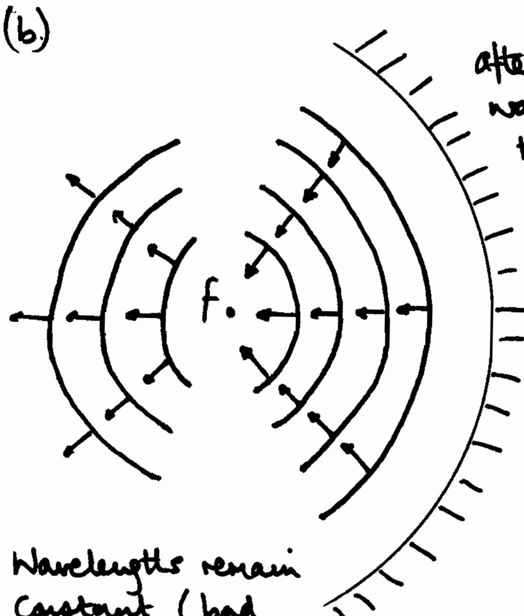
Key Points:
- $i = r$
- Wavelength remains constant.

2. Plane wave fronts approaching a CONCAVE BARRIER.

(a) As the plane wavefronts approach the barrier



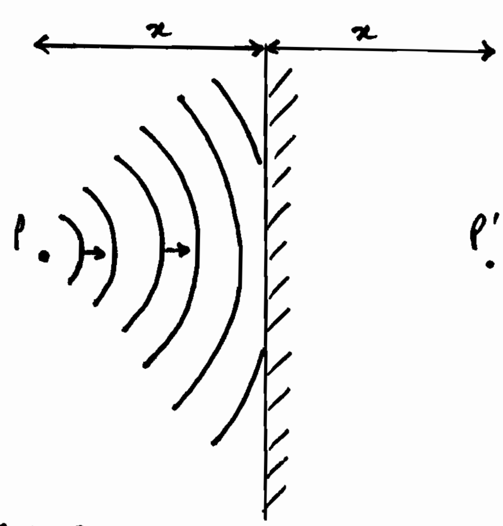
(b)



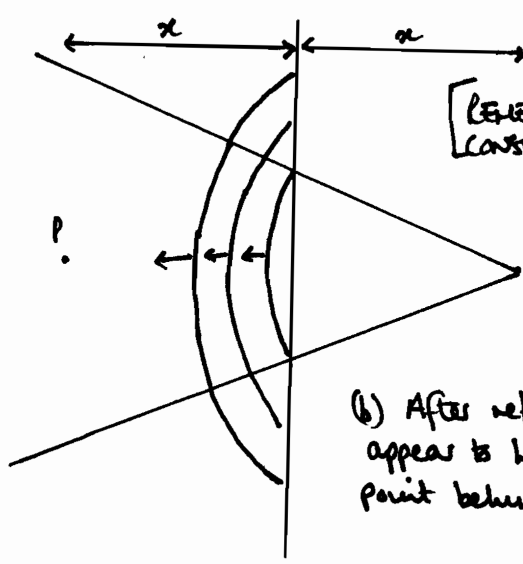
After the reflection, the wavefronts are brought to a focus at F, and the continue to move beyond.

NB Wavelengths remain constant (bad drawing!!).

3. CIRCULAR WAVEFRONTS hitting a straight barrier.



(a) CIRCULAR WAVE FRONTS SPREAD OUT FROM A POINT



[REMEMBER THIS CONSTRUCTION TECHNIQUE]

(b) After reflection, the waves appear to have come from the point behind the barrier (P').

