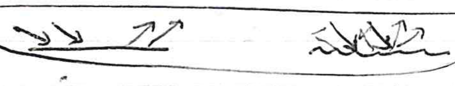
LIGHT

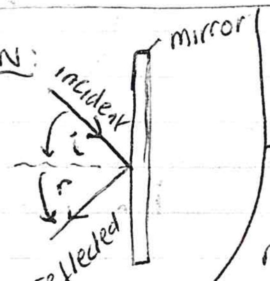
Specular reflection light hits smooth surface

Diffuse reflection (light hits uneven surface)



Light can be studied using geometry to predict path of light rays → reflection / refraction
or it can be viewed as a wave

REFLECTION:



i = r
4 plane mirror

Laws of Reflection:

(i) Incident ray, reflected ray & normal lie in same plane
(ii) i = r angle of incidence = angle of reflection

Demo

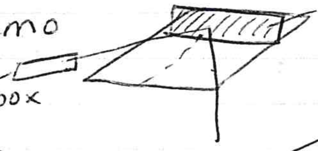
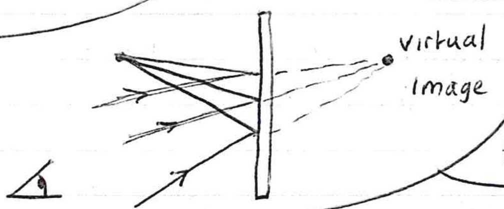
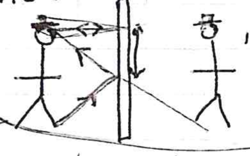


image is formed when 2 light rays intersect!

REAL image = actual intersection
VIRTUAL image = appear to intersect and brain works out image location



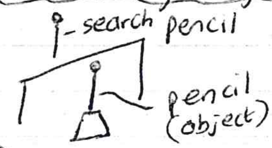
you only need a mirror ½ your height to see your full height.



Parralax
the difference in apparant position of an object viewed along 2 different lines of sight.

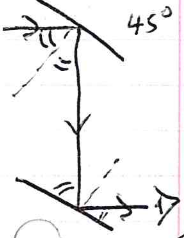
Placing a ruler on its side reduces paralax error

to locate an image by method of no parallax:

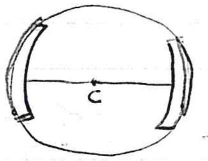


move search pencil until it is in a position of no parallax with pencil (object)

periscope
45°



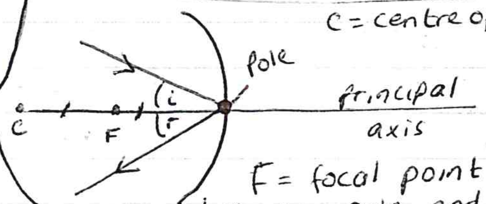
SPHERICAL mirrors



Concave - reflected surface on inside

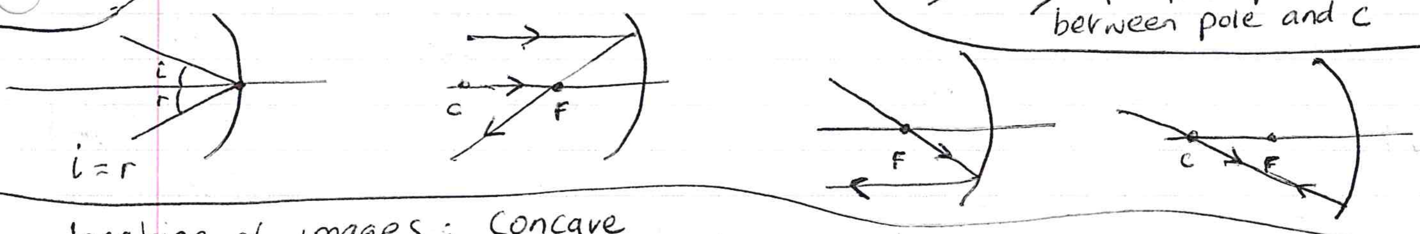
Convex - reflected surface on outside

c = centre of curvature

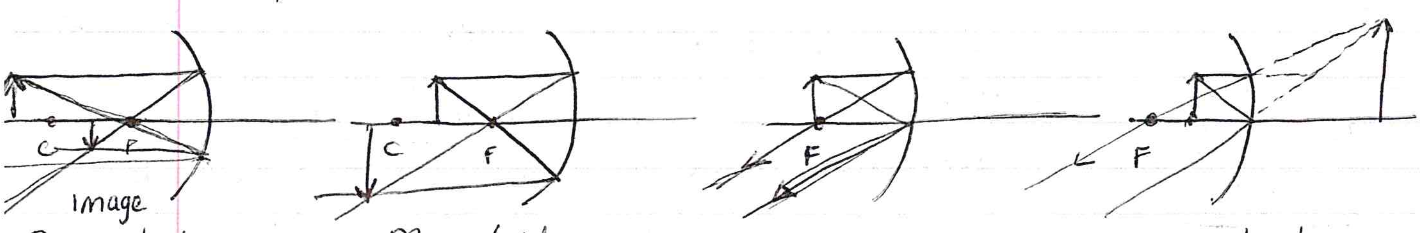


F = focal point ½ way between pole and c

Rules of reflection:



location of images: Concave



Diminished Inverted Real	Magnified Inverted Real	no image	virtual upright magnified