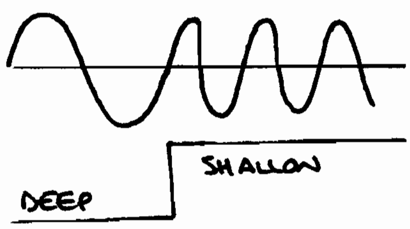
Refraction of Waves

- In shallow water, waves travel more SLOWLY than they do in DEEP WATER.
- There must be the same number of waves passing through both the deep and shallow region (source continues to produce at a constant rate) - this means the frequency is constant.
- Take the wave eqn:

$$v = f\lambda$$ (f — remains constant)

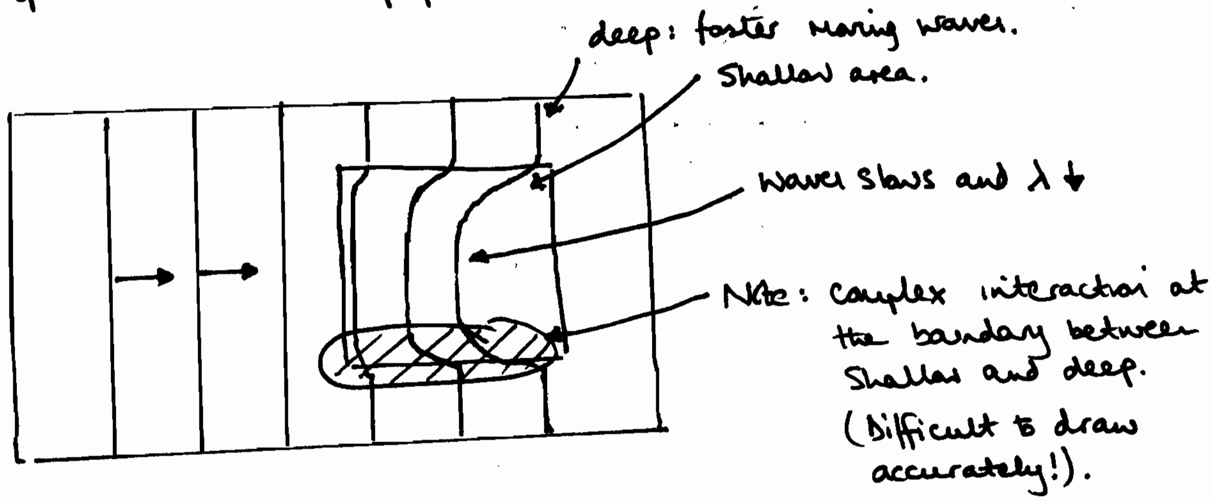
$\therefore$ as $v \downarrow$ $\lambda \downarrow$ in shallow water.

(a) Water depth changes:

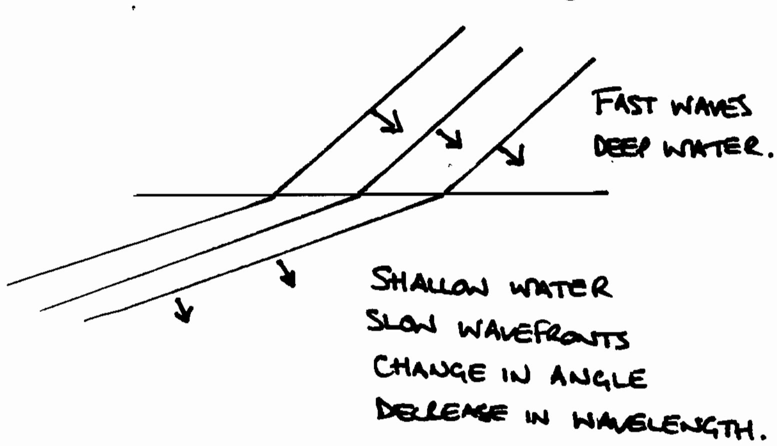


$\therefore$ Deep to Shallow
Frequency = constant
Wavelength = ↓ decreases
Velocity = ↓ decreases.

(b) A region of shallow in a deep pool:



(c) When waves approach a shallow region at an angle, the slow down and change direction (like refraction of light).



LIGHT AND OPTICS

- This section covers notes that are not included in the Refraction ~~notes~~ and Total Internal Reflection Notes.

REFLECTION OF LIGHT

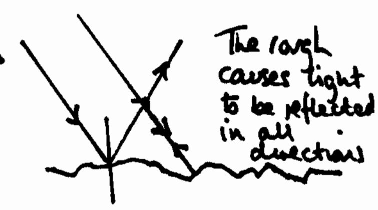
- The ray of light before it strikes the surface is called the INCIDENT RAY
- The ANGLE OF INCIDENCE is the angle between the INCIDENT RAY and the NORMAL.
- The ~~normal~~ NORMAL is a line (imaginary) that passes at right angles through the reflecting surface.
- After the ray has been reflected it is called the REFLECTED RAY
- The angle between the NORMAL and the REFLECTED RAY is called the ANGLE OF REFLECTION.

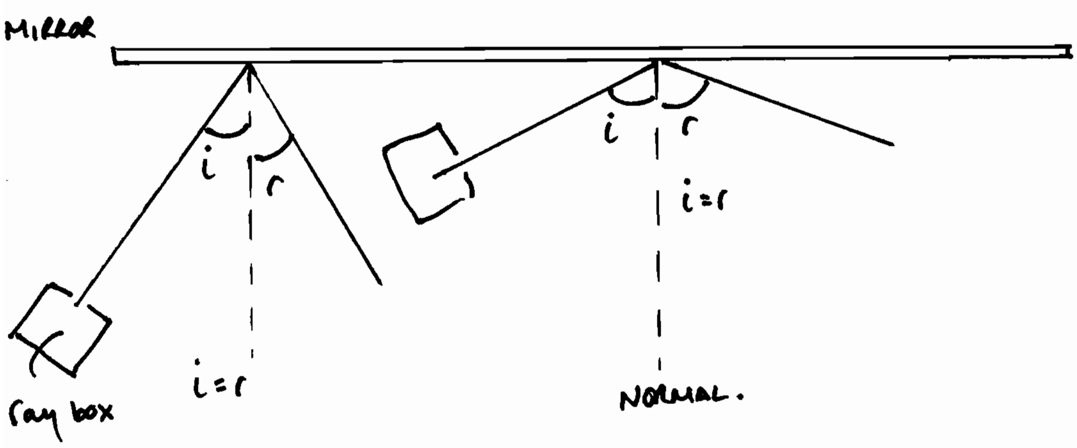
FOR REFLECTION:

① The angle of Incidence always equals the angle of reflection (i=r)

② The Incident ray, the reflected ray and the normal always lie in the same plane.

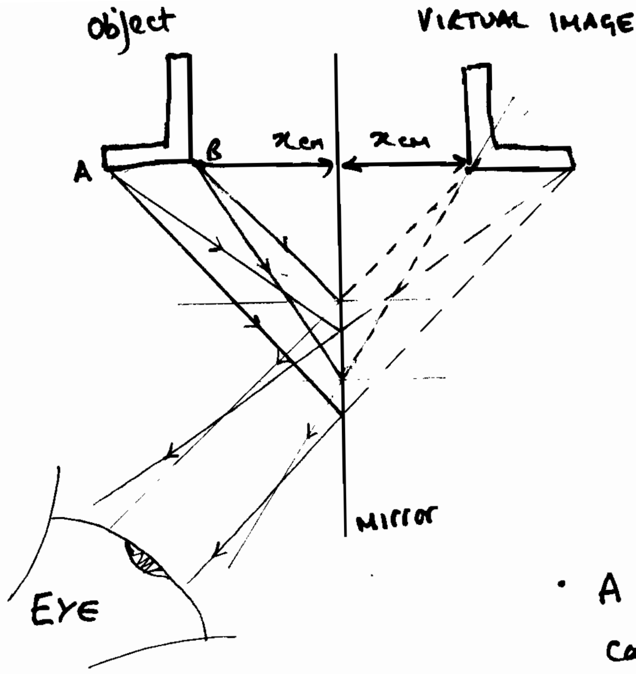
- All surfaces can reflect light
  - Shiny smooth surfaces → clear image.
  - Rough surface → no clear image →





AN IMAGE IN A PLANE MIRROR

- Can use the rules of reflection to find the IMAGE of an OBJECT in a plane mirror.
- See diagram.



- By drawing two construction line from both A and B, and then extrapolating the reflected ray back into the mirror, the location of the VIRTUAL IMAGE of the object can be found.

- A virtual image is defined as one that cannot be put on a screen.

- An image that can be put on a screen, like a pin-hole camera is called a REAL IMAGE.