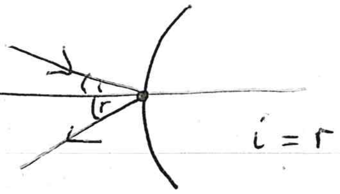
$$m = \frac{v}{u}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Concave mirror
u ⊕, v ⊕ real image, f ⊕
⊖ virtual image

uses: vanity mirror, shaving mirror, headlights

Convex Mirror: Rules of Reflection



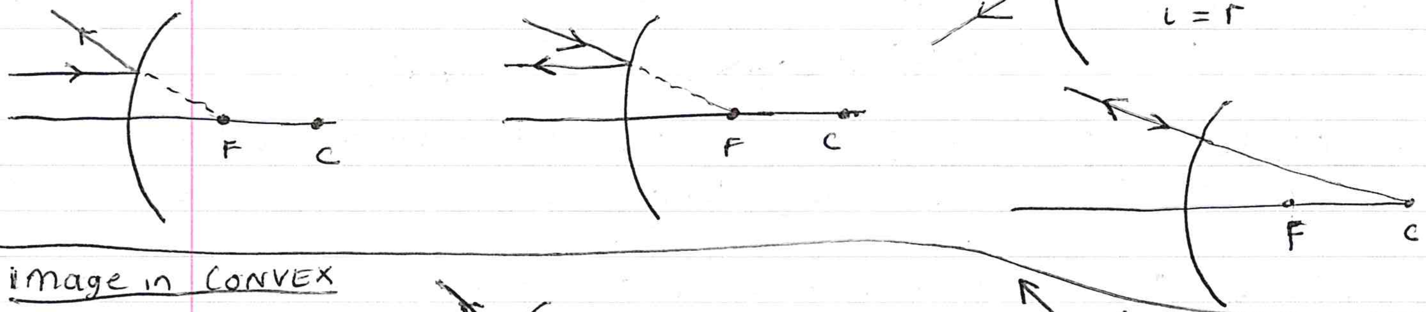


image in convex

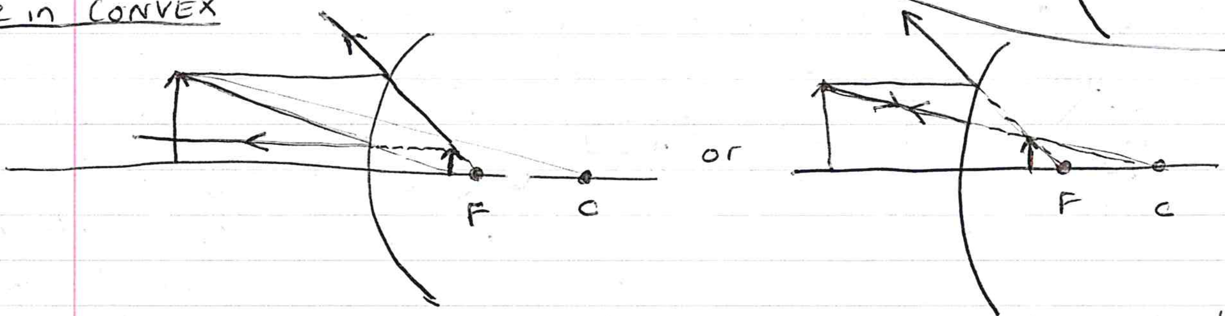


image always same, inverted, upright, virtual, diminished
As you move closer to mirror it gets bigger but always smaller than object

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

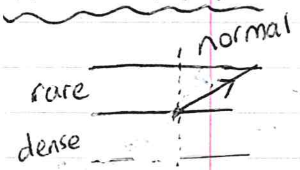
$u = \oplus$
$v = \ominus$ always
$f = \ominus$ always

$$m = \frac{v}{u}$$

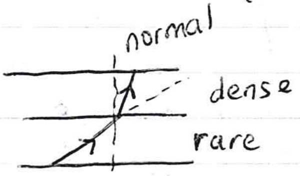
Convex mirror: used in car wing mirrors → greater field of view
- may think objects are further away because they are smaller!!
- concealed junctions, security in shops → greater field of view

REFRACTION:

'rare' medium (easier for light to pass through than 'dense' one)

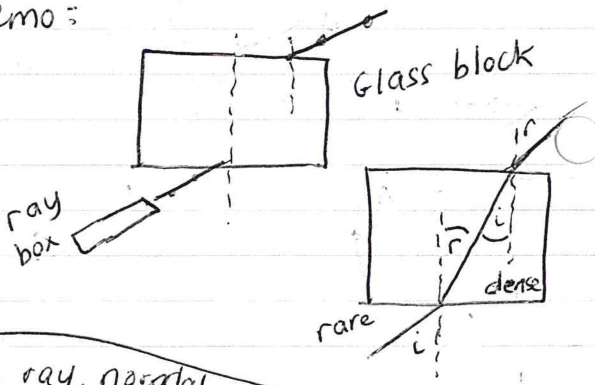


dense to rare
light is bent away from normal



rare to dense
light is bent towards normal

demo:



Laws of refraction: (i) Incident ray, refracted ray, normal all lie in same plane
(ii) $\frac{\sin i}{\sin r}$ = constant (refractive index) n
i = angle of incidence
r = angle of refraction

Snell's law: $\frac{\sin i}{\sin r} = n$

Refractive Index of a medium $= \frac{\sin i}{\sin r}$ when ray of light travels from vacuum into medium

$n_{glass} = {}_{air}n_{glass}$ ${}_{a}n_{m}$ is always ≥ 1

Refractive index from medium 1 to medium 2 $= \frac{\sin i}{\sin r}$ when light travels from medium 1 into medium 2 $= {}_{1}n_{2}$ can be >1 or <1 depending on the mediums

$${}_{1}n_{2} = \frac{1}{{}_{2}n_{1}}$$

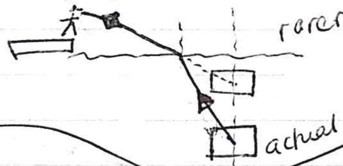
${}_{1}n_{2} = \frac{c_1}{c_2}$ speed in med... speed of light in ...