- The diagram shows that the VIRTUAL IMAGE appears to be the same distance behind the mirror as the real ~~image~~ object is in front of the mirror.
- The image also appears to be back to front. (Look at yourself in the mirror - lift your left hand → image appears to lift its right hand). The image is said to be LATERALLY INVERTED.

Sound Waves

- Sound is a longitudinal waves.
- Molecules in air oscillate backwards and forwards along the direction in which the sound travels.
- Pluck a guitar string:
  - Produces a sound wave in the form of a series of COMPRESSIONS + DECOMPRESSIONS as it vibrates.
  - COMPRESSION : air pressure > normal atmospheric pressure.
  - DECOMPRESSION: air pressure < normal atmospheric pressure.
- The compression and decompressions travel through air in the same way that energy moves along a slinky.
- The ear detects the changes in pressure caused by the sound waves
  - compression push ear drum in.
  - decompression let ear drum out.

  } movement transmitted through ear by bones - then nerves transmit electrical signal to brain.

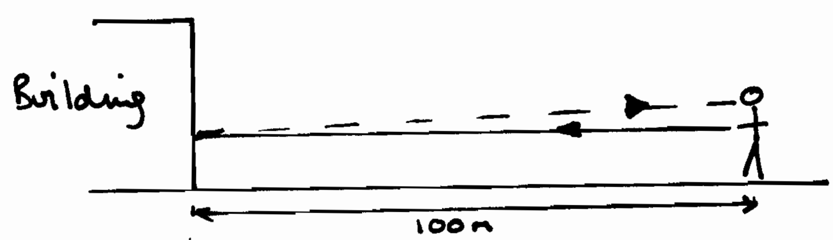
Speed of Sound

- Speed of sound depends on the medium it travels through:
- Air = 330 m/s. In solids and liquids it is faster as the molecules are packed together more tightly.

air	330 m/s
water	1500 m/s
steel	500 m/s

- SOUND CANNOT TRAVEL THROUGH A VACUUM.

Simple Method of Measuring the Speed of Sound



- Stand 100m from building
- Clap hands
- Sound waves reflected back
- Each time you hear echo, clap again ∴ clap in time with the echo.

- A colleague, watching the clapping times how long it takes for 10 claps.
- In this instance 10 claps in 6 (six) seconds ∴ we know it took 0.6s for the sound to travel 200m (there and back - very important!).

$$\therefore \text{Speed of Sound} = V = \frac{d}{t} = \frac{200\,m}{0.6\,s} = \underline{330\,m/s}.$$

LOUDNESS, PITCH AND QUALITY

- Human ears detect sounds over the following frequency range:

  20 Hz – 20,000 Hz.

- LOUDNESS – Loudness of a ~~sound~~ noise depends on the pressure caused by the sound wave.
  - Therefore the AMPLITUDE of the wave determines the LOUDNESS.
  - During normal conversation, voice will cause the air pressure to change by about 1 pa → small change in comparison to atmospheric pressure @ 100,000 Pa.

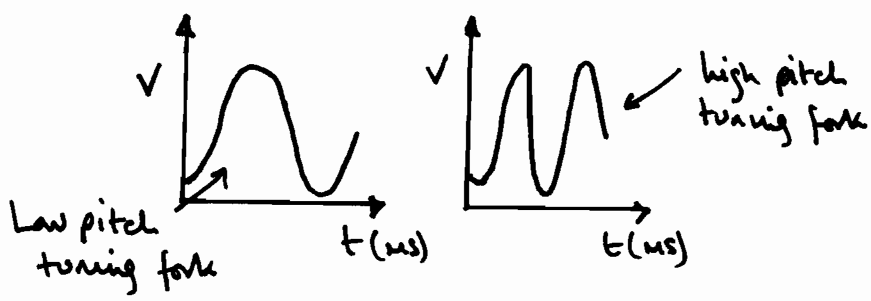
- PITCH – Used to describe how a noise of musical note sounds to us.

  Bass → low pitch treble → high pitch

  Men voice → low pitch woman voice → high pitch.

PITCH is directly related to the FREQUENCY.

High Pitched → HIGH FREQUENCY.



(obviously nice smooth curves for the two diagrams!)

- QUALITY
  - The quality of a note depends on the shape of its waveform.
  - Two note may have the same frequency + amplitude, but if there waveforms are of a different shape, you will detect a different sound.

RAY OPTICS

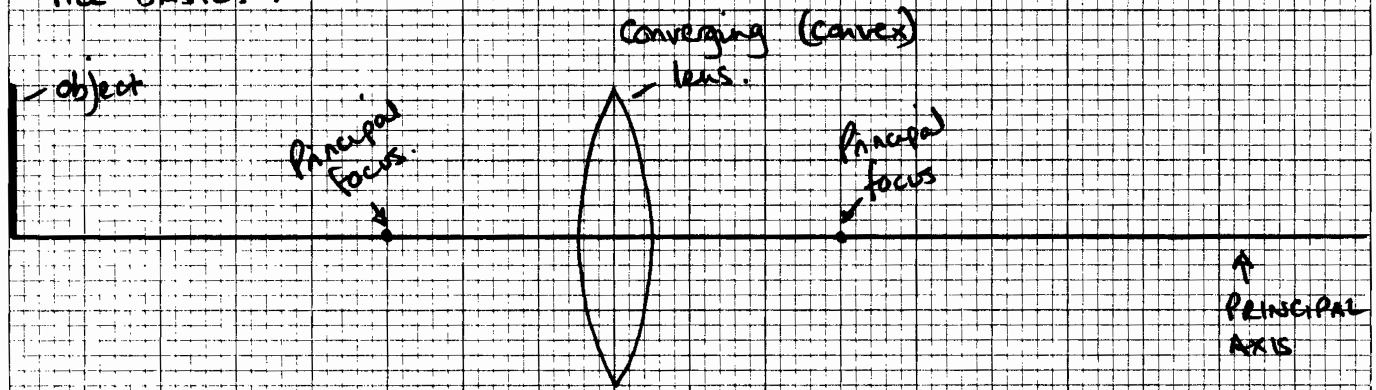
FINDING THE IMAGE: 3 SIMPLE RULES

① A RAY PARALLEL TO THE PRINCIPAL AXIS IS REFRACTED THROUGH THE PRINCIPAL FOCUS.

② A RAY THROUGH THE CENTRE OF THE LENS, DOES NOT CHANGE IT'S DIRECTION

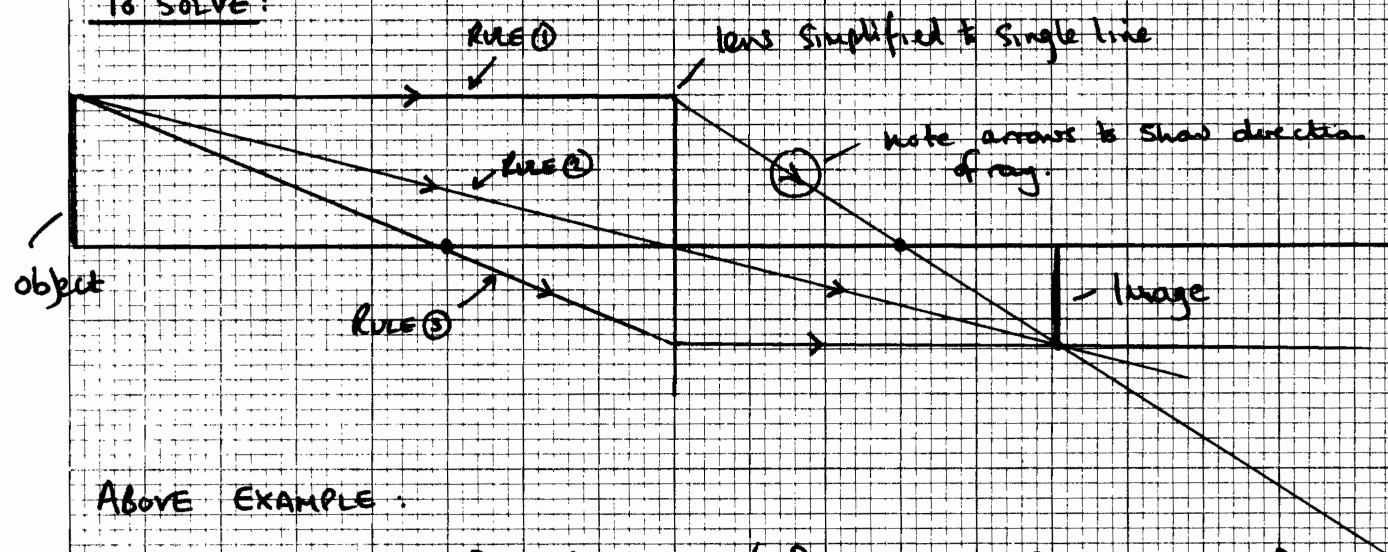
③ A RAY THROUGH THE PRINCIPAL FOCUS ON THE FIRST SIDE OF THE LENS IS REFRACTED PARELLEL TO THE PRINCIPAL AXIS.