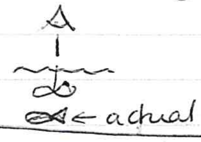
Refraction cont'd:

$_{vac}n_{medium} \approx {}_{air}n_{medium} = n_{medium}$

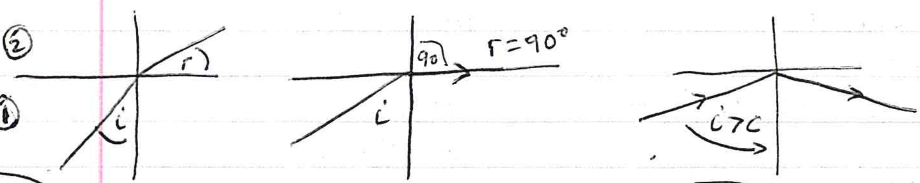
When viewing objects under water they appear closer than they are.

$_{vac}n_{m} = \dfrac{\text{real depth}}{\text{apparant depth}}$





Total internal reflection: As you increase i when going from more dense to less dense medium, eventually you will reach an i for which the angle of reflection is 90°. This value of i is known as the critical angle. For larger values of $i > c$ all light rays are totally, internally refleted.



T. I. R. $\quad {}_1n_2 = \dfrac{\sin i}{\sin r} = \dfrac{\sin c}{\sin 90}$

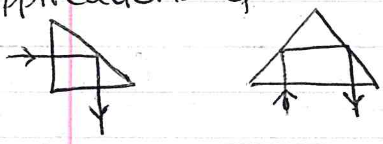
${}_1n_2 = \sin c$

${}_2n_1 = \dfrac{1}{\sin c}$

$_{vac}n_{medium} = \dfrac{1}{\sin c}$

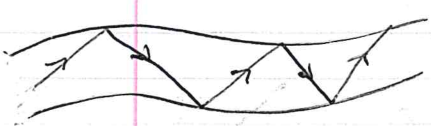
Applications of T.I.R:

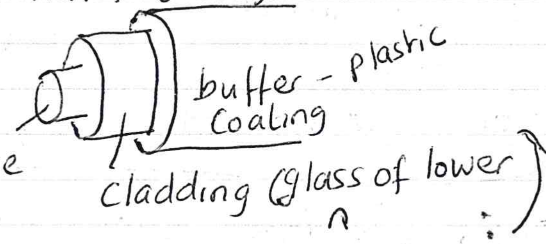
(i)



Reflectors clothes bikes to turn (reflect) light as glass is much cheaper than mirror

(ii) Fibre Optics: Approx diameter of a human hair. Arranged in bundles of multiple fibres = optical cables.





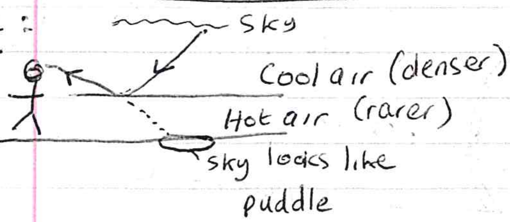
light enters @ angle > C
so TIR occurs as light travels down fibre

If fibre bends too much then light might hit surface of core at angle less than C and would escape. Also, if one core touched another core light would pass through as there would be no dense → less dense. To prevent both of these, cladding is of lower refractive index which makes T.I.R. happen keeping information intact. Buffer material to coat keeps core free from moisture and keeps individual cladding's seperate.

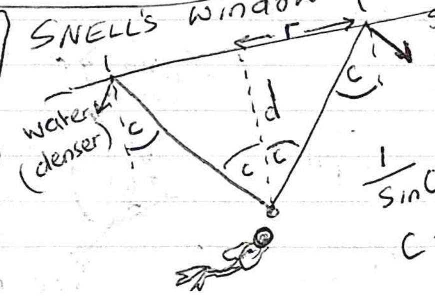
Advantages of Opticle fibres over Copper caples

- cheaper over long distances,
- thinner ⇒ more optical bundles,
- more durable
- carry more information
- signal stays strong over distance
- no fire danger
- less energy lost since less power required
- more flexible

Mirage:



SNELL'S window



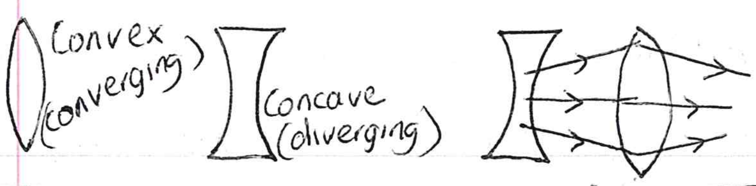
transparent circle of water seen by divers looking up at angle > critical C

$\dfrac{1}{\sin C} = \mu_w$, $\tan C = \dfrac{r}{\text{depth}}$

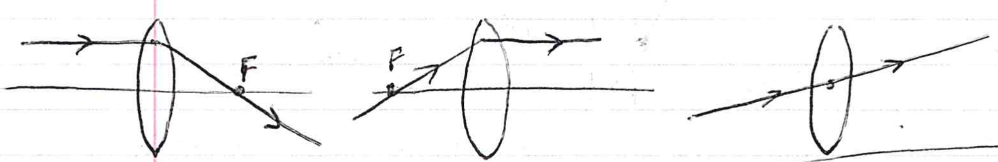
$C = \sin^{-1}\left(\dfrac{1}{\mu_w}\right)$

Area of O $= \pi r^2$

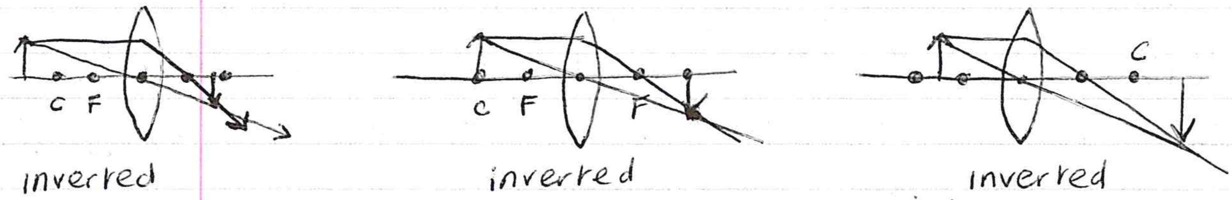
LENS



work by refraction



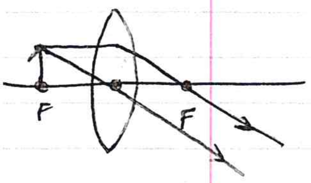
Rules ↙



inverted
real
diminished
inside C

inverted
real
same size, at C

inverted
real
magnified
outside C



no image
lines are parallel

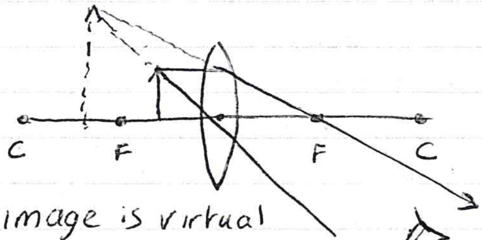


image is virtual
upright
magnified

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

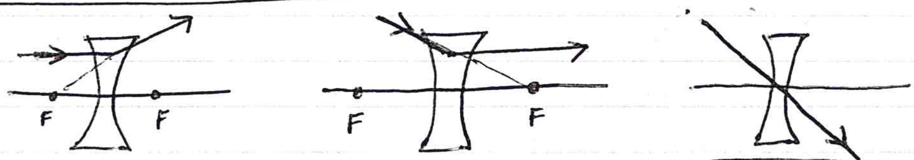
v ⊖ for virtual images

$$m = -\frac{v}{u}$$

m ⊖ if inverted

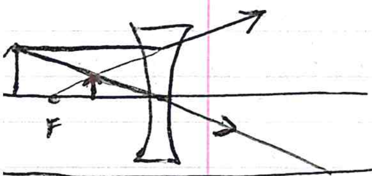
Convex lens used: magnifying glass, glasses, telescopes, binoculars

Concave lense rules:



Type of image is ALWAYS same, always virtual, upright, diminished

$$m = -\frac{v}{u}$$



$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

v is ⊖ f is ⊖
u is ⊕ m is ⊕ (upright)

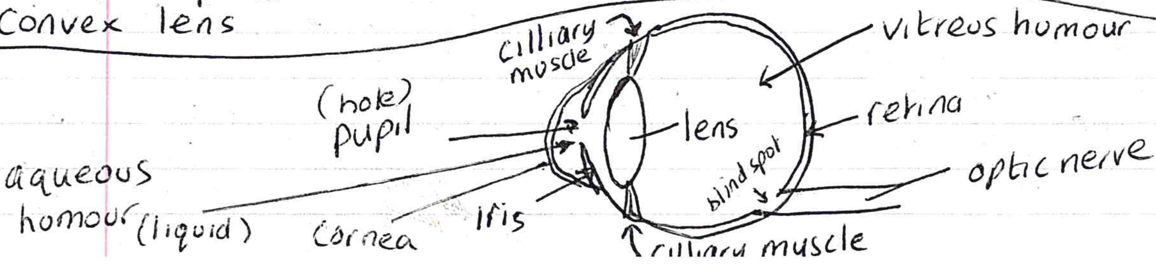
Use of Concave lenses: glasses, door peepholes, cameras

POWER of lenses: $P = \frac{1}{f}$, $f = \frac{1}{P}$ {if f ⊖, P ⊖ so concave lenses P = ⊖}

Combining lenses: $P = P_1 + P_2$ $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

if P ends up ⊕ ⇒ acts as convex lens

P ends up ⊖ it acts as concave lens



: Cilliary muscles change the shape of the lens (power of accomodation)
Fat lens => focus on near objects, thin lens => focus on distant objects.

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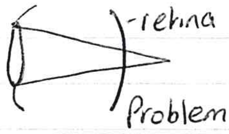
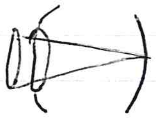
longsighted: means you can see distant objects but not near objects (cant make lens fat enough)
fix: use convex lens to increase P.
bigger P means smaller f.



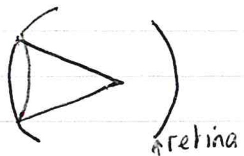


Shortsighted: means you can see near objects can't see distant objs
lens isn't thin enough - eye is too powerful - need to reduce P
Fix: Concave lens to make compined Power less.

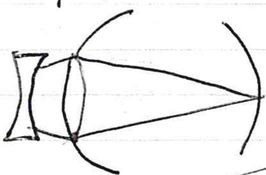
longsighted = hyperopia

Short sighted = myopia

problem:



fix:



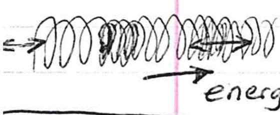
WAVES: Mechanical waves physically vibrate the molecules in a medium
medium is temporarily disturbed but once the energy passes the medium returns to normal (Sound waves, Slinky, water waves)

Electromagnetic waves: Can travel thro a vacuum and thro media
They cause a disturbance in the electric and magnetic fields in the region they pass thro. (light, UV, Xrays, radio waves)

Any wave that carries energy away from its source is a travelling wave
How? Sound causes vibrations → transfers energy
EM waves cause heat → transfers energy
x rays, γ rays cause ionisation (knock $\bar{e}$ out of orbit)

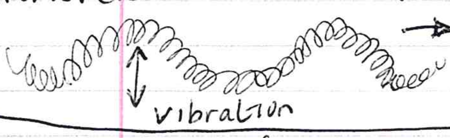
Travelling waves carry energy thro a medium without any overall movement of the medium

Longitudinal wave => squashing (compression) & expanding (rarefaction) the vibration cycle
(SOUND)



vibrate in direction Parallel to direction of energy transfer.

Transverse wave ⇒ vibration is in direction Perpendicular to direction of energy transfer



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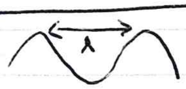
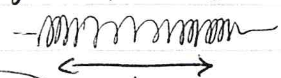
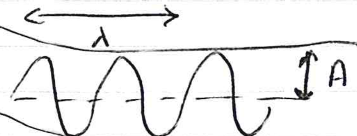
wavelength λ (distance pk to pk) length of 1 cycle



= distance compression to compression in longitudal



Amplitude = Maximum displacement from mean position



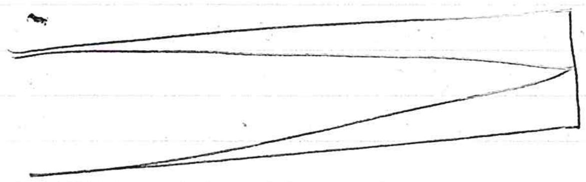
Frequency: Number of vibrations per sec (Hertz)

Speed (c): How quickly/speed at which wave travels (m/s)

Period: Time for one complete cycle (s) $T = 1/f$ | $c = f\lambda$

$C = f\lambda$

$f = \frac{c}{\lambda} = \frac{c}{4l}$



256Hz.

$c = 335$ m/s

$\lambda = \frac{c}{f} = \frac{335}{256}$

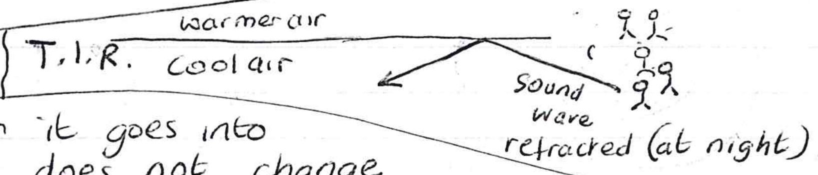
$l = \frac{\lambda}{4}$

waves can reflect, refract, diffract, interfere, be polarised,

echo ↙ (reflect) mirror ↘

Refraction of waves:

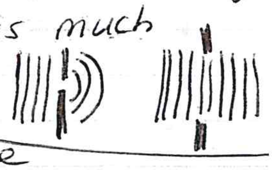
wave gets slowed down when it goes into more dense material. Frequency does not change but wavelength does $c = f\lambda$ (c, λ change) f stays same



DIFFRACTION:

Spreading out of a wave as it moves through a gap or around an object

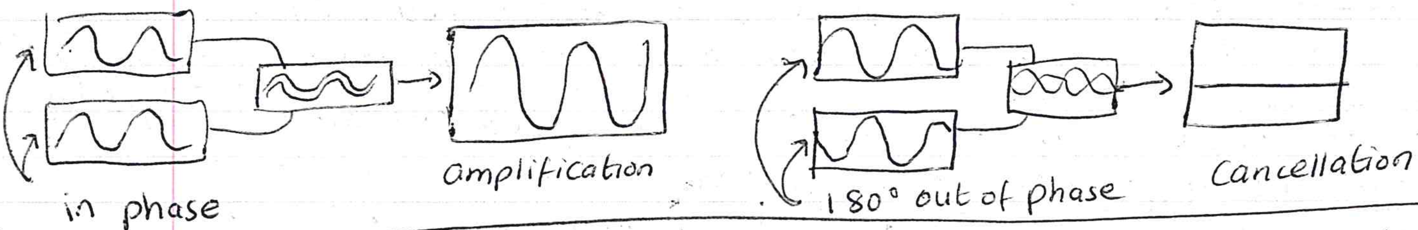
The amount that a wave diffracts depends on the relative size of the gap to the wavelength. If gap width is close to the wavelength then wave will diffract (spread out) a lot. If the gap is much larger than the wave length it will barely diffract!



INTERFERENCE:

Since waves are disturbances they can interfere with each other. Can ADD = constructive interference or SUBTRACT = destructive interference. Constructive interference results in an amplitude greater than each individual wave. Destructive ... less.

NOISE CONTROL: uses interference to 'cancel' noise.



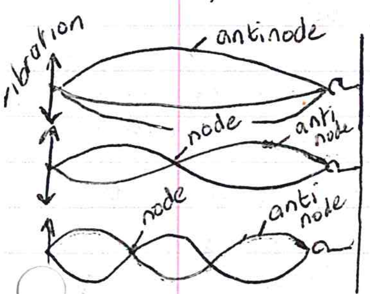
Polarization:

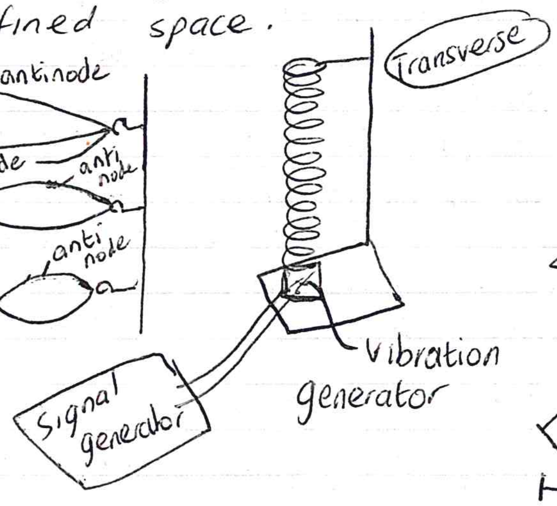
Only applies to transverse waves: Wave is confined to one particular plane. e.g. pass a rope through picket fence wave it all over the place but only the vertical vibration will go thro. All other vibrations in other directions would be blocked.

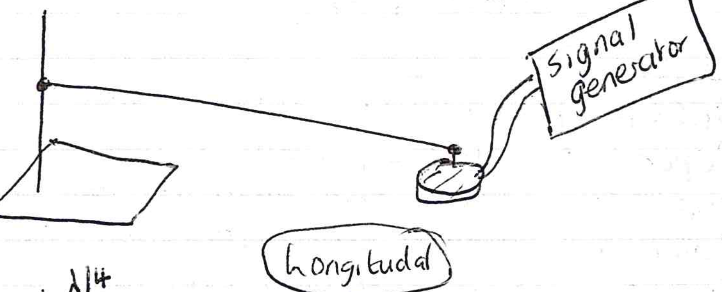
Polaroid material: Has a series of bars that are parallel and spaced to only allow certain dimensions of wave through. Polaroid lenses - very small spaces - block a lot of the light. Turn 2 pces of polaroid material at right angles → no light gets through. Light reflecting off glass is partly polarised. If you view this thro polaroid lens it will be mostly blocked. Used to reduce glare from reflected light on water & glass

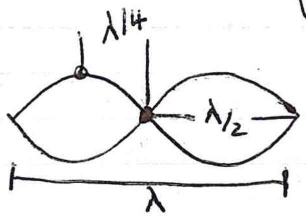
Stationary waves:

(standing waves) waves of same freq and Amp that constructively and destructively interfere to produce a wave pattern in a confined space.

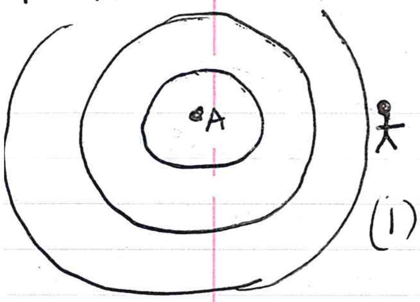


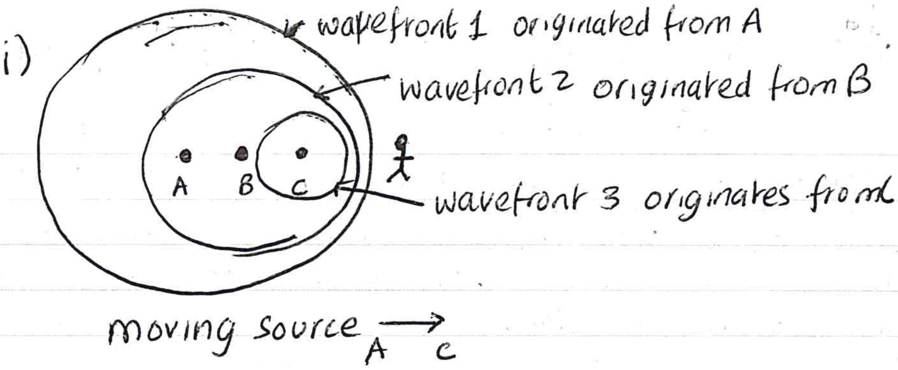




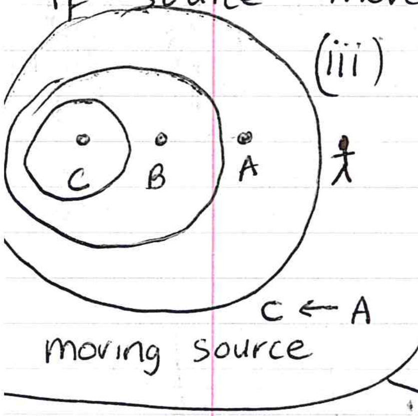


DOPPLER EFFECT





When source is moving the observer detects the time between pks as being different from the actual time.
If source moves towards observer (ii) he detects a higher freq
if source moves away from observer (iii) he detects a lower freq



Doppler effect occurs for all waves.
In EM waves: A change in frequency means a change in the nature of the wave (x ray, U.V, Radio, light)
For visible light, red is low freq, violet is high
So if a light source is moving away from you at high speed it will appear red (red shift)
If it moves towards you at high speed, it appears Violet/blue

From the frequency of the light (colour), the speed and direction of a stars movement can be calculated.

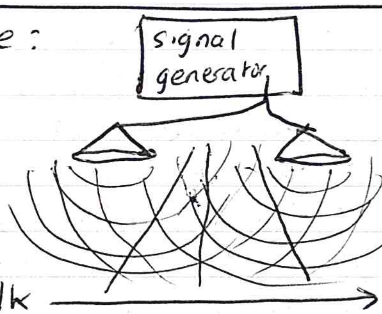
TOWARDS OBSERVER: $f' = \frac{fc}{c-u}$

f' = apparent freq, u = speed of source

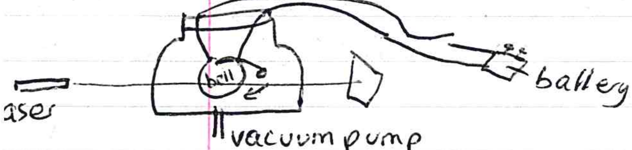
AWAY FROM OBSERVER: (lower f) $f' = \frac{fc}{c+u}$

SOUND:

To demonstrate sound interference:
same signal to both speakers
=> in phase, coherent (same frequency)
As you walk from 1 to 2
you hear sound louder (antinodes)
quieter (nodes)
demonstrates wave nature of sound



To demonstrate that sound needs a medium to travel through:



turn on bell
as air is pumped out
sound gets quieter until it disappears
hammer still seen to hit bell.
=> conclusion no air no sound gets out.
but light still passes through => light does NOT need a medium

SPEED OF SOUND:
Depends on elastic property and Density of material
The more elastic the medium => the faster the speed of sound in it
Solids have higher elasticity than gases ∴ sound travels faster thro solid
Temperature also effects speed of sound. Higher temp => faster sound/gas

Pitch → depends on frequency higher pitch if higher freq
Loudness → depends on amplitude
Quality → depends on # overtones present & their harmony with fundamental freq.

Overtones & Harmonics: used to describe acoustical behaviour & characteristics of musical instruments.

Overtones are integer multiples of the fundamental frequency. The first overtone is at 2f (the 2nd harmonic)

freq		Harmonic	Overtone
420	f	1st H	
840	2f	2nd H	1st O
1260	3f	3rd H	2nd O

Audible limits Human 20Hz – 20,000Hz. lose with age & exposure to loud noise

Sound measured in dB → a 3dB rise means a double in sound intensity. a 6dB rise means sound intensity x4

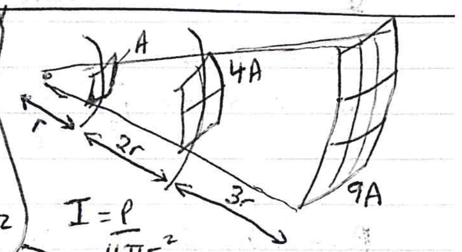
The exposure time to a loud sound contributes to hearing loss also

EAR protection V.I.P.

The INTENSITY of a sound is the rate of sound energy incident on $1m^2$ at right angles to the direction of motion of the sound

$$\text{Sound } I = \frac{\text{Power}}{\text{Area}}$$

W/m^2 or Wm^{-2}



$I = \frac{P}{4\pi r^2}$

Inverse square law

$4\pi r^2$ = Surface Area of sphere. use unless told otherwise

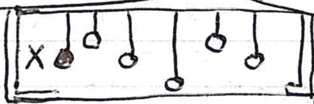
Threshold of hearing = $I = 1 \times 10^{-12}\ W/m^2$ lowest sound intensity a human can hear at 1000Hz

Resonance: the transfer of energy between 2 bodies with same natural frequency

e.g speed a car starts to vibrate at

e.g. speaker can cause a vibration

To demonstrate Resonance: Swing X and only masses at same length as X will also swing.



E.G's of Resonance

Swing → best timing to make it go higher is to push it when it is about to go away from you. If you time it wrong, swing stops

sound causes glass to shatter

Soldiers have to break formation going over a bridge as if their marching feet match resonant freq of bridge, it would Collapse. France - wind swayed bridge, forced soldiers to march in step → bridge Collapsed 200 dead. Millenium bridge in London had to be adjusted due to resonance caused by pedestrians.

Sound level meter measures sound intensity. dB setting or dBA setting

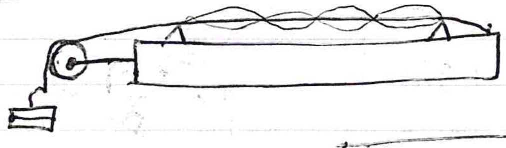
Our ear resonates better at certain frequency's – enables us to percieve some sounds better than others. Human ear has resonant freq range of 2000-4000Hz. Any sound in this range seems louder because eardrum vibrates more. This can cause damage. dBA (decibel adapted setting) weights amplitude readings in 2-4KHz range – allows Health & Safety officials to record sound intensity from human perspective.

string between 2 fixed points, plucked causes a stationary wave.

Depending on where you pluck, type of vibration changes. Pluck middle you get antinode at middle, node at ends. Pluck 1/4 way in, get 2 antinodes and 3 nodes etc. Fundamental freq (H  1 antinode.

$$f \propto \frac{1}{l}$$

Sonometer verifies this.



4th harmonic

μ = mass of string per meter (kg/m)

$$f \propto \sqrt{T}$$

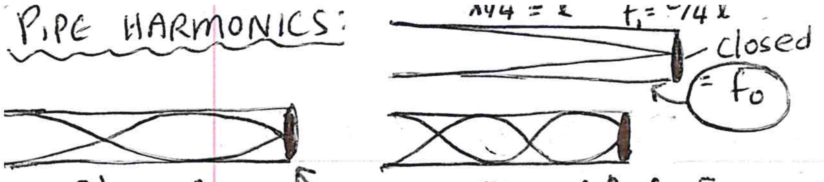
$$F \propto \frac{1}{\sqrt{\mu}}$$

$$F = \frac{K}{l}\sqrt{\frac{T}{\mu}}$$

$K = \frac{1}{2}$ so

$$F = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

PIPE HARMONICS:



$\lambda/4 = l$, $f_1 = c/4l$ $= f_0$

$\frac{3\lambda_2}{4} = l$, $f_2 = \frac{3c}{4l} = 3f_0$

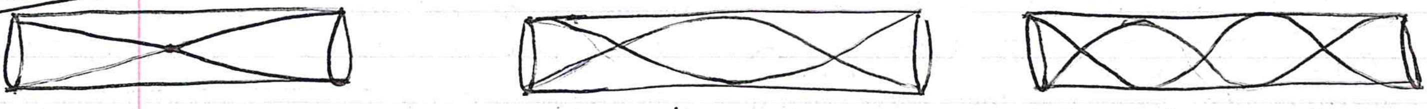
$\frac{5\lambda_3}{4} = l$, $f = \frac{5c}{4l} = 5f_0$

Antinode always at open end for max amplitude

Rem $f = \frac{c}{\lambda}$

closed Pipe – only get ODD harmonics

OPEN



$l = \lambda/2$

$2l = \lambda \Rightarrow f_0 = \frac{c}{2l}$

$l = \lambda$, $f = \frac{c}{l}$

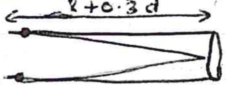
$f = 2f_0$

$l = \frac{3\lambda}{2}$, $\lambda = \frac{2l}{3}$

$f = \frac{3c}{2l} = 3f_0$

ALL Harmonics are possible in open pipes

Speed of sound in closed pipe
antinode is actually just outside open end so $\frac{\lambda}{4} = l + 0.3d$



$\lambda/4 \approx l$

$\lambda \approx 4l$ $\lambda = 4(l+0.3d)$

$c = f\lambda$

$c = f.4(l+0.3d)$

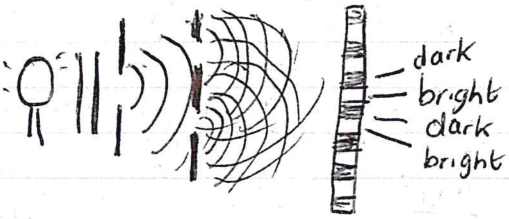
(d = diameter of pipe)

WAVE NATURE of LIGHT:

Light has property of waves and particles

Th. YOUNG showed light undergoes diffraction and interference

DOUBLE SLIT exp:



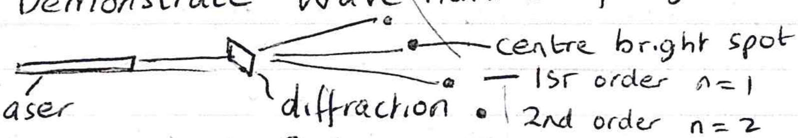
Grating was originally a carbon coated glass slide with slits scratched into it

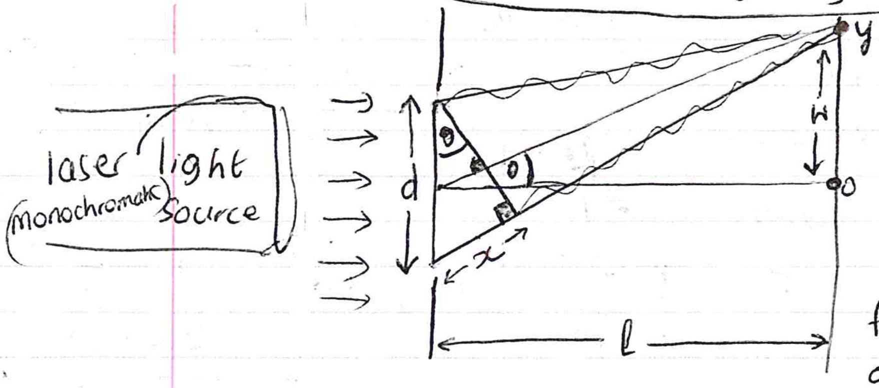
The narrower the slits the more the light was diffracted – Diffraction gratings are modern versions of Young's slits – transparent material with precision engraved parallel lines that block light.

$d = \frac{1}{N}$ d = grating constant = distance between 2 slits.

Proving $d\sin\theta = n\lambda$; finding λ of light

To Demonstrate wave nature of light:





$x = d\sin\theta$

for constructive interference at y, x must be an integer no of wave lengths

$d\sin\theta = n\lambda$

for 1st bright fringe $n=1$

$d\sin\theta = \lambda$, but $\theta = \tan^{-1}\frac{W}{l}$

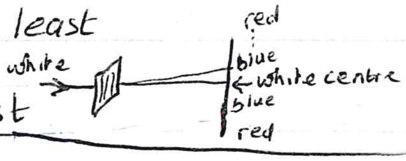
so, this is an exp that can be used to calc λ

Light as a transverse wave:

Polarisation of light: (i) Reduces glare from reflected light
(ii) Lessens amount of sunlight entering our eyes
(iii) Stress testing in industry - models of structures made from plastic placed between 2 pieces of polaroid at right angles to each other. When model is illuminated stress points are identified - parts under strain deviate light far more than low stress areas → appears as colour changes.

DISPERSION: Separation of light into its constituent colours.

PRISM disperses light, blue bends most, red bends least
GRATING diffracts light, red diffracts most, blue least



RECOMBINATION: Colours combine to form white light

3 Primary Colours → 3 Colours that combine to make white R, B, G

Complementary Colours → 2 Colours (1 primary, 1 secondary) that combine to give white
R + Cyan = W
B + Yellow = W
G + Magenta = W

Secondary colours are made from combining 2 primary colours in <u>equal</u> amounts

To Demonstrate Combination of Colours: raybox, Coloured filters

→ wavelength

Gamma rays	X rays	Ultra Violet	Visible	Infra Red	Micro waves	Radio TV waves	long waves

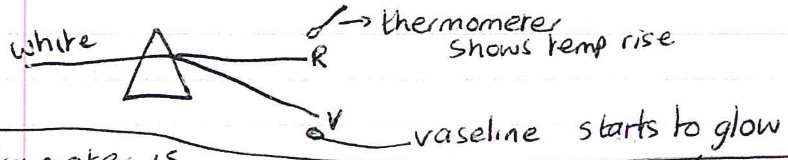
← freq

EM waves,
- c = speed of light
- travel in a vacuum
- Transverse
- All EM can cause damage

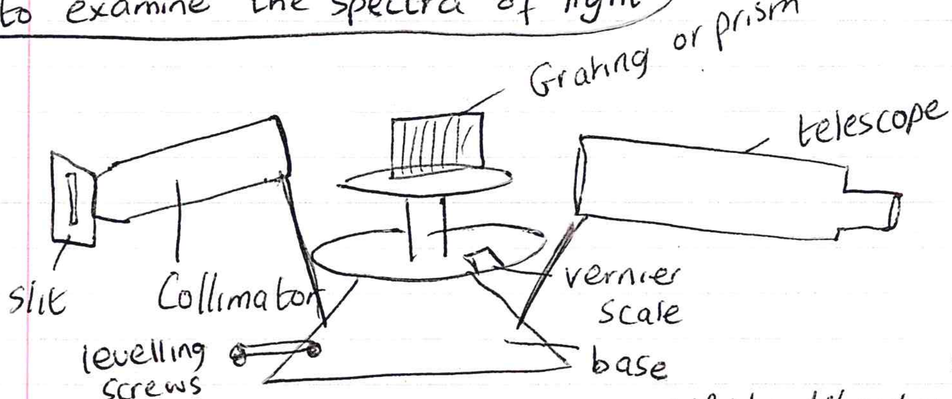
Infra red → emitted by all hot objects, can be used to take thermograms (heat images) - indicate presence of life etc, Remote controls use IR to send signals

Ultraviolet: Causes sunburn, darkening of skin, skin cancer
- helps produce vitamin D, causes some objects to flouresce, can't penetrate glass

To detect U.V. and IR: Shine white light through a prism



A spectrometer is used to examine the spectra of light



1.) focus crossthreads in eyepiece
2.) Focus telescope on a distant object
3.) Place light at slit and move collimator until slit in focus of telescope
4.) Adjust width of slit → as narrow as possible
5.) level turntable
6.) Position diff grating
7.) Use telescope to locate zero order image