THE BASICS:



Notes: Lens has principal focus on both side, equidistance from the centre of the lens.

TO SOLVE:

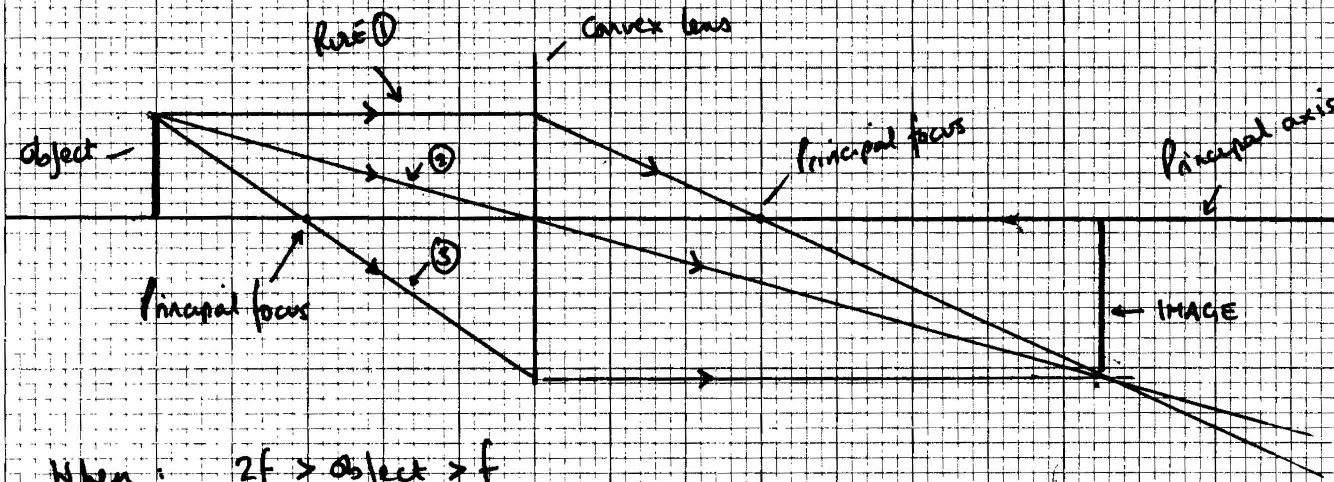


ABOVE EXAMPLE:

- Object > 2f from lens (f = distance from lens to focal point).
- Object > 2f implies IMAGE IS SMALLER, REAL & INVERTED
- Similar to a CAMERA

TWO OTHER EXAMPLES:

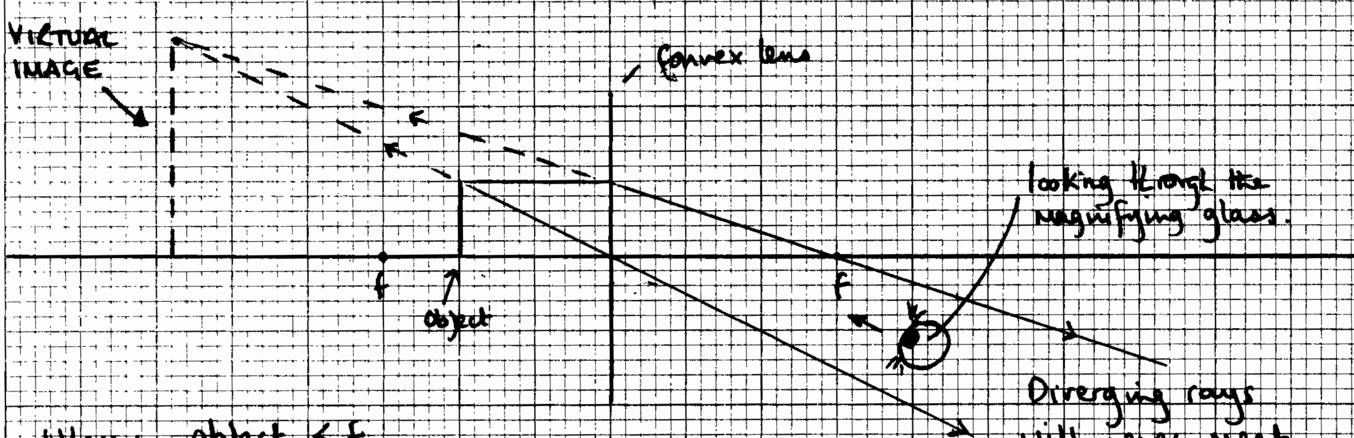
① Object 2f > object > f (between f and 2f)



When: 2f > object > f

- IMAGE IS LARGER, REAL AND INVERTED
- Similar to SLIDE PROJECTOR

② Object between lens and focal point (Object < f)



When: object < f

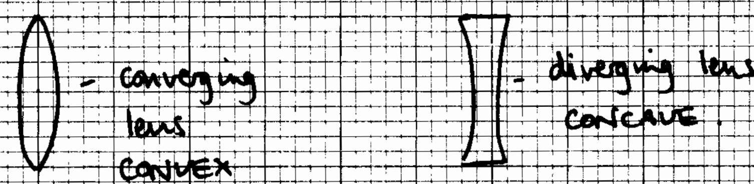
- IMAGE IS VIRTUAL + BIGGER
  & ON THE SAME SIDE AS THE OBJECT.

REAL IMAGE - one that can be put onto a screen

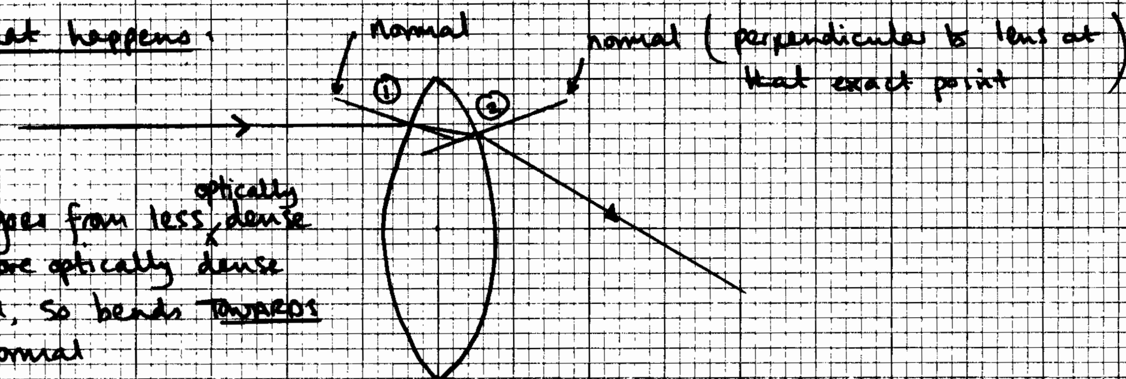
VIRTUAL IMAGE - you cannot put a virtual image on a screen.

CONVERGING LENS

- Convex (~~conv~~ converging lens) focus light by REFRACTION.
  - curvature of lens is such that rays further from the optic axis ~~are~~ are bent more than those close to it.
  - convex lenses are manufactured so that rays parallel to the optic (principal) axis are focussed to a real focal point beyond the lens.



- What happens:



① Ray goes from less optically dense to a more optically dense medium, so bends TOWARDS the normal

② Ray goes from more optically dense to less optically dense medium, so bends away from the normal.

- How do we find the PRINCIPAL FOCUS: