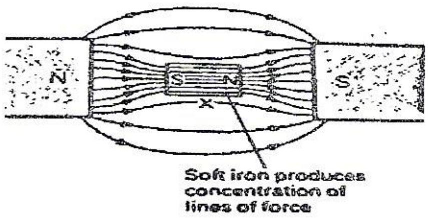
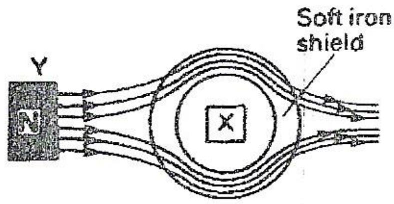
3. The more crowded the field is, the stronger it is.
4. Magnetic shielding/screening: this is the protection of objects against external magnetic fields by concentrating the magnetic fields in the soft-iron.



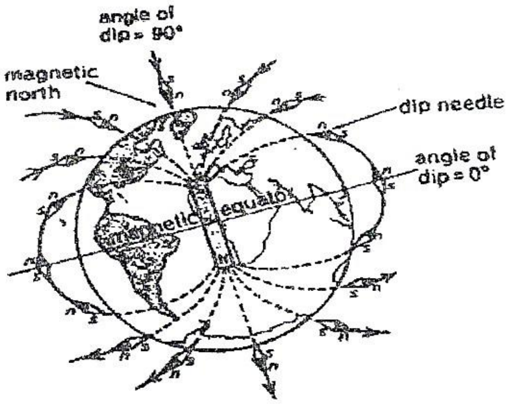


The magnetic field lines are attracted to the soft-iron ring shielding the region enclosed by the ring.

Thick-walled soft-iron boxes are used to shield delicate and sensitive electrical instruments from external magnetic fields.

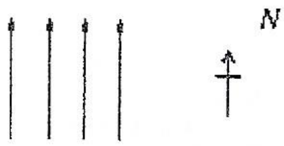
Earth's magnetism

It has been suggested that there is a large permanent magnet inside the earth which responsible for the earth's magnetic field.



The figure above shows the magnetic field of an imaginary magnet at the centre of the earth.

Using a plotting compass, parallel straight lines are obtained pointing roughly from S to N pole geographically. *See figure below.*

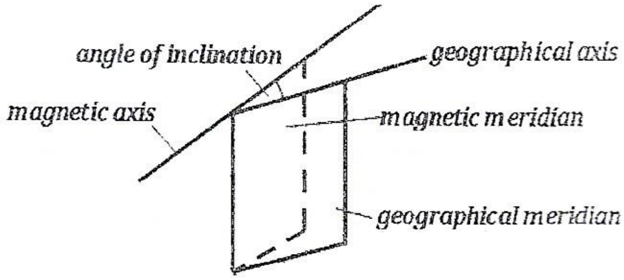


Note: All magnetic axes over earth's surface point towards one point called the north magnetic pole.

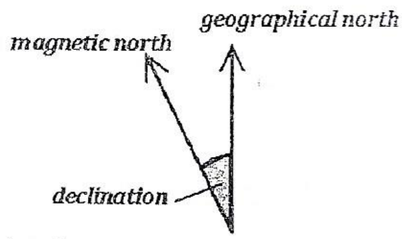
True North Pole is in the Arctic which lies on the axis of rotation of the earth.

Definitions:

1. Magnetic meridian: this is a vertical plane containing magnetic axis of a freely suspended magnet at rest under the action of earth's magnetic field.

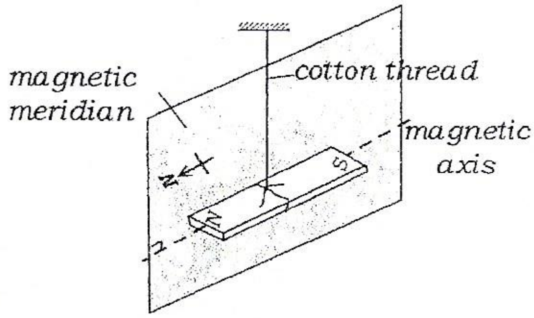


2. Angle of declination: this is the angle between the magnetic north and the geographical north.
   Or it is the angle between the true north and the magnetic north.
3. Angle of dip/inclination: is the angle between the magnetic meridian and geographical meridian.
   Or it is the angle between the horizontal surface of the earth and the direction of earth's magnetic field.



Describe how the earth's magnetic meridian may be determined

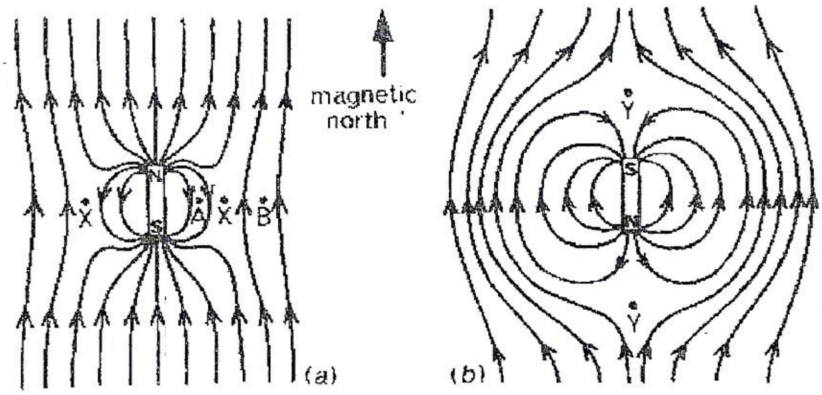
- A permanent magnet is suspended on a retort stand using a thread
- It is allowed some time to settle.
- Direction of its magnetic axis is noted.
- The vertical plane parallel to the magnetic axis represents the earth's magnetic meridian.



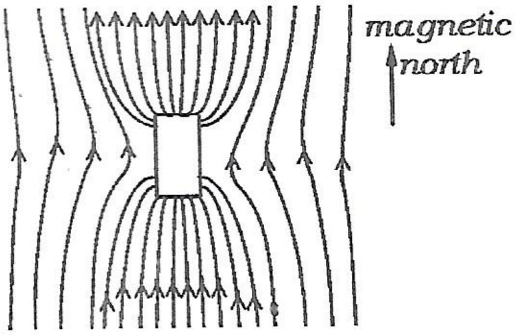
Magnetic flux pattern of a horizontal bar magnet in earth's magnetic field

Fig.(a) south pole S of bar magnet pointing to north [attraction occurs]

Fig.(b) north pole N of bar magnet pointing to north [repulsion occurs]



Magnetic flux pattern due to soft iron in earth's horizontal magnetic field

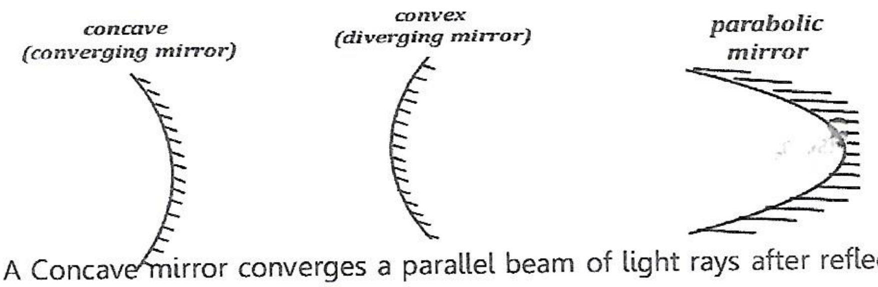


SENIOR 2: TERM ONE

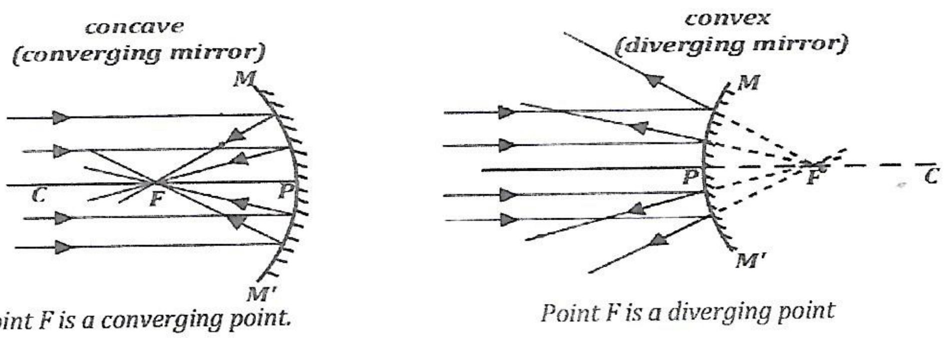
REFLECTION OF LIGHT ON CURVED SURFACES

Curved reflecting surfaces are classified as concave (converging) mirror, convex (diverging) mirror and the parabolic mirrors (reflectors of torches, bicycle and car headlamps).

A concave mirror has a reflecting surface curving inwards and a convex mirror has a reflecting surface curving outwards.



A Concave mirror converges a parallel beam of light rays after reflection where as a convex mirror diverges a parallel beam of light rays after reflection.



Point F is a converging point.

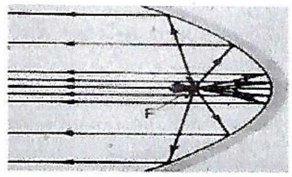
Point F is a diverging point

Terms used

1. The centre of the reflecting surface of a curved mirror is called *pole*, P.
2. The centre of the circle of which the reflector is a part is called *centre of curvature*, C.

3. The line joining the centre of curvature and the pole $(\overline{CP})$ is called the *principal axis.*
4. The width of the mirror MM' is its *aperture.*
5. The point on the principal axis where parallel rays close to the principal axis converge at after reflection is called *focal point* or principal focus F of a concave mirror.
6. The point on the principal axis where parallel rays close to the principal axis appear to diverge from after reflection is called *focal point* F of a convex mirror.
7. The distance between the focal point and the pole of the mirror is called *focal length, f* i.e $\overline{FP} = f$
8. The distance between the centre of curvature and the pole of the mirror is called *radius of curvature, r*. Where $r = 2f$

Parabolic mirrors



Parabolic mirrors (reflectors that have the shape of a parabola) reflect wide beam of light rays from a light source placed at the mirror's focus as a perfectly parallel beam without reducing its intensity as the distance from the mirror increases.

Parabolic mirrors also bring parallel rays of light to a focus. This type of reflector is therefore valuable in astronomical telescopes.

<u>Caustic curve</u>

Incident rays parallel and very close to the principal axis are called *paraxial rays.*
Incident rays parallel and far from the principal axis are called *marginal rays (See fig 1).*
When a wide parallel beam of light is incident to a curved mirror of large aperture, paraxial rays and the marginal rays converge at different focal points and a brightly illuminated area called *caustic curve* is formed as a result *(See fig 2).*

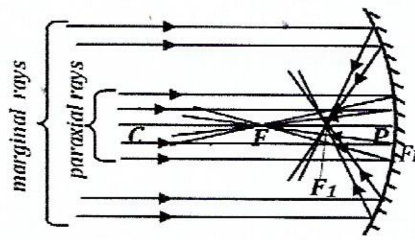


Fig.1

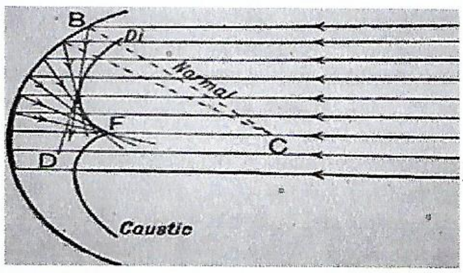


Fig.2

The reflected rays are tangential to the curve.

A caustic curve is often seen in cups due to reflection from the inner surfaces of the cup half full of tea *(See fig 1)*.

A caustic curve is overcome by using parabolic mirrors or using a slit that cuts off the marginal rays *(See fig 2)*.

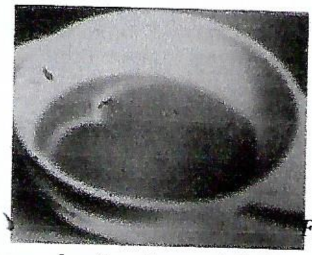


Fig.1

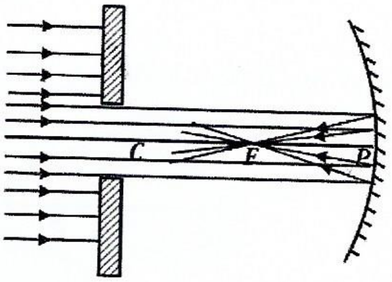
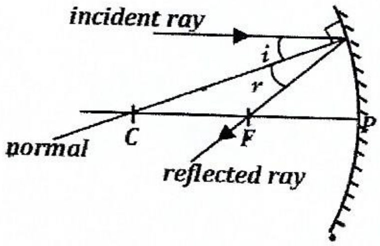


Fig.2

Laws of reflection of light

1. The angle of incidence is equal to the angle of reflection $\angle i = \angle r$.
2. The incident ray, the reflected ray and the normal at a point of incidence, all lie in the same plane.



Laws of reflection of light apply to curved reflecting surfaces and at any point of incidence, the normal passes through the centre of curvature.

Formation of images by curved mirrors (Ray diagrams)

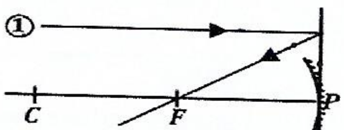
The position of images of objects and their nature depend entirely on the position of the object from the curved mirror.

In constructing ray diagrams,

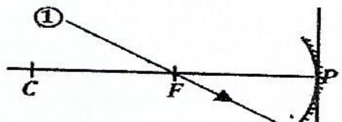
- rays originate from the head of the object,
- images are formed where rays intersect after reflection from the mirror,
- both the images and objects are perpendicular to the principal axis

Key rays to consider

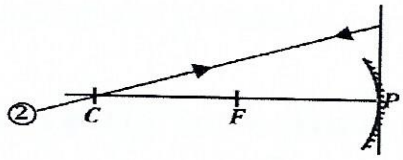
1. A ray parallel to principal axis is reflected through the focal point, F



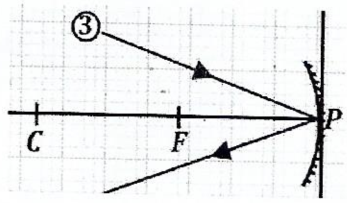
Or



2. A ray through centre of curvature C is reflected along original path (incident along the radius where angle of incidence is 0^0)

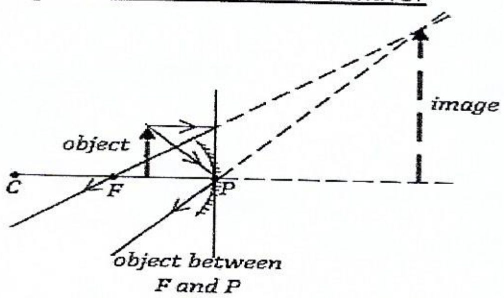


3. A ray incident at the pole is reflected such that angle of incidence is equal to angle of reflection.



Two rays are used to locate the image or sometimes the object.

<u>Images formed in a concave mirror</u>



<u>Nature of image formed</u>

magnified(bigger than object), erect, virtual and formed behind the mirror as the object is in front

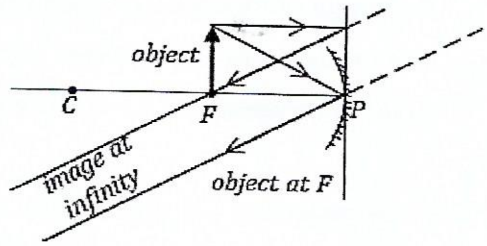
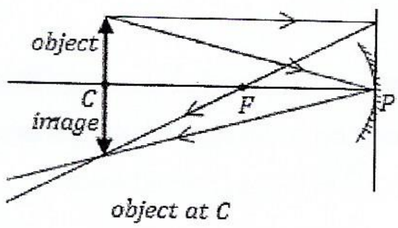
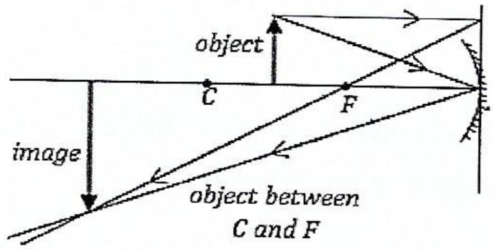


Image is formed at infinity



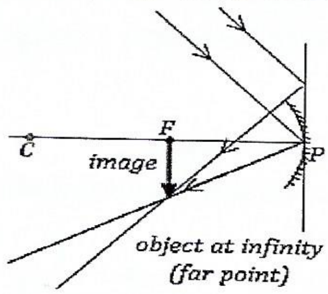
<u>Nature</u>

Real, inverted and same



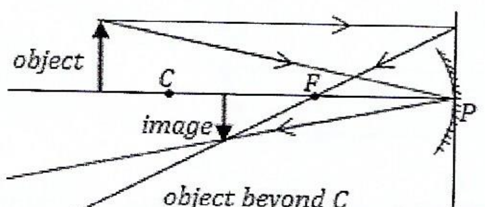
<u>Nature</u>

Magnified, inverted and real



<u>Nature</u>

image is real and inverted



<u>Nature</u>

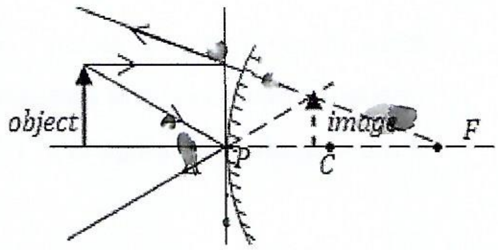
real, inverted, diminished (smaller than object)

Note: real images are inverted and virtual images are erect

Images formed in a convex mirror

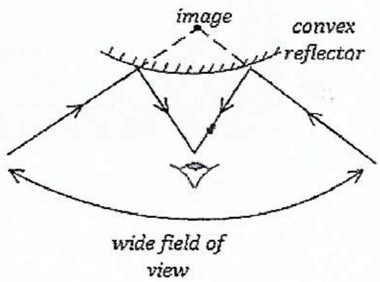
Regardless of position of the object, images formed by convex mirrors are always

- virtual
- erect
- diminished
- formed between P and F



Uses of curved mirrors

1. Concave mirrors are usually used for shaving and by dentists for examining teeth. These mirrors form magnified, erect and virtual images when objects are placed between F and P.
2. Concave mirrors are used as reflectors when the source of light is placed at their focal points F. e.g. in projectors, ophthalmoscope (instrument used by doctors to examine interior of the eye).
3. Concave mirrors concentrate sun's rays to a small area to produce very high temperatures.
4. Convex mirrors are use as car driving mirrors since they give a wide field of view than plane mirrors. Because of this, convex reflectors are used in supermarkets.



5. Parabolic mirrors are used in automobile headlights, reflectors in torches and in searchlights.
   Parabolic reflectors are also used as antennas in radio astronomy and radar to concentrate signals sent out by radio-transmitters.

Linear magnification(m): This the ratio of height of image to the height of the object $m = \frac{h_I}{h_O}$ Or it is the ratio of image distance to object distance $m = \frac{v}{u}$

Thus $m = \frac{h_I}{h_O} = \frac{v}{u}$.

Sign convention: "real" is "positive" and "virtual" is "negative"

Graphical construction

A scale is chosen to ensure that the given information fits on the graph paper.

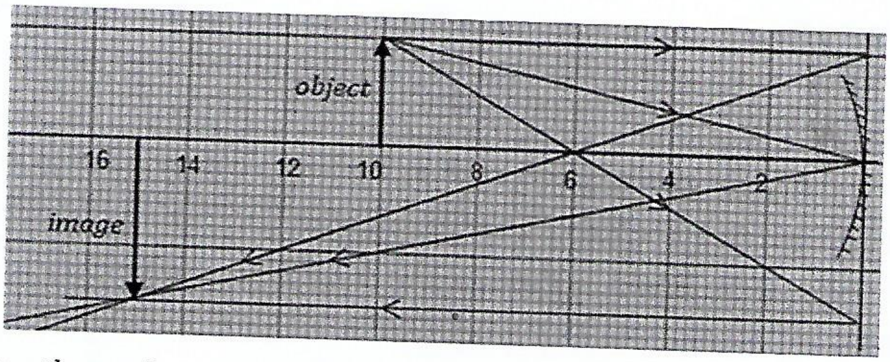
Note

- If the image formed is on the same side of the concave mirror as the object, image formed is real and inverted.
- If the magnification mage $m > 1$, image formed is magnified.

Examples

1. An object is placed 10cm from a concave mirror of focal length 6cm. Determine the position, magnification of the image formed by graphical construction. State the nature of the image formed.

   Solution: $u = 10cm, \quad f = 6cm, \quad v = ?$

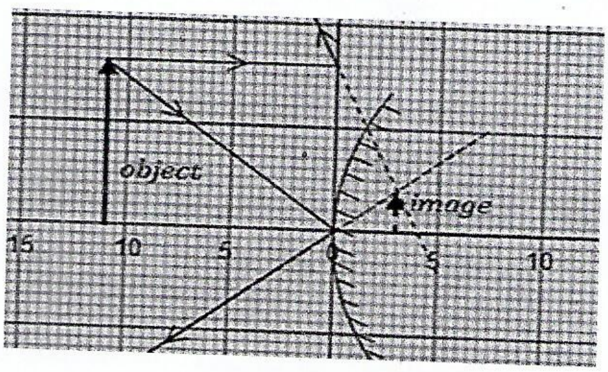


   From the graph, image is $v = 15cm$ *in front of the mirror.*

   Magnification $m = \frac{15}{10} = 1.5$

   Nature: image formed is magnified (since $m > 1$*), real (since* v *is positive), inverted (since* $u > f$*)*

2. An object 8cm high is placed perpendicularly on the principal axis 12cm away from a convex mirror. Find the focal length of the mirror if the height of the image formed is 2cm.



   Solution: $h_0 = 8cm, \quad u = 12cm, \quad f = ?, \quad h_I = 2cm$

   $m = \frac{h_I}{h_0} = \frac{v}{u} \Rightarrow \frac{2}{8} = \frac{v}{12} \quad \Rightarrow v = 3cm$

From the graph, focal length of the mirror is $4cm$.

Exercise

1. An object 10cm high is placed at a distance of 60cm from a concave mirror of focal length 20cm. Find the height of the image.

   Solution $h_0 = 10cm,\ u = 60cm, f = 20cm,\quad h_I = ?$ *Image is* $25cm$ *high.*

2. An object is placed 4cm from a convex mirror of focal length 8cm. By graphical construction, determine the position of the image formed and state its nature.

   Image is $8cm$ *behind the mirror, Magnification* $m = \frac{8}{4} = 2$

   Nature: image is magnified (since $m > 1$ *), virtual (since* v *is negative), erect (since* $u < f$*)*

3. When an object is placed 20cm from a concave mirror, a real image magnified three times is formed. By graphical method, find the focal length of the mirror

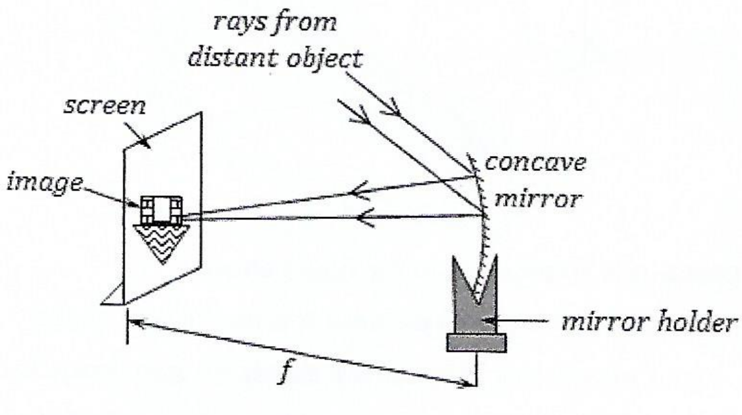
   Solution: $u = 20cm, f = ?,\ m = 3\ ,\ m = \frac{v}{u} \Rightarrow 3 = \frac{v}{20} \Rightarrow v = 60;\quad f = 15cm$

Methods of measuring focal length of a concave mirror

(a) Focusing a distant object

Apparatus: concave mirror, metre rule and screen.

- A mirror and the screen are arranged as in the figure below.

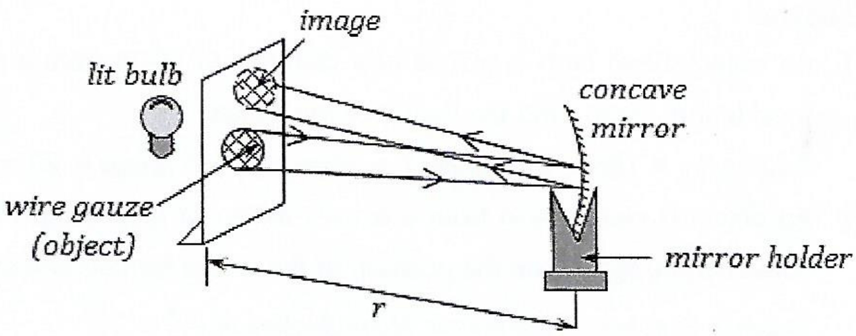


- A mirror is moved to and fro until sharp image of a distant object is formed on the screen
- Distance f from the mirror to the screen is measured and recorded.
- This distance is the estimated focal length f of the mirror.

(b) Focusing a lit/illuminated object

Apparatus: concave mirror, screen with wire gauze mounted, metre rule, lit torch bulb

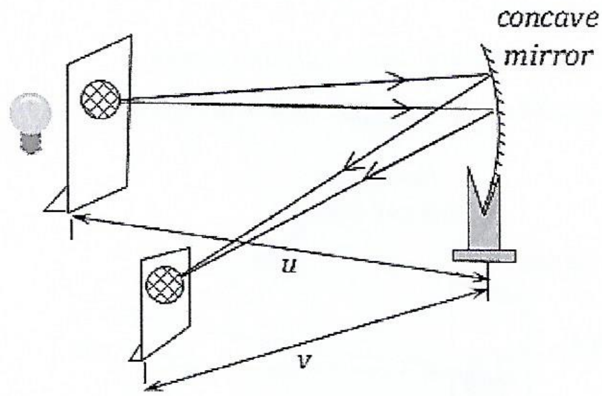
- The apparatus is arranged as in the figure below.



- A lit bulb is placed near the wire gauze and the mirror move to and from until a sharp image is formed alongside the object.
- Distance r between the screen and the mirror is measured.
- Focal length f of the mirror is obtained from $f = \frac{r}{2}$

(c) *Measurement of image and object distances*

Apparatus: concave mirror, 2 screens one with wire gauze mounted, metre rule, and lit torch bulb.



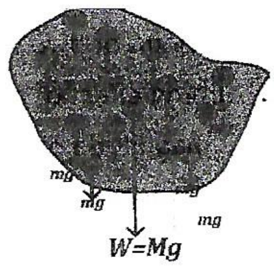
- The apparatus is arranged as in the figure above.
- A mirror is placed at a known distance u from the wire gauze.
- The screen is moved to and fro until a clearly focused image is observed.
- The distance v between the mirror and the screen is measured and recorded.
- Experiment is repeated for different values of u. Different values of uv and $u + v$ are obtained.
- A graph of uv against $u + v$ is drawn.
- Gradient f of the graph gives the focal length of the mirror.

CENTRE OF GRAVITY AND TURNING EFFECT OF FORCES

A body consits of tiny particles each of mass m and weight mg.

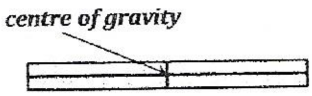
The total weight,W (resultant force) acts through a point called *centre of gravity, G* where its mass is concetrated.

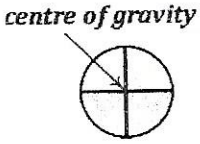
Centre of gravity is defined ***as the point of application of the resultant force due to the earth's attraction on it.***



Centre of gravity of a regular/uniform body

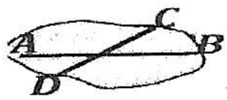
Centre of gravity of a regular body is located at the intersection of its lines of symmetry.





Centre of gravity of an irregular lamina(thin layer)

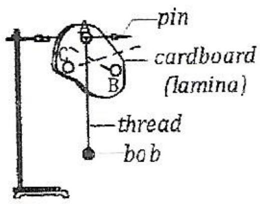
(A) method of balancing



- An irregular lamina is balanced on a knife edge.
- A line AB along which it balances is drawn on it
- The lamina is rotated and a new line CD is drawn where it again balances.
- The point of intersection of the lines AB and CD is the centre of gravity of the irregular lamina.

(B) Plumbline method

Apparatus: retort stand, pendulum bob, thread (1m), irregular cardboard, 1 optical pin.



- Three holes marked A, B and C are drilled on the cardboard.
- The cardboard is hung through hole A on a clamped pin.
- A bob tied on thread is hung on the pin as in the figure.
- The path of the thread on the card board is marked and a line drawn.
- The experiment is repeated with thread hung through holes B and C.
- The centre of lines is the centre of gravity of the cardboard.

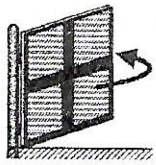
TURNING EFFECT OF FORCES

When a force(s) act(s) on a body, either

- the body rotates about a point e.g opening a door, a padlock, tap, a nut, tunning a radio, rotating steering wheel, rotating chairs.

- remains fixed and in this case it is said to be in equilibrium.

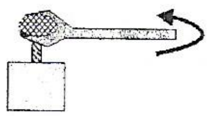
The turning effect of a force is called moment of a force about the turning point or pivot.



The turning effect of a force depends on

- magnitude of force applied
- distance from the line of action from the turning point

Examples



- Doors are easily opened by applying a small force at a longer distance from the hinge causing a large turning effect.
- Nuts are easily loosened by using a long spanner than a short one
- A log is easily lifted by applying a force at the end than in the middle.

Moment of a force about a point is defined as ***the product of the force and the perpendicular distance from that point.***

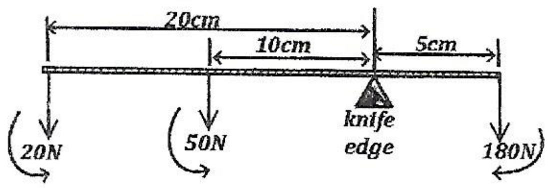
S.I units of moment of a force are Nm.

If a force rotates a body in an anti-clockwise direction,it produces an anti-clockwise moment about a point and if a force rotates a body in a clockwise direction,it produces a clockwise moment about a point.

Examples

1. The figure below shows a number of forces acting on the rod and is balanced horizontally about the knife edge

Find the moment of each force about the knife edge and state whether it is a clockwise or anti-clockwise moment.



Solution:

if each force would act on the rod, it causes the rod rotate in the directions indicated.

Moment of $20N$ *about the pivot is* $20 \times \frac{20}{100} = 4Nm$ *[anti-clockwise moment]*

Moment of $50N$ *about the pivot is* $50 \times \frac{10}{100} = 5Nm$ *[anti-clockwise moment]*

Moment of $180N$ *about the pivot is* $180 \times \frac{5}{100} = 9Nm$ *[clockwise moment]*

- The experiment is repeated for different walues of W_1 and W_2 and values of b obtained.
- Moments of W_1 and W_2 are calculated and it will be found out that $W_1a = W_2b$.
- This verifies the principle of moments

Conditions for a body to be in equilibrium

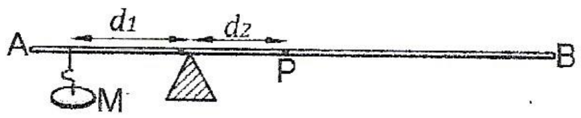
A body is said to be in equilibrium if

- algebraic sum of moments about a point is zero i.e. sum of clockwise moments about a point is equal to the sum of anti-clockwise moments about the same point.
- algebraic sum of forces in opposite directions is zero i.e. sum of upward forces is equal to sum of downward forces.

Determination of mass of a metre rule

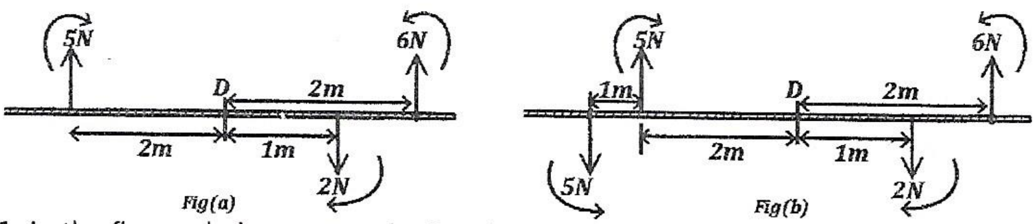
Apparatus: metre rule, thread, knife edge, known mass M.

- A metre rule placed on a knife edge is adjusted until it balances horizontally.
- The balance point P is noted.
- A known mass M is hung at a known distance from end A on the metre rule using a thread. The metre rule is a gain adjusted until it balances horizontally.



- Distances d_1 and d_2 are measured and recorded.
- The mass of metre rule is obtained from $M \frac{d_1}{d_2}$

Calculations



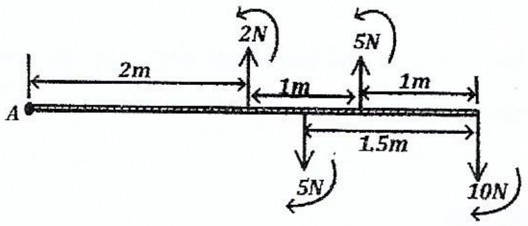
1. In the figures below, state whether the system is in equilibrium.

Solution:

In figure (a)if D is a turning point,

Moment of $5N$ *is* $5 \times 2 = 10Nm$ [*clockwise moment*]

2. Find the moment of each force in the figure below about point A.



Moment of $10N$ *about A is* $10 \times 4 = 40Nm$ [*clockwise moment*]

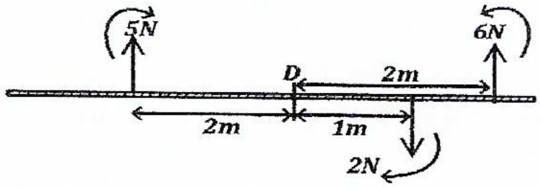
Moment of $5N$ *about A is* $5 \times (4 - 1.5)$

$= 5 \times 2.5 = 12.5Nm$ [*clockwise moment*]

Moment of $2N$ *about A is* $2 \times 2 = 4Nm$ [*anti-clockwise moment*]

Moment of $5N$ *about A is* $5 \times 3 = 15Nm$ *anti-clockwise moment*]

3. Find the moment of each force in the figure below about point D.



Moment of $5N$ *is* $5 \times 2 = 10Nm$ [*clockwise moment*]

Moment of $2N$ *is* $2 \times 1 = 2Nm$ [*clockwise moment*]

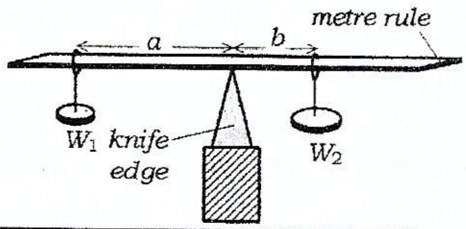
Moment of $6N$ *is* $6 \times 2 = 12Nm$ [*anti-clockwise moment*]

Principle of moments

If a body is in equilibrium under action of forces, the sum of clockwise moments about a point is equal to the sum of anti-clockwise moments about the same point. This is called *principle of moments.*

Experiment to verify the principle of moments

- A uniform metre rule is balanced on a knife edge and the balance point noted.
- A known weight W_1 is hung on one side of the knife edge at a known distance a.
- Another weight W_2 is hung on the other side of the knife edge and its position adjusted until the metre rule balances horizontally again.
- Distance b of W_2 from the knife edge is measured and recorded.



Moment of 2N is $2 \times 1 = 2Nm$ *[clockwise moment]*

Moment of 6N is $6 \times 2 = 12Nm$ *[anti-clockwise moment]*

Sum of clockwise moments about D is $10 + 2 = 12Nm$ *and Sum of anti-clockwise moments about D is* $= 12Nm$

Since Sum of clockwise moments about D is equal to sum of anti-clockwise moments about the same point then the system is in equilibrium.

In figure (b) if D is a turning point,

Moment of 5N is $5 \times 2 = 10Nm$ *[clockwise moment]*

Moment of 2N is $2 \times 1 = 2Nm$ *[clockwise moment]*

Moment of 6N is $6 \times 2 = 12Nm$ *[anti-clockwise moment]*

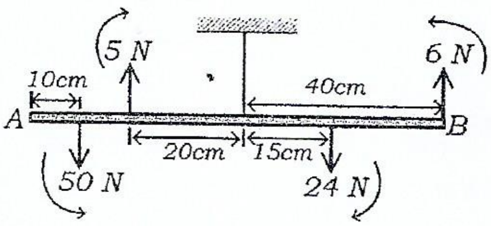
Moment of 5N is $5 \times 3 = 15Nm$ *[anti-clockwise moment]*

Sum of clockwise moments about D is $10 + 2 = 12Nm$ *and Sum of anti-clockwise moments about D is* $12 + 15 = 27Nm$.

Since Sum of clockwise moments about D is not equal to sum of anti-clockwise moments about the same point then the system is not in equilibrium.

Infact, the rod rotates about D in an anti-clockwise direction.

2. In the figure below, AB is is a beam75cm long suspended on a thread. State whether the system is in equilibrium.



Sum of clockwise moments about point of suspension is $24 \times \frac{15}{100} + 5 \times \frac{20}{100} = 4.6Nm$

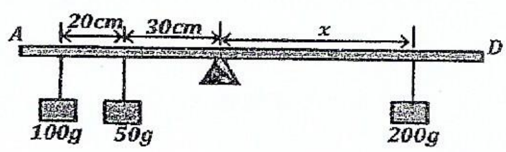
Sum of anti-clockwise moments about point of suspension is $6 \times \frac{40}{100} + 50 \times \frac{25}{100} = 14.9Nm$

Since sum of clockwise moments about point of suspension is not equal to sum of anti-clockwise moments about the same point then the system is not in equilibrium. The beam rotates about point of suspension in an anti-clockwise direction.

3. Masses of 100g, 50g and 200g are suspended from a horizontal beam. If the system is in equilibrium, find the

(a) Value of distance x

(b) Force(normal reaction) exerted by the pivot.



Solution: Weight of 100g mass $mg = \frac{100}{1000} \times 10 = 1N,$

Weight of 50g mass $mg = \frac{50}{1000} \times 10 = 0.5N,$ *Weight of 200g mass* $mg = \frac{200}{1000} \times 10 = 2N$

(a) Sum of clockwise moments about the pivot is $2x\ Nm$

Sum of anti-clockwise moments about the pivot is $1 \times \frac{50}{100} + 0.5 \times \frac{30}{100} = 0.65Nm$

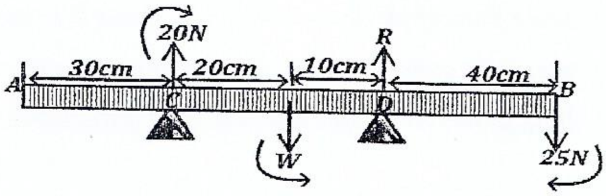
Since the system is in equilibrium, $2x = 0.65 \Rightarrow x = \frac{0.65}{2} = 0.325m$

(b) let the reaction at the pivot be R acting upwards since the pivot must supprot the masses.

At equilbrium, total upward forces = total downward forces $\Rightarrow R = 1 + 0.5 + 2 = 3.5N$

Force exerted by the knife edge is $3.5N$

4. A uniform beam AB 1m long rests horizontally on two supports C and D placed at 30cm and 60cm marks respectively from A. When a load of 25N is hung from B, the reaction at C is 20N.



Calculate the

(i) weight of the beam

(ii) reaction at D

Solution

Let the weight of the beam be W. This acts in the middle of the beam since the beam is uniform.

(i) Taking moments about D,

Sum of clockwise moments is $20 \times \frac{30}{100} + 25 \times \frac{40}{100} = 16\ Nm$

Sum of anti-clockwise moments is $W \times \frac{10}{100} = 0.1W\ Nm$

Since the system is in equilibrium, $0.1W = 16 \Rightarrow W = \frac{16}{0.1} = 160N$

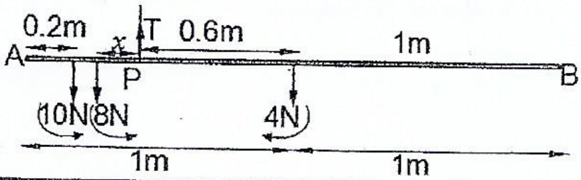
(ii) let reaction at D be R A.t equilibrium, upward forces are equal to downward forces.

$\Rightarrow 20 + R = 25 + W \Rightarrow 20 + R = 25 + 160 \Rightarrow R = 185 - 20 = 165N$

5. A uniform beam AB of length 2.0m and amass 0.4kg is suspended from a string fixed at appoint 0.4m from end A. A mass of 1.0kg is hung on the beam at a point 0.2m from A. using a diagram, show forces acting on the beam and hence find how far from A, a mass of 0.8kg must be hung so that beam balances horizontally.

Solution: weight $= mg$

Weight of 0.4kg $= 0.4 \times 10 = 4N$



Weight of 1.0kg $= 1.0 \times 10 = 10N$ *Weight of 0.8kg* $= 0.8 \times 10 = 8N$

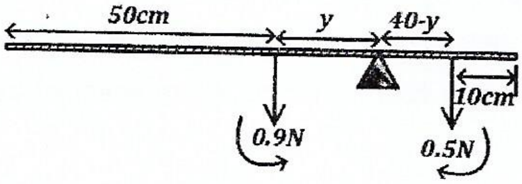
Let T be the tension in the string. Take moments from point about P

$10 \times 0.2 + 8x = 4 \times 0.6 \Rightarrow 8x = 2.4 - 2 \Rightarrow x = 0.05m$

$0.8kg$ *is* $0.4 - 0.05 = 0.35m$ *from A*

6. A uniform metre rule of mass 90g is balanced on a knife edge when a 0.5N weight is hung 10cm from one end. How far is the knife edge from the centre of the metre rule?

Weight of metre rule $W = \frac{90}{1000} \times 10 = 0.9N$ *and acts at a 50cm mark. Let the knife edge be y cm from the centre of the metre rule.*



At equilibrium, $0.9y = 0.5(40 - y)$

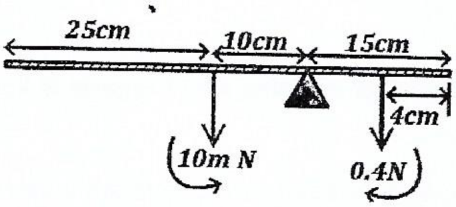
$\Rightarrow 0.9y = 20 - 0.5y$

$\Rightarrow 1.4y = 20 \Rightarrow y = \frac{20}{1.4} = 14.3cm$

The the knife edge is 14.3 *cm from the centre of the metre rule.*

7. A uniform half metre rule is freely pivoted at a 15cm mark and balances horizontally when a mass of 40g is hung from a 4cm mark. Draw a force diagram and calculate the mass of the metre rule.

Weight of half metre rule $W = mg = (10m)$ *N and acts at a 25cm mark*



At equilibrium, $10m \times 10 = 0.4 \times 11$

$\Rightarrow 100m = 4.4 \Rightarrow m = \frac{4.4}{100} = 0.044kg$

mass of the metre rule is $0.044kg$

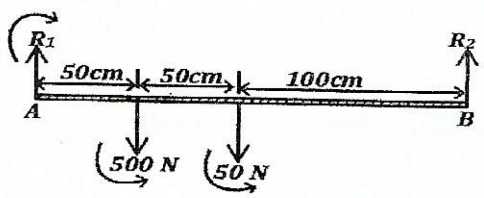
8. Two laborers A and B carry between them a load of weight 500N on a uniform pole of weight 50N. If the pole is 2m long and the load is 50cm from A towards B,

(i) Draw a diagram to show the forces acting on the pole.

(ii) Find the fraction of the total weight that is supported by B.

Solution:

(i) Let R_1 *and* R_2 *be reaction forces on A and B respectively. Weight of the load acts in the middle since it is uniform.*



(ii) Taking moments about B,

$\Rightarrow 500 \times \frac{150}{100} + 50 \times \frac{100}{100} = R_1 \times \frac{200}{100}$

$\Rightarrow 800 = 2R_1 \Rightarrow R_1 = 400\ N$

At equilibrium, $R_1 + R_2 = 500 + 50 = 550 \Rightarrow 400 + R_2 = 550 \Rightarrow R_2 = 150N$

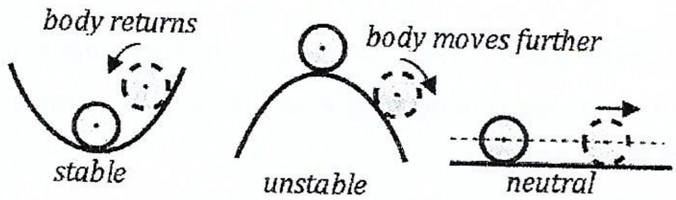
B supports $\frac{150}{550} = \frac{3}{11}$ *of the total weight*

Stability

A body is in *stable equilibrium* if when slightly displaced and released it returns to its previous position due to moment of its weight.

A body is in *unstable equilibrium* if when slightly displaced and released the position of its centre of gravity falls and the body moves further due to the moment of its weight.

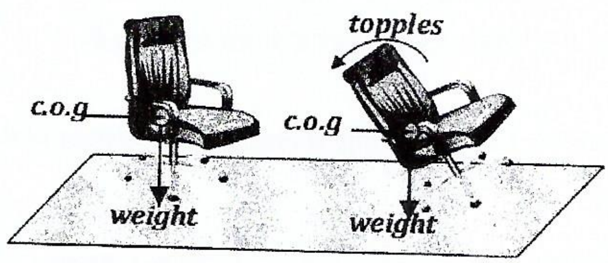
A body is in *neutral equilibrium* if when slightly displaced and released the position of its centre of gravity does not change and its weight has no moment.



Stability of a body can be increased by

- Lowering the position of its centre of gravity (this explains why luggage is kept in lower decks of buses than on top racks)
- Increasing the area of its base (this explains why tyres of racing cars are wider)

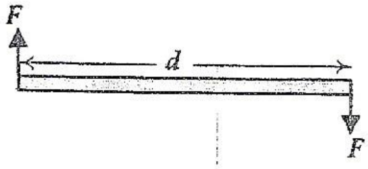
Note: When a body is given a small displacement and the line of force of gravity falls outside the base, the body topples/overtuns.



Question: *Explain why trailers normally overtun on corners while moving at higher speeds.*

The centre of gravity of a trailer is raised and this makes it unstable. When the line of its weight falls outside the base, it topples.

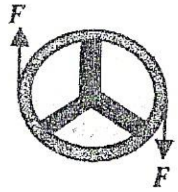
Couples:

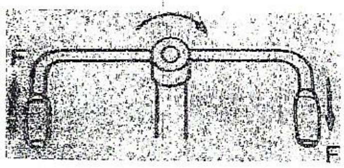


These are two equal and opposite forces acting on an objects.

Couples are applied in

- opening a tap or a padlock,
- unscrewing nuts
- turning a steering wheel and
- turning handles of bicycles.



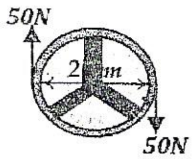


Moment of a couple sometimes called a *torque* is defined as ***the product of one of the forces and the perpendicular distance between the forces;***

$Torque = F \times d$ and its units are Nm

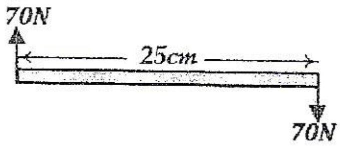
Examples

1. A driver applied a force of 50N to turn a steering wheel of a car. If the diameter of the steering wheel is 20cm, find the torque applied.



$Torque = 50 \times \frac{20}{100} = 10N$

2. The figure below shows forces of 70N applied at the end of the rod fixed in the middle. Calculate the moment of the couple.

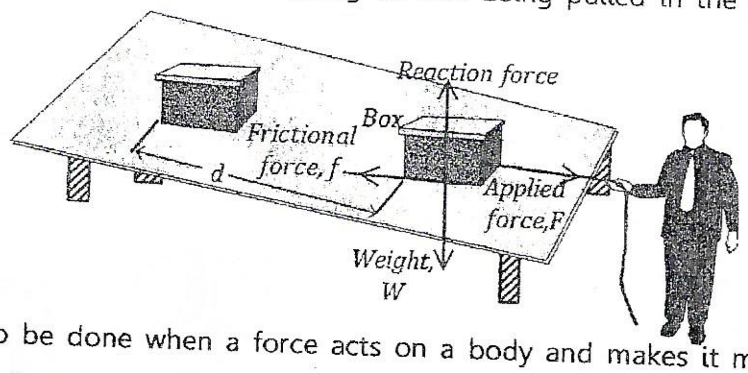


$Torque = 70 \times \frac{25}{100} = 17.5N$

WORK, ENERGY AND POWER

Work

The figure below shows the forces acting on box being pulled in the direction of pulling force.



Work is said to be done when a force acts on a body and makes it move in the direction of the force.

Work done is therefore defined as ***the product of force and the distance moved in the direction of force.***

Work done by force, $(W) = force(F) \times distance(d)$; $W = F \times d$

S.I units of work are joules, J

$1J = 1\,N \times 1\,m$

A joule is the work done when a force of one newton moves an object through a distance of one metre in the direction of the force.

Other units of work are

- kilojoules $(kJ) = 1000J$ e.g $5kJ = 5 \times 1000\,J = 5000\,J$
- mega joules$(MJ) = 1{,}000{,}000J$. e.g $50\,MJ = 50 \times 1{,}000{,}000\,J = 5.0 \times 10^7\,J$

Forms of work done

A. Work done by applied force $(W) = force(F) \times distance(d)$; $W = F \times d$

Examples

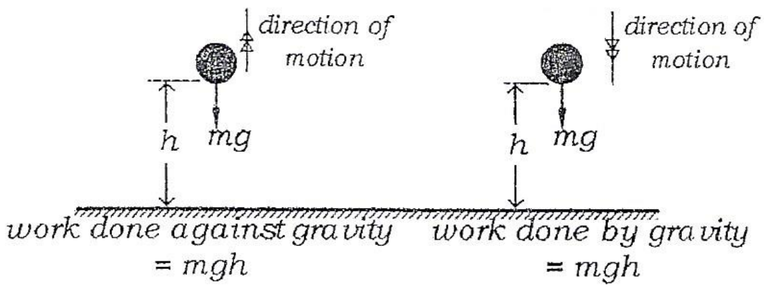
1. A constant force of 5kN is used to pull a piece of wood through a distance of 200cm. Find the work done by the force.

   $F = 5\,kN = 5000\,N,\ d = 200cm = \frac{200}{100} = 2m$

   $\Rightarrow W = F \times d = 5000 \times 2 = 10{,}000J$

B. Work done by or against gravity: If a body is thrown upward or released downward, the only force acting on it is gravitational force (its weight).

Work done by gravity is the product of gravitational force and the distance (vertical height) moved under gravity.



where $g = 10ms^{-1}$ is acceleration due to gravity on the earth's surface.

Examples

1. A shopkeeper lifts a tin of mass 2kg vertically through a distance of 17cm. Find the work done against gravity. (acceleration due to gravity $g = 10ms^{-1}$)

   $m = 2kg,\ h = \frac{17}{100} = 0.17m \Rightarrow W = mgh = 2 \times 10 \times 0.17 = 3.4J$

2. A girl of mass 60kg walks upstairs for a vertical height of 7m, find the work done by the girl against gravity.

   $m = 60kg, h = 7m \Rightarrow W = mgh = 60 \times 10 \times 7 = 4200J$

C. Work done against friction: If the surface over which a body moves is rough, work is done against friction to make the body move.

Work done against frictional force is the product of the frictional force and the distance a body moves under friction.

Therefore work done against friction W = *frictional force* $(f) \times$ *distance moved under friction* (d) $W = f \times d = fd$

Useful work done $= Fd - fd$. This is used to accelerate the body in the direction of motion.

Example

The engine force of 5,000N pulls a train 100m from one station to another against a constant resistance of 500N. Calculate the

(i) work done by the engine

(ii) work done against the resistance

(iii) useful work that accelerates the system.

Solution

$F = 5{,}000N,\ d = 100m, resistance\ force\ f = 500N$

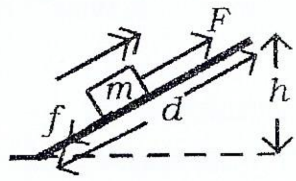
(i) $Work\ done\ by\ engine = F \times d = 5{,}000 \times 100 = 500{,}000J$

(ii) $Work\ done\ against\ resistance = f \times d = 500 \times 100 = 50{,}000J$

(iii) $Useful\ work\ done\ is\ 500{,}000 - 50{,}000 = 450{,}000J$

D. Work done on an incline: an incline is a plane surface making an angle to the horizontal.

If a body of mass m is thrown up an incline, work is done against gravity and against friction to make it move.



F is the applied force, f is the frictional/resistance force, h is the vertical distance moved to the top of an incline of length d

Work done against gravity $= mgh$

Work done by applied force F is $F \times d = Fd$

Work done against friction is got from $fd = Fd - mgh$

<u>*Example*</u>

A box of mass 30kg is pushed with a force of 130N up an incline 14m long into a lorry 2m high. Calculate

(i) work done by the force

(ii) work against gravity

(iii) work done against friction

(i) $work\ done\ by\ the\ force = 130 \times 14 = 1820\ J$

(ii) $work\ against\ gravity = 30 \times 10 \times 2 = 600\ J$

(iii) $work\ done\ against\ friction = 1820 - 600 = 1220\ J$

Energy

This is the ability of doing work. S.I units of energy are joules, J

Other units of energy are kilojoules $(kJ) = 1000J$ and mega joules $(MJ) = 1{,}000{,}000J$.

Forms of energy: energy appears in many forms such as

- Light energy; this enables us to see
- Chemical energy; energy obtained from our foods or from cells
- Heat energy; this is received from hot substances due to temperature difference
- Solar energy; this is received from sun and helps in manufacture of chlorophyll in plants
- Electrical energy; used for lighting in our homes
- Kinetic energy; this is possessed by a body by virtue of its motion
- Potential energy; this is possessed by a body by virtue of its position
- Geothermal energy; energy obtained from hot springs
- Sound energy; this enables us to hear
- tidal energy; this is obtained from tides (periodic rise and fall of all ocean waters)

Sources of energy

1. Renewable sources: these are sources of energy that do not easily run out but can be replaced once they have been used.

Examples include:

- solar,
- geothermal,
- biomasş energy – the fuel energy that can be derived directly or indirectly from biological sources e.g from wood, crop residues and dung remains,
- tidal energy,
- biogas (a mixture of methane and carbon dioxide produced by decomposing organic matter as cooking fuel
- wind power
- water power

2. Non- renewable sources: these are sources of energy that can not be replaced once they have been used. They are the energy sources that take a million of years before they are replaced.

   Examples include:

   - Fossils (plant and animal remains; fossil fuels are main sources of energy for motor vehicle and industrial manufacturing plants).
   - Nuclear power.

(a) **Potential energy**

- **Gravitational potential energy**: When a body of mass m is raised through a height h above the ground the work done against gravity is stored as gravitational potential energy. $G.P.E = mgh.$

  Gravitational potential energy is defined as the energy possessed by a body by virtue of its position in the gravitational field.

Examples

1. An orange of mass 500g drops from a tree 10m high. Find its potential energy.

   $m = 500g = \frac{500}{1000} = 0.5kg, h = 10m \Rightarrow P.E = mgh = 0.5 \times 10 \times 10 = 50J$

2. A box of mass 50kg requires 1000J of energy to lift it. At what height will it reach?

   $m = 50kg \quad h = ? \quad P.E = mgh \Rightarrow 1000 = 50 \times 10 \times h \Rightarrow h = 2m$

   It will reach 2m high.

- **Elastic potential energy**: this is the energy stored in stretched strings or springs. The work done by a stretching force is stored as elastic potential energy (E.P.E)

Questions

1. How many joules of energy are needed to raise a mass of 200 g through 3 m against the pull of gravity?
2. A student of mass 50 kg runs up a flight of 50 stairs each of height 20 cm. Calculate the work done by the girl.

(b) **Kinetic energy**: This is the energy a body possesses by reason of its motion.

When a body of mass m moves with a speed/velocity v, its kinetic energy $K.e = \frac{1}{2}mv^2$

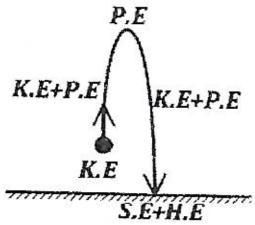
Calculate the kinetic energy of the ball of mass 300g moving with a speed of $4ms^{-1}$.

$m = 300g = \frac{300}{1000} = 0.3kg, \; v = 4ms^{-1} \Rightarrow K.E = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.3 \times 4^2 = 2.4\,J$

Principal of Conservation of energy

When a stone is thrown upwards it possesses kinetic energy. As it rises, its velocity decreases and so loses kinetic energy. At the same time, its height increases meaning that it gains potential energy.

At its highest point, it is stationary for a moment during which it has no kinetic energy but has potential energy.



$Kinetic\ energy \rightarrow gravitational\ P.E + K.E \rightarrow gravitational\ P.E$

As it falls, it loses potential energy but it gains kinetic energy. On hitting the ground, sound is heard and some heat develops.

$gravitationa\ P.E \rightarrow gravitationa\ P.E + K.E \rightarrow sound\ energy + heat\ energy$

Principal of Conservation of energy states that; ***in any closed system, total amount of energy is constant.*** Or ***energy can neither be destroyed nor created but can be transformed into other forms of energy.***

By using suitable machines or apparatus, energy can be changed from one form to another.

Machine	**Energy changes**
Microphone	Sound to electrical
Dry cell	Chemical to electrical
Bell	Mechanical to sound
Loud speaker	Electrical to sound
Dynamo	Mechanical to electrical
Photocell	Light to electrical
Candle	Chemical to light
Fluorescent tube	Electrical to light
Motor	Electrical to mechanical
Bulb	Electrical to light and heat

Calculations: In calculations, $energy\ lost = energy\ gained$

1. An object of mass 20kg is released from rest at a height of 20m above the ground. Calculate the speed with which the object hits the ground.
   ($Use\ g = 10ms^{-2}$).
   $m = 20kg,\ u = 0ms^{-1}\ v = ?ms^{-1},\ h = 20m,$
   As the object falls, its height decreases hence PE is lost. Its velocity increases hence KE is gained. Thus $PE\ lost = KE\ gained$
   $\Rightarrow mgh - 0 = \frac{1}{2}mv^2 - \frac{1}{2}m \times 0^2$
   $\Rightarrow 20 \times 10 \times 20 = \frac{1}{2} \times 20v^2 \Rightarrow v = 20ms^{-1}$ *Object fall with a speed of* $20ms^{-1}$

2. A trolley of mass 0.5kg moves from rest down a frictionless track and falls vertically a distance of 0.4m. Find its final speed.

   $m = 0.5kg,\ u = \ 0ms^{-1}\ v = ?\,ms^{-1},\ h = 0.4m,$

   $Using\ PE\ lost = KE\ gained \quad \Rightarrow mgh - 0 = \frac{1}{2}mv^2 - \frac{1}{2}m \times 0^2$

   $\Rightarrow 0.5 \times 10 \times 0.4 = \frac{1}{2} \times 0.5v^2 \Rightarrow v = 2\sqrt{2}ms^{-1}$

   Final speed of trolley is $2\sqrt{2}ms^{-1}$.

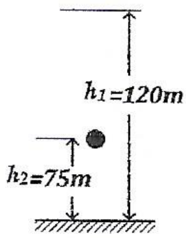
3. A catapult projects a stone of mass 800 g vertically to a height of 20 m. Calculate the speed of the stone as it leaves the catapult.

   $Using\ KE\ gained\ = P.E\ lost \quad \Rightarrow \frac{1}{2}mu^2 - \frac{1}{2}m \times 0^2\ = mgh - 0$

   $\Rightarrow \frac{1}{2} \times \frac{800}{100}u^2 = \frac{800}{100} \times 10 \times 20 \Rightarrow u = 20\ ms^{-1}$

   Speed of the stone is $20\ ms^{-1}$

4. A stone of weight 10N falls from rest from a height of 120m. Find its kinetic energy and the velocity when it is 75m above the ground.

   $W = mg = 10N \Rightarrow m = \frac{10}{10} = 1kg,\ \ u = \ 0ms^{-1}\ \ v = ?\,ms^{-1},$

   $h_1 = 120m, h_2 = 75m$

   $Using\ KE\ gained\ = PE\ lost$

   $\Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}m \times 0^2 = mgh_1 - mgh_2$

   $KE\ gained = 10 \times 120 - 10 \times 75 = 450J$

   $KE\ gained\ \ 450 = \frac{1}{2} \times 1 \times v^2 = 30ms^{-1}$

   Velocity at 75m is $30ms^{-1}$.

The simple pendulum

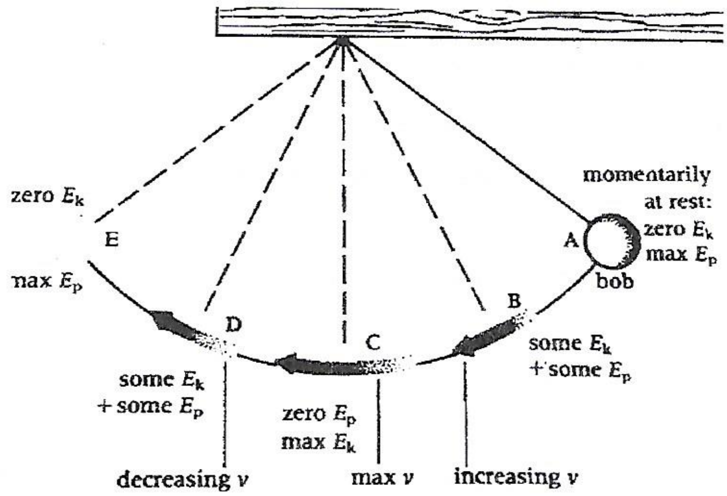
A simple pendulum consists of a pendulum bob tied on a thread. If the thread is fixed and the pendulum is displaced, it moves in a to and fro motion called an ***oscillation***.

The time taken for one complete oscillation is called ***periodic time***, T.

The periodic time depends on:

- Length, ***l*** of the thread; the longer the length of the pendulum the longer the periodic time.
- Air resistance; in windy environment the periodic time is longer
- Acceleration due to gravity, ***g***; in places where ***g*** is great, the periodic time is small.

Energy transformations in a simple pendulum



When the pendulum is displaced to A and released,

- at A and E, the velocity of the bob is zero since it is momentarily at rest hence has zero kinetic energy
- at A and E, the bob is at its highest point hence has maximum potential energy
- as it moves from A to C, its speed/velocity increases hence increased kinetic energy but its height decreases hence potential energy decreases. Thus from A to C $\boldsymbol{P.E\ lost = K.E\ gained}$.
- as it moves from C to E, its speed/velocity decreases hence decreased kinetic energy but its height increases hence potential energy increases. Thus from C to E, $\boldsymbol{K.E\ lost = P.E\ gained}$
- at C (the lowest point) the bob has maximum speed hence maximum K.E.

Between A and C or C and E the bob possesses partial P.E and partial K.E.

In calculations of a pendulum bob, $\boldsymbol{mgh = \frac{1}{2}mv^2}$ where v is the maximum velocity of the bob at C.

Example: A simple pendulum with a bob of mass 2kg is raised through a height of 4m above the lowest level. Find the maximum velocity with which it passes the lowest position.

$m = 2kg,\ u = \ 0ms^{-1}\ v = ?\,ms^{-1},\ h = 4m$

$Using\ \ mgh = \frac{1}{2}mv^2\ \Rightarrow 2 \times 10 \times 4 = \frac{1}{2} \times 2v^2\ \ \Rightarrow v^2 = 80\ \ \ \Rightarrow v = 8.9ms^{-1}$

$Maximum\ velocity = 8.9ms^{-1}$

Power

Power is defined as the rate of doing work or it is the rate of transfer of energy i.e

$Power = \frac{work\ done}{time\ taken} = \frac{F \times d}{t} = F \times v$ where $v = \frac{d}{t}$

S.I units of power are ***watts, W*** where $1watt = 1Js^{-1}$

A watt is the rate of transfer of energy of one joule per second.

Other larger units of power are kilowatts $(1kW = 1000W)$ and megawatts $(1MW = 10^6W)$

Examples

1. A girl of mass 50kg climbs 40steps upstairs in 2 seconds. If each step is 0.2m high, find
   (i) the work done by the girl
   (ii) the power she expended

   The work done by the girl is $mgh = 50 \times 10 \times 40 \times 0.2 = 4000\ J$

   The power she expended is $\frac{mgh}{t} = \frac{4000}{2} = 2000\ J$

2. A force of 50kN moves an object through a distance of 100m in 40s. Find the power expended.

   The power expended is $\frac{wd}{t} = \frac{50 \times 1000 \times 100}{40} = 125000\ J$

3. An engine exerts a force of 2000N to pull a train at speed of $15ms^{-1}$. Find the power developed by the engine.

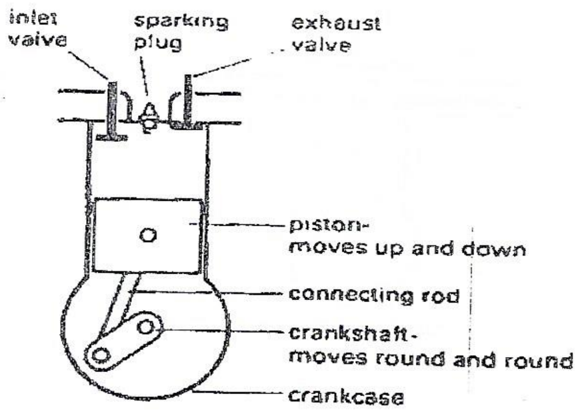
   Power developed by the engine is $F \times v = 2000 \times 15 = 30000\ J$

Questions

1. A man pulls a handcraft with a force of 1000 N through a distance of 100 m in 80 seconds. What is the power developed?
2. An engine raises 15 kg of water through a height of 100 m in 30 seconds. What is the power of the engine?
3. Calculate the velocity at which a body of 5 kg is raised by a machine whose power is 1000 W.
4. A student of mass 50 kg runs up a flight of 50 stairs each of height 20 cm in 5 seconds. Calculate the
   (a) work done
   (b) average power of the student.

The four-stroke petrol engine

Petrol engines are used to power cars and motor bikes where the petrol-air mixture is burnt in the cylinder.

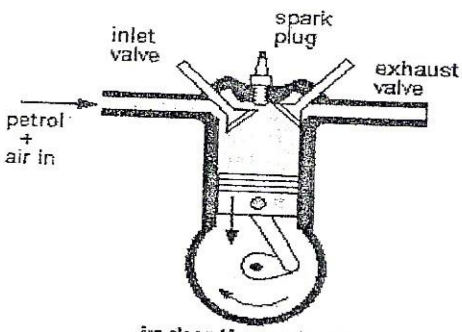


The in and out movement of the piston is called ***stroke.***

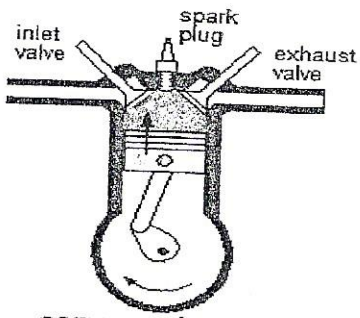
Order of strokes

1. Inlet or induction:
   - The piston moves outwards
   - Inlet valve opens allowing petrol-air mixture into the cylinder
   - The exhaust valve closes.
2. Compression: The piston moves inward to compress the petrol-air mixture forcing both valves to close.
3. Explosion/power:
   - Both valves remain closed
   - Further compression causes the spark plug to ignite the petrol-air mixture.
   - The explosion produced forces piston outwards.
4. Exhaust:
   - Inlet valve is close and the outlet valve opens
   - The piston moves inwards pushing the burnt gases

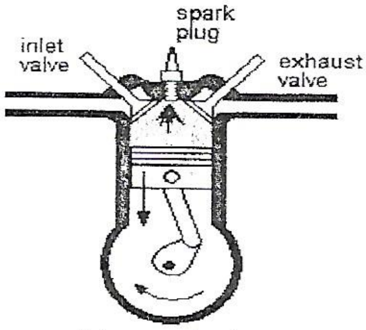
The cycle repeats itself making the car work continuously.

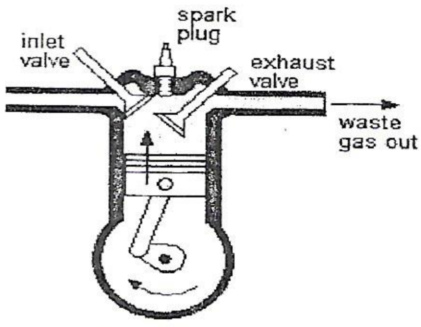


induction stroke



compression stroke





MACHINES

A machine is a device that makes work easier. In a machine a small force called the *effort* is applied at one end to overcome another force called *load* at the other position.

Terms used

1. Mechanical advantage (M.A) of a machine

   In any machine, mechanical advantage is defined as the ratio of the load to the effort

   $M.A = \frac{L}{E}$

   In a machine where a small effort is applied to overcome a big load, M.A is higher.

2. Velocity ratio of a pulley

   This is the ratio of distance moved by the effort to the distance moved by the load in the same time. $V.R = \frac{effort\ distance}{load\ distance}$

3. Efficiency of a machine is defined as the ratio of useful work done by a machine to the total work put into the machine expressed as percentage.

$$eff = \frac{work\ output}{work\ input} \times 100\% = \frac{load \times distance\ load\ moves}{effort \times distance\ effort\ moves} \times 100\%$$

$$= \frac{load}{effort} \times \frac{distance\ load\ moves}{distance\ effort\ moves} \times 100\%$$

$$eff = MA \times \frac{1}{VR} \times 100\% = \frac{MA}{VR} \times 100\%$$

$$eff = \frac{MA}{VR} \times 100\%$$

Note: Efficiency is always less 100% because some energy is wasted in overcoming friction between moving parts and to move some parts of the machine.

As a result more energy is put into the machine in overcoming friction

i.e $\frac{work\ input}{(work\ done\ by\ effort)} = \frac{useful\ work\ done}{(work\ output/work\ done\ by\ load)} + useless\ work\ done.$

Efficiency of a machine can be increased by lubricating or using ball bearings in moving parts of a machine.

Calculations

1. A machine of velocity ratio 8 is used to lift a load of 300N and the effort required is 60N. Find the efficiency of the machine.

   $M.A = \frac{300}{60} = 5 \quad \Rightarrow eff = \frac{MA}{VR} \times 100\% = \frac{5}{8} \times 100\% = 62.5\%$

2. In a machine, an effort of 250N raises a load of 900N through 5m. If the effort moves through 25m, find

   (i) useful workdone in raising the load

   (ii) work done by the effort

   (iii) work done against friction (*useless work done*)

   (iv) efficiency of the machine

   $Useful\ workdone\ (work\ output) = L \times load\ distance = 900 \times 5 = 4500\ J$

   $Work\ done\ by\ the\ effort(work\ input) = E \times effort\ \ distance = 250 \times 25 = 6250\ J$

   $Work\ input = useful\ work\ done(\ work\ output) + useless\ work\ done$

   $Work\ done\ against\ friction\ = work\ input - work\ output$

   $= 6250 - 4500 = 1750\ J$

   $Efficiency\ of\ the\ machine\ is\ \frac{work\ output}{work\ input} \times 100\% = \frac{4500}{6250} \times 100\% = 72\%$

Questions

1. Calculate the efficiency of a machine if 8000J of work is needed to lift a mass of 120kg through a vertical distance of 5m. [75%]

   $Work\ output/\ work\ done\ by\ load = 120 \times 10 \times 5 = 6000\ J$

   $Efficiency\ of\ the\ machine\ is\ \frac{work\ output}{work\ input} \times 100\% = \frac{6000}{8000} \times 100\% = 75\%$

2. In a machine, a load of 400N is steadily raised through a height of 15m. If the work done against friction is 1000J, calculate the

   (i) work input

   (ii) efficiency of the system

   $Useful\ work\ done\ (\ work\ output/\ work\ done\ by\ load) = 400 \times 15 = 6000\ J$

   $Work\ input = useful\ work\ done(\ work\ output) + useless\ work\ done$

   $= 400 \times 15 + 1000 = 7000\ J$

$Efficiency\ of\ the\ machine\ is\ \frac{work\ output}{work\ input} \times 100\% = \frac{6000}{7000} \times 100\% = 85.7\%$

3. A machine of efficiency 75% lifts a mass of 90 kg through a vertical distance of 3 m. Find the work required to operate the machine.

$eff = \frac{work\ out\ put}{work\ input} \times 100\% = \frac{load \times distance\ load\ moves}{effort \times distance\ effort\ moves} \times 100\%$

$\Rightarrow 75 = \frac{90 \times 10 \times 3}{work\ input} \times 100 \qquad \Rightarrow work\ input = 3600\,J$

4. In a machine where velocity ratio is 6 and efficiency 75%, find the energy wasted when a load of 1500 N is lifted through 2 m.

$Work\ output = 1500 \times 2 = 3000\,J$

$eff = \frac{work\ out\ put}{work\ input} \times 100\% \Rightarrow 75 = \frac{1500 \times 2}{work\ input} \times 100 \Rightarrow work\ input = 4000\,J$

$Energy\ wasted = 4000 - 3000 = 1000\,J$

Types of simple machines

Simple machines include levers, pulleys, wedges, inclined plane, screws, wheel and axle, gears and hydraulic press.

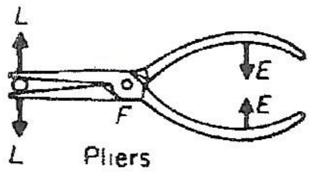
(a) Levers

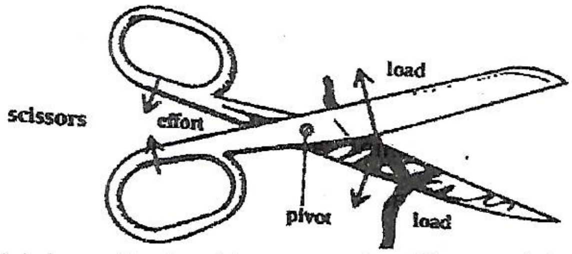
A lever is a rigid rod pivoted about a point called the fulcrum to transfer work done by effort to load.

Levers are classified into three classes in accordance to **PLE** where P is the pivot/fulcrum, L is the load and E is the effort.

(i) First class: These are levers which have the fulcrum/pivot between the effort and the load.

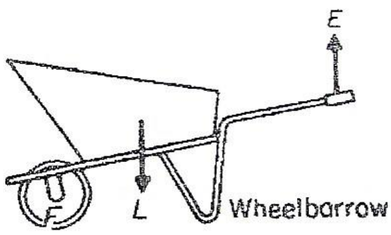
Examples include sea-saw, claw hammer, pair of scissors, pair of pliers, crow bar, shadouf, lever balance.

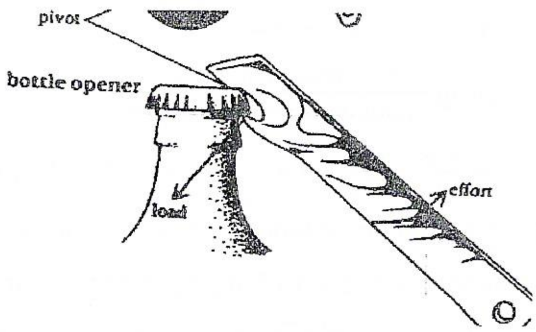


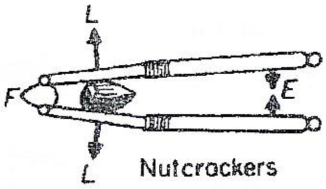


(ii) Second class: These are levers which have the load between the effort and the fulcrum.

Examples include wheel barrow, nut crackers, paper cutter, bottle openner.

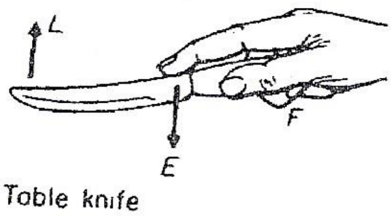


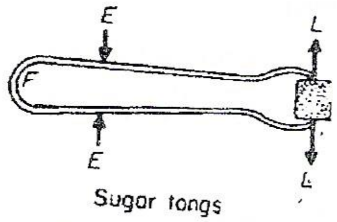


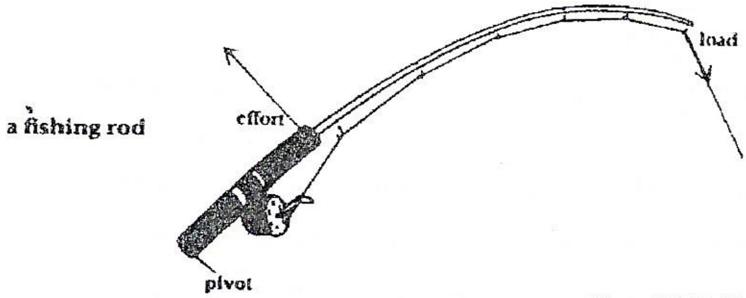


(iii) Third class: These are levers which have the effort between the load and the fulcrum [ELF]

Examples include pair of tongs, steppling machine, spade, table knife, fishing rod





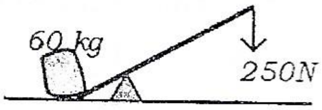


Verocity ratio of a lever is obtained from $\frac{effort\ distance}{load\ distance}$ and for a perfect lever, $V.R = M.A$

$$\frac{effort\ distance}{load\ distance} = \frac{Load}{effort}$$

Calculations

1. A worker used a crow bar 2m long to push a stone of mass 60kg as in figure below. calculate the position of the pivot if he applied an effort of 250N. (asume crow bar is weightless and no friction at the pivot)



$Weight\ of\ stone\ (load) = 60 \times 10 = 600\ N$

Let the pivot be a distance y from the stone

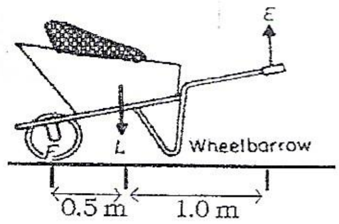
Effort distance $= 2 - y$ *and load distance* $= y$

Using $\frac{effort\ distance}{load\ distance} = \frac{Load}{effort}$

$\Rightarrow \frac{2-y}{y} = \frac{600}{250}$ $\Rightarrow y = 0.59\ m$ *effort is applied* $0.59\ m$ *from the stone.*

2. A hand cart of length 1.5m, has the centre of gravity at a length 0.5m from the wheel when loaded with 50kg as shown in the figure below.

   If the mass of the cart is 10 kg, find the effort needed to lift the cart.



Total weight of stone (load) $= (50 + 10) \times 10 = 600\ N$

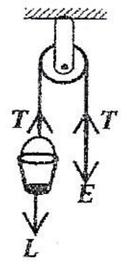
Efort distance $= 1.5\ m$ *and load distance* $= 0.5\ m$

Using $\frac{effort\ distance}{load\ distance} = \frac{Load}{effort}$ $\Rightarrow \frac{1.5}{0.5} = \frac{600}{E}$ $\Rightarrow E = 200\ N$ *effort applied is* $200N$.

(b) Pulleys

A pulley is a wheel with a grooved rim. Effort is applied on the ropes passing over the pulley. A number of pulleys fixed in a framework is called block and tackle.

<u>Single fixed pulley</u>



This is used to raise small loads such as raising;

- sand from pit latrines
- flags
- building materials
- Water from deep wells

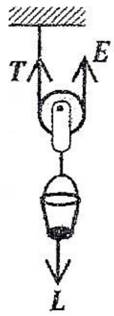
Its $V.R = 1$ since the effort moves the same distance as the load.

The force in the string is called tension T and is same throught the string

The applied force E, at equilibrium, is equal to the tension in the string i.e $E = T$.

At equilibrium of the bucket, when frictional forces and weight of ropes are ignored, upward force on bucket is equal to the load, i.e $T = L$. Thus $M.A = \frac{L}{E} = \frac{T}{T} = 1$

<u>Single movable pulley</u>



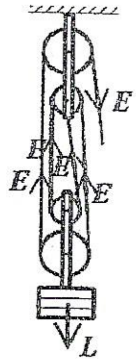
In this case tension in the string is equal to the effort applied $T = E$

Total upward pull on the pulley $= E + E = 2E$

At equilirium $L = 2E$

$\Rightarrow M.A = \frac{L}{E} = \frac{2E}{E} = 2$

Its $V.R = 2$. If the load moves 1 m upwards, effort will have moved 2 m upwards since each section of the rope moves 1 m upwards.



Block and tackle system

When several movable and fixed pulleys are used together, the entire system is called a block and tackle.

Block and tackle systems are commonly used in lifts and cranes to raise heavy loads with application of small forces.

The lower pulley system is supported by four strings and the tension in each string is equal to the effort E applied.

At equilibrium of the lower pulley system, total upward pull on it, $E + E + E + E = 4E$

This force is equal to downward force, L. i.e $L = 4E \Rightarrow M.A = \frac{L}{E} = \frac{4E}{E} = 4$

Because of

- frictional forces between moving parts
- weight of moving pulley and string.

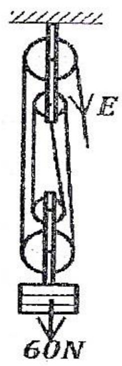
the effort applied to overcome them is great and some energy is lost as a result $M.A < 4$.

In the block and tackle above, the number of sections supporting the lower pulley system is equal to the total number of pulleys in the whole system. This number also gives velocity ratio of the block and tackle system. i.e $V.R = 4$ since there are 4 pulleys

Examples

1. Using a block and tackle, a person exerts an effort of 500N to pull a hauling rope 12m in 1minute. During this time, the load of 800N rises 0.6m. Calculate the
   (i) velocity ratio
   (ii) mechanical advantage
   (iii) efficiency of the system
   (iv) rate at which work is done

   solution



$(i)\ velocity\ ratio,\ V.R = \frac{distance\ effort\ moves}{distance\ load\ moves} = \frac{12}{0.6} = 20$

$(ii) Mechanical\ advantage, M.A = \frac{load}{effort} = \frac{8000}{500} = 16$

$(iii) eff = \frac{MA}{VR} \times 100\% = \frac{16}{20} \times 100\% = 80\%$

$(iv)\ rate\ at\ which\ work\ is\ done\ (power) = \frac{work\ in\ put}{time\ taken} = \frac{5000 \times 12}{60} = 100W$

2. The figure shows a load of 60N being lifted. Find the velocity ratio and the effort required to lift the load if the efficiency of the system is 75%.

Solution

V.R is the number of pulleys $\therefore V.R = 4$

$eff = \frac{MA}{VR} \times 100\% \Rightarrow 75\% = \frac{M.A}{4} \times 100\% \quad \Rightarrow M.A = 3$

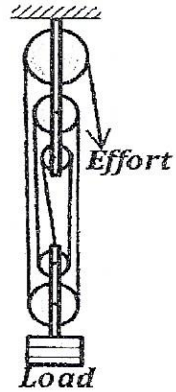
But $M.A = \frac{L}{E} \quad \Rightarrow 3 = \frac{60}{E} \Rightarrow E = 20N$

3. The effort of 40N is required to raise a load of 120N. If the velocity ratio of the system is 4, find the efficiency of the system.

Solution

$M.A = \frac{L}{E} \ = \frac{120}{40} = 3 \ eff = \frac{MA}{VR} \times 100\% = \frac{3}{4} \times 100\% = 75\%$

4. The figure shows a block and tackle system.



(i) What is the verocity ratio of the system?

(ii) Find how far the load is raised if the effort moves down by 4m.

(iii) Calculate the effort required to raise a load of 800N, if the mechanical advantage of the system is 4.

(iv) Calculate the efficiency of the system.

Solution

(i) *V.R is the number of pulleys* $\therefore V.R = 5$

(ii) $V.R = \frac{distance\ effort\ moves}{distance\ load\ moves} \Rightarrow 5 = \frac{4}{y} \Rightarrow y = 0.8$ *Load moves 0.8m*

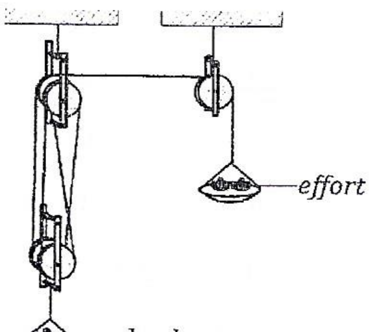
(iii) $M.A = \frac{L}{E} \quad \Rightarrow 4 = \frac{800}{E} \Rightarrow E = 200N$

(iv) $eff = \frac{MA}{VR} \times 100\% = \frac{4}{5} \times 100\% = 80\%$

<u>Variation of M.A and efficiency with load</u>

Apparatus: A block and tackle of 4 pulleys, different masses, 2 scale-pans and threads.

- The apparatus is set as in the figure below.

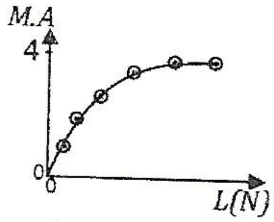


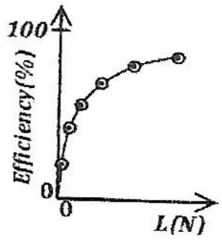
- A mass $M(kg)$ is added to the load pan and further masses $m(kg)$ are added to the effort pan until the load just rises slowly with a steady velocity.
- Load and effort are obtained from $\mathrm{L} = 10m$ and $\mathrm{E} = 10\mathrm{M}$.
- Mechanical advantage is calculated from $M.A = \frac{L}{E}$
- Velocity ratio of the system is 4
- Efficiency of the system is calculated from $eff = \frac{MA}{VR} \times 100\%$

- Experiment is repeated for a series of increasing masses m and M.

$M(kg)$	$m(kg)$	L(N)	E(N)	M.A	Efficiency
0.5	0.25	5	2.5	2.0	50
1	0.35	10	3.5	2.9	72

- Graphs of M.A against L and efficiency against L are drawn.





From the graphs,

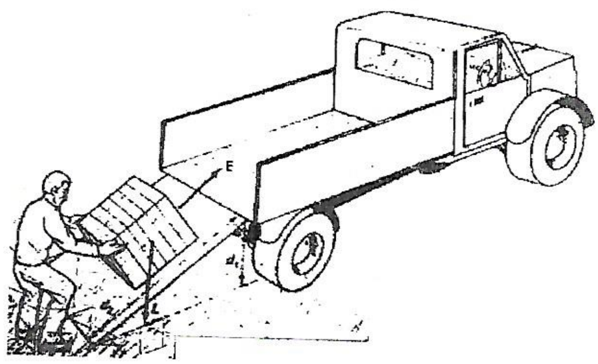
- for smaller loads, effort applied is mainly used to overcome friction at the axle and weight of the movable parts hence less M.A.
- at higher loads, weight of the movable parts and frictional forces is very small compared to the load hence M.A increases. The velocity ratio limits the mechanical advantage to a maximum value not exceeding 4.
- as the load increases the efficiency also increases and can not reach 100%.

In practice, the $M.A < 4$ and efficiency can not reach 100% because,

- the effort is required to carry useless load (weight of moving pulleys and rope)
- some energy is lost in overcoming the frictional forces between parts of the rope and the pulleys.

(c) Inclined plane

A plank of wood placed at an angle to the horizontal forms an ancline plane. Heavy barrels are easily loaded into cars by use of inclined planes.



One of the most common examples of an inclined plane is a staircase, which allows people to move within a building from one floor to another with less effort than climbing straight up.

The load is raised through a distance $h = d_1$ and the effort is exerted through a distance equal to length, $l = d_2$ of the incline.

$V.R = \frac{l}{h}$

The longer the inclined plane, the larger the V.R will be.

Example

1. An inclined plane of length 3m is used to push oil drums each of mass of 80kg into a lorry which is 0.8m above the ground by application of 300N. (take $g = 10ms^{-2}$)
   (a) Calculate the velocity ratio of the inclined plane.
   (b) Efficiency of the of the inclined plane.

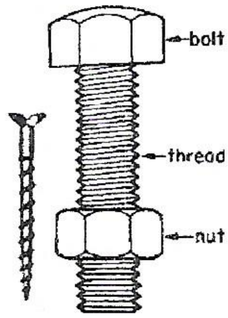
Solution

(a) $V.R = \frac{l}{h} = \frac{3}{0.8} = 3.75$

(b) $Load = mg = 80 \times 10 = 800N,\ M.A = \frac{L}{E} = \frac{800}{300} = 2\frac{2}{3}$

$eff = \frac{M.A}{V.R} \times 100\% = \frac{2\frac{2}{3}}{3.75} \times 100\% = 71.1\%$

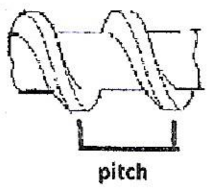
(d) Screws



Screws and bolts are used

- for holding things together
- in screw jacks to raise heavy objects such as automobiles off the ground.
- in various machine tools, such as lathes, where the cutting tools can be advanced with a high degree of precision.

The distance between two successive threads on a screw is called *pitch.*



If a spanner of length l is turned through one revolution to loosen or tighten the bolts or nuts, the efort moves a distance equal to the circumference of the circle of radius, l. The load (screw) moves a distance equal to its pitch, p.

$V.R = \frac{2\pi l}{p}$

Examples

1. A car-jack has to be used to lift a car of weight 22,000N. its handle is of length 35cm and the pitch of the screw is 0.5cm. If the efficiency of the jack is 40% calcilate the
   (i) Velocity ratio of the jack
   (ii) Effort needed to raise the car

Solution

(i) $V.R = \frac{2\pi l}{p} = \frac{2\times3.14\times35}{0.5} = 439.6$

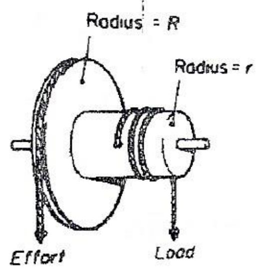
(ii) $eff = \frac{MA}{VR}\times 100\% \Rightarrow 40 = \frac{M.A}{439.6}\times 100 \Rightarrow M.A = 175.84$

$M.A = \frac{L}{E} \Rightarrow 175.84 = \frac{22,000}{E} \Rightarrow E = 125.1N$

(e) Wheel and axle

These are two wheels of different radii on the same axis of rotation. The principle of a wheel and axle is applied in

- fixing screws using screw drivers,
- tightening nuts using box spanners,
- drilling holes using braces,
- raising water from deep wells using a windlass

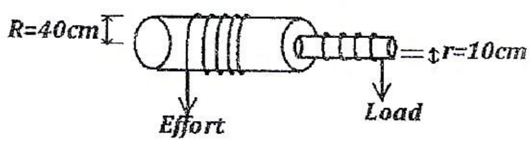


From the figure above, in one complete turn, effort moves through a distance equal to the circumference of the large wheel ($2\pi R$) and the load moves through a distance equal to the circumference of the small wheel ($2\pi r$)

$V.R = \frac{2\pi R}{2\pi r} = \frac{R}{r}$

Example

1. In the figure below, when an effort of 300N is applied a load of 900N is raised through 1m. Calculate the
   (i) velocity ratio
   (ii) efficiency of the system.

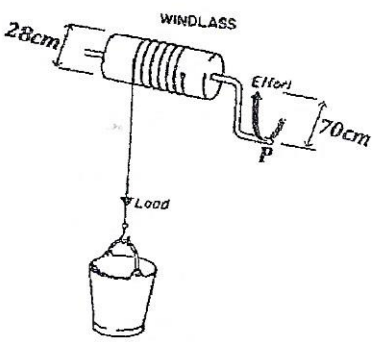


Solution

(i) $V.R = \frac{2\pi R}{2\pi r} = \frac{R}{r} = \frac{40}{10} = 4$

(ii) $M.A = \frac{L}{E} = \frac{900}{300} = 3$ $eff = \frac{M.A}{V.R}\times 100\% = \frac{3}{4}\times 100\% = 75\%$

2. In the figure, effort P is applied to the handle of radius 70cm. As the handle turns, a rope wound on the drum of diameter 28cm raises a bucket out of a well . If an effort of 10N is needed to lift a bucket full of water and of mass 4kg, calculate the
   (i) energy gained by bucket when a drum turns through one revolution
   (ii) work done by the effort in this time



(iii) velocity ratio

(iv) efficiency of the winch.

Solution

(i) distance moved by bucket $= 2\pi r = 2 \times 3.14 \times 14 = 88cm = 0.88m$

force of gravity(load) $W = mg = 4 \times 10 = 40N$

energy gained $=$ work done against gravity $= 40 \times 0.88 = 35.2J$

(ii) distance moved by effort $= 2\pi R = 2 \times 3.14 \times 70 = 440cm = 4.4m$

(iii) work done by effort $= 10 \times 4.4 = 44J$

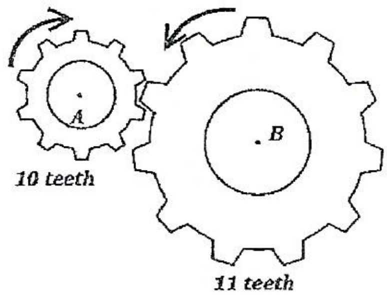
(iv) $V.R = \frac{2\pi R}{2\pi r} = \frac{R}{r} = \frac{70}{14} = 5$

(v) $M.A = \frac{L}{E} = \frac{40}{10} = 4$ $\quad eff = \frac{M.A}{V.R} \times 100\% = \frac{4}{5} \times 100\% = 80\%$

$Or\ eff = \frac{work\ output}{work\ input} \times 100\% = \frac{35.2}{44} \times 100\% = 80\%$

(f) Gears

These are toothed wheels of different diameters. They are found in bicycles, watches, alarm clocks and in gear boxes of cars.



When one gear turns, the other gear turns in the opposite direction.

Gears of the same size turn at the same speed. However, if one gear is larger than the other, the smaller gear turns faster than the larger gear.

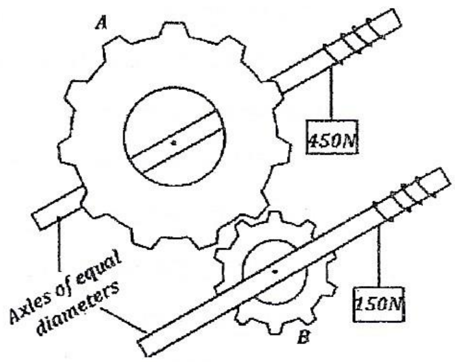
$$V.R\ of\ gears = \frac{number\ of\ teeth\ in\ driven\ wheel}{number\ of\ teeth\ in\ driving\ wheel}$$

If wheel A drives wheel B, the $V.R = \frac{11}{10} = 1.1$ and if wheel B drives wheel A, the $V.R = \frac{10}{11} = 0.91$.

Note: Gears provide a turning effect at either low speed (large M.A and V.R) or high speed (low M.A and V.R) depending on the gears engaged.

<u>Example</u>

1. A and B are gear wheels of teeth 80 and 20 respectively. If a weight of 150N raises a load of 450N, calculate the
   (i) velocity ratio
   (ii) efficiency of the system

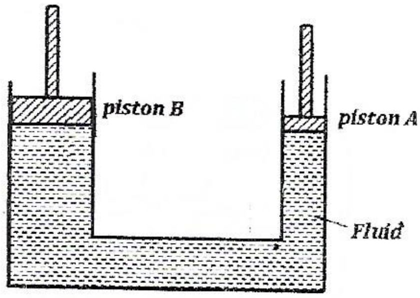


Solution

(i) $V.R = \frac{80}{20} = 4$

(ii) $M.A = \frac{450}{150} = 3$ $eff = \frac{M.A}{V.R} \times 100\% = \frac{3}{4} \times 100\% = 75\%$

(g) Hydraulic press



It uses a principle that pressure is transmitted equally throught the liquid since liquids are incompressible.

i.e volume of liquid pushed by effort piston (A)

= volume of liquid which lifts up the load piston (B)

$area\ of\ A \times effort\ distance = area\ of\ B \times load\ distance$

$\frac{effort\ distance}{load\ distance} = \frac{area\ of\ B}{area\ of\ A} = \frac{\pi R^2}{\pi r^2} = \frac{R^2}{r^2}$

Thus $V.R = \frac{R^2}{r^2}$ where R and r are radii of load and effort pistons respectively.

Examples

1. The diameters of the pistons of a hydraulic press are 4cm and 80cm respectively. Calculate the velocity ratio of the press.

   Solution: $r = \frac{4}{2} = 2cm,\ R = \frac{80}{2} = 40cm\ \ V.R = \frac{40^2}{2^2} = \frac{1600}{4} = 400$

SENIOR 2: TERM 2

ELECTRICITY 2

Terms used

1. **Electric current (I)**

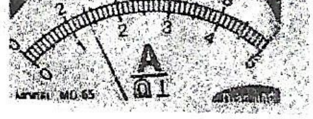
In a complete circuit, negative charges called the electrons flow from a negative terminal of a dry cell to the positive terminal.

An electric current is defined as the number of electric charges flowing in a conductor in a given time.

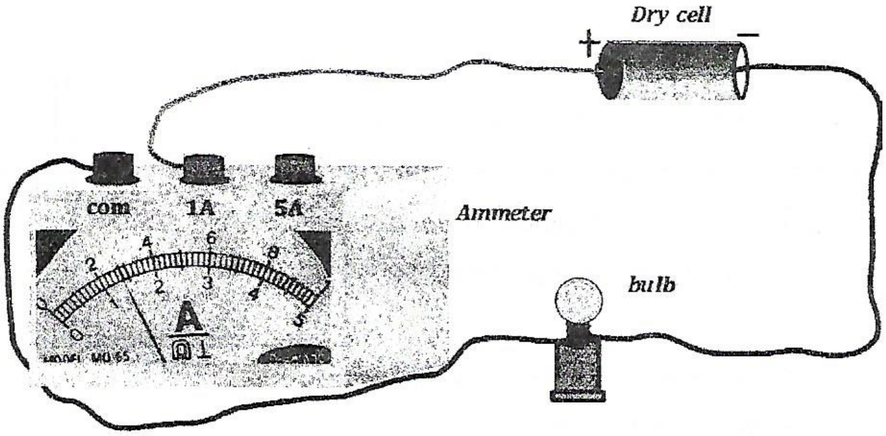
Electric current is measured by ammeter. S.I units of electric current are amperes (A)

The symbol of ammeter is —(A)—

In any electric circuit, ammeter is connected in series (along/in line) with an electric device(s) to measure current passing through the device(s).



The circuit above is connected as in the figure below



Reading scale of ammeter

A black terminal is marked a negative terminal and a red terminal is marked positive.

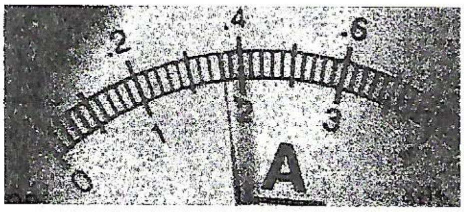
A terminal of 1A is preferred since a small current is supplied by the dry cells.

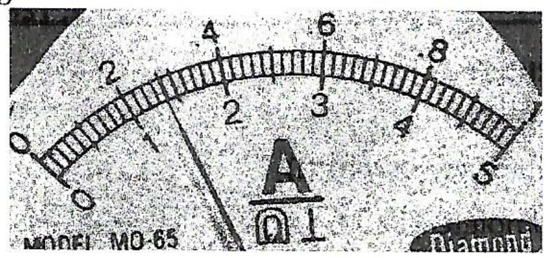
On a scale ending with $1A$, *every* 10 *divisions* $= 0.2A$

$Thus\ 1division = 0.02A\ (2d.p)$

Exercise;

a. *Find the ammeter readings in the figures below*

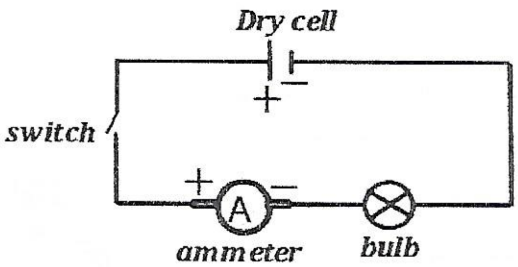




$0.02 \times 18 = 0.36A\ (2d.p)$

$0.02 \times 14 = 0.28A\ (2d.p)$

b. *Connect the circuit as shown in the figure below. Record the ammeter reading*



2. Potential difference p.d (V)

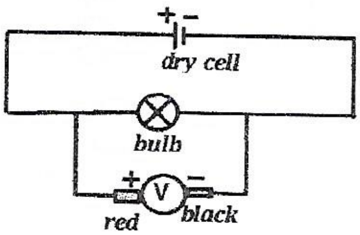
Negative terminal of a dry cell has excess electrons and is said to be at low potential. The positive terminal has excess positive charges and is said to be at high potential. Electrons flow from a negative terminal to a positive terminal due to potential difference.

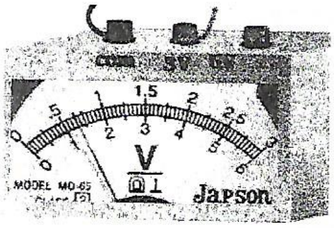
Potential difference (p.d) is defined as *the work done to move a charge from a point of lower potential to a point of higher potential.*

P.d is measured by a voltmeter. S.I units of p.d are volts (V)

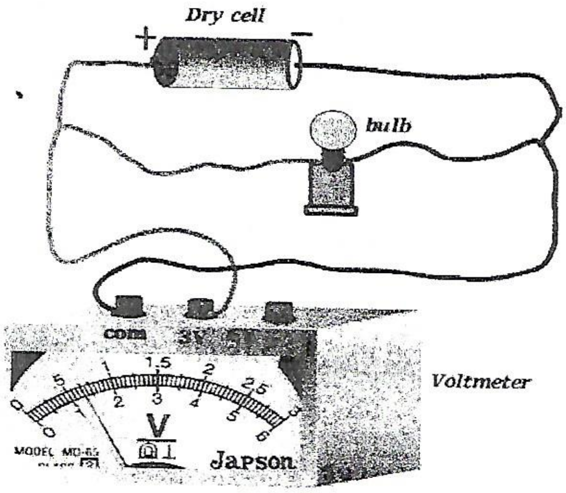
The symbol of a voltmeter is 

In any circuit, a voltmeter is connected in parallel (across) to an electric device (bulb, resistor, wire) whose p.d is to be measured.





The circuit above is connected as in the figure below



Reading scale of voltmeter

A black terminal is marked a negative terminal and a red terminal is marked positive.

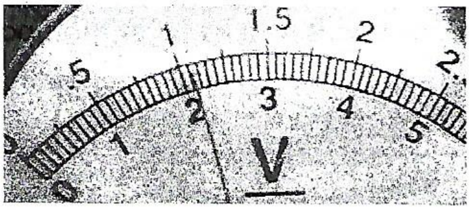
A terminal of $3V$ *is preferred since p.d of the dry cells is about* $3V$.

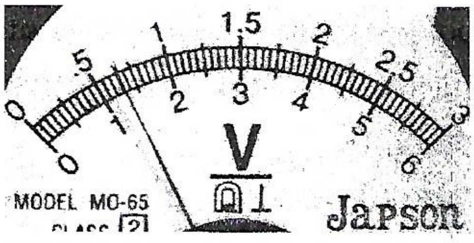
On a scale ending with $3V$, *every* 10 *divisions* $= 0.5V$.

Thus $1 division = 0.05V\ (2d.p)$

Exercise

1. *Find the voltmeter readings in the figures below*





$0.05 \times 21 = 1.05V\ (2d.p)$ $\qquad$ $0.05 \times 13 = 0.65\ (2d.p)$

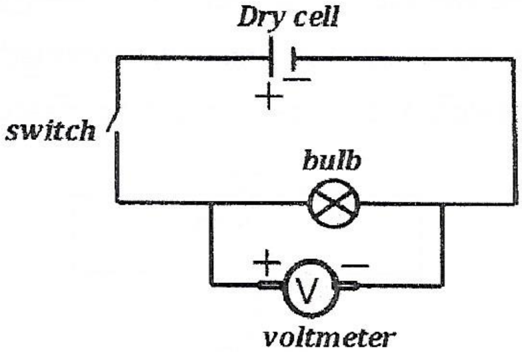
PRACTICAL ACTIVITY

Group 1

Connect the circuit below

Close the switch.

Record the voltmeter reading



3. **Resistance**

Resistance is the opposition offered to the flow of electric current in a conductor.

In metals, atoms are closely and regularly packed vibrating about their mean positions. When current flows in a conductor, free electrons move and collide with the vibrating atoms reducing the speed of the electrons hence resistance.

Note: When resistance increases the flow of electric current reduces since the flow of electrons reduces.

Resistance is calculated from $R = \frac{V}{I}$ and its S.I units are ohms (Ω)

Effect of temperature on resistance of a conductor

Increase in temperature of a conductor increases its resistance.

Explanation

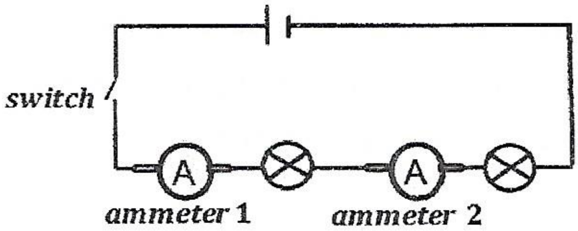
When temperature of a conductor (metal) is increased its atoms vibrate with increased amplitude. The free electrons collide more frequently with the atoms causing increase in resistance.

Arrangement of devices e.g. resistors, in a circuit

(a)Series arrangement

Experiment 1

Connect the circuit below



Close the switch.

Record the reading of the ammeters.

Ammeter 1 reads I_1 =....................

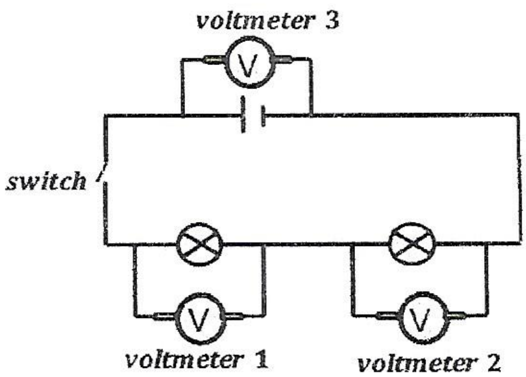
Ammeter 2 reads I_2 =....................

What do you say on the ammeter readings? $I_1 = I_2$

Conclusion: Current through devices in series is the same.

Experiment 2

Connect the circuit below



Close the switch.

Record the reading of the voltmeters.

Voltmeter 1 reads V_1 =....................

Voltmeter 2 reads V_2 =....................

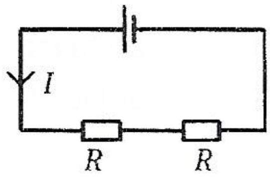
Voltmeter 3 reads V_3 =.......................

What is $V_1 + V_2$*?* $V_1 + V_2$ =......................

$V_1 + V_2 = V_3$

Conclusion: Sum of p.ds across devices (bulbs) is series is equal to p.d across the cell.

From the experiments above, when two electric bulbs are connected in series, the bulbs light ***less bright*** than when a single bulb is used.



(a) series

Explanation:

When two identical bulbs are connected in series, total resistance in the circuit increases. This lowers the current flowing than when a single bulb is used. Thus the bulbs light less bright.

(b)Parallel arrangement

Connect the circuit below

Close the switch.

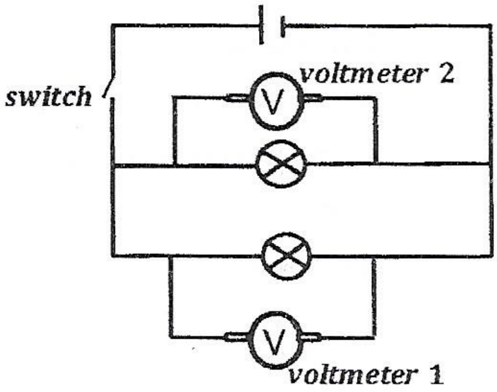
Record the reading of voltmeters

Voltmeter 1 reads $V_1 =$....................

Voltmeter 2 reads $V_2 =$....................

What do you say on the voltmeter readings?

$V_1 = V_2$



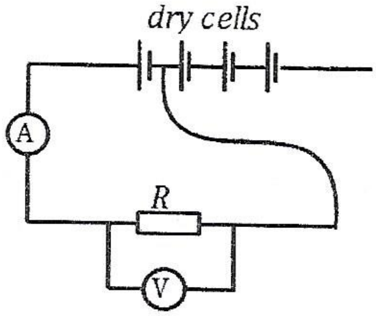
Conclusion: p.d across devices in parallel is the same but the currents through them are different.

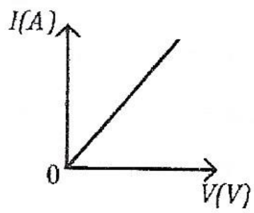
From experiment, when two electric bulbs are connected in parallel, the bulbs light ***equally bright*** like when a single bulb is used since they have the same p.d.

Thus when identical devices such as a resistor are connected in parallel, p.d across each device is the same. Current flowing in the circuit increases than when a single device is used and this is due to decreased resistance in the circuit.

Note: Bulbs and other electrical devices (radios, T.Vs, fans, fridges) in our homes are connected in parallel with the mains (supply) since they must be at the same p.d for normal operation.

Experiment to investigate relationship between current and p.d across a conductor





The circuit is connected as in the figure above using one dry cell.

Ammeter reading I and voltmeter reading V are recorded.

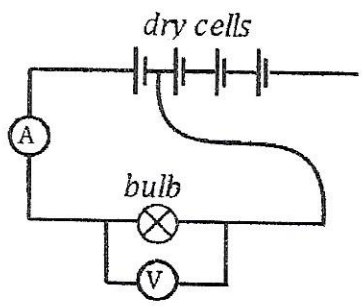
The experiment is repeated using 2, 3, 4 .... dry cells.

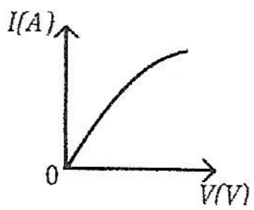
Number of dry cells	$V(V)$	$I(A)$
-	-	-
-	-	-
-	-	-

A graph of I against V is plotted.

A straight line is obtained and this indicates that current is proportional to the p.d across the resistor $I \propto V$ [see *the graph above*]

Experiment to investigate relationship between current and p.d across a bulb (filament lamp)





The circuit is connected as in the figure above using one dry cell.

Ammeter reading I and voltmeter reading V are recorded.

The experiment is repeated using 2, 3, 4 .... dry cells.

Number of dry cells	$V(V)$	$I(A)$
-	-	-
-	-	-

A graph of I against V is plotted [See *the graph above*]

A curve is obtained and this indicates that when p.d increases, current also increases but at a decreasing rate.

PRESSURE

This is defined as the force acting normally/perpendicularly per unit area.

$pressure = \frac{force, F}{area, A}$, $P = \frac{F}{A}$

Its S.I units are *pascals* (Pa) or *newton per square metre* (Nm^{-2}) where $1Pa = 1Nm^{-2}$)

A pascal is a pressure exerted by a force of one newton acting normally on an area of one square metre.

E.g. A sharp point of a needle has an area of $0.00001m^2$ and that of a pen is $0.001m^2$. If a force of 5N is used, find the pressure exerted by the needle and the pen on a body.

Area of needle point is $A = 0.00001m^2$ $F = 5N$; $P = \frac{F}{A} = \frac{5}{0.00001} = 500{,}000Pa$

Area of a pen point is $A = 0.001m^2$ $F = 5N$; $P = \frac{F}{A} = \frac{5}{0.001} = 5{,}000Pa$

From the two answers it is observed that, pressure increases when the surface area reduces. It is for this reason that

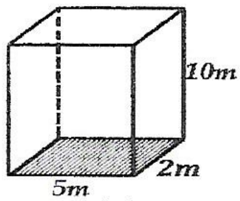
- some ends of nails, needles, pangas, knives are sharp and cut easily. Their smaller ends when pressed exert greater pressure thus cutting easily.
- a goat sinks in mud whereas a hippo does not. A goat's foot has a small surface area thus exert a greater pressure than a hippo whose foot has a large surface area.

Pressure in solids

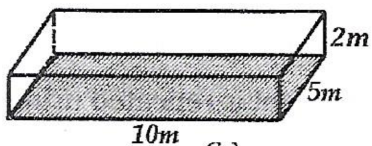
Pressure exerted by a solid on another depends on the area on which it lies.

<u>Calculations</u>

1. A brick of weight 50N is made to rest on a horizontal tables in the figures below



(a)



(b)

Calculate the pressure exerted in each case. Which position is the pressure greatest/maximum?

In fig (a), area in contact with the table is $A = 5 \times 2 = 10m^2$

Pressure exerted $P = \frac{F}{A} = \frac{50}{10} = 5Pa$

In fig (b), area in contact with the table is $A = 10 \times 5 = 50m^2$

Pressure exerted $P = \frac{F}{A} = \frac{50}{50} = 1Pa$

Pressure is greatest in fig (a) where a small area is in contact with the table.

2. The dimensions of a cuboid are $5cm \times 10cm \times 20cm$ and its weight is 60N. Calculate the maximum pressure the cuboid can exert.

   For maximum pressure, a small area is used.

   Area in contact is $A = 0.05 \times 0.01 = 5 \times 10^{-4}m^2$

   Pressure exerted $P = \frac{F}{A} = \frac{60}{5\times10^{-4}} = 1.2 \times 10^5 Pa$

3. Calculate the pressure exerted by a man whose mass is 75kg and the area of both feet is $280cm^2$.

   Area in contact is $A = 280cm^2 = 280 \times 10^{-4}m^2 = 2.8 \times 10^{-2}m^2$

   Force exerted by the man $F = mg = 75 \times 10 = 750N$

   Pressure exerted $P = \frac{F}{A} = \frac{750}{2.8\times10^{-2}} = 26{,}785.7Pa$

4. The pressure exerted by a point of a needle on a body is approximately $1.0 \times 10^8 Nm^{-2}$. If the area of the needle point is $0.1mm^2$, calculate the force a doctor needs to exert to produce necessary pressure.

   Area needle point is $A = 0.1mm^2 = 0.1 \times 10^{-6}m^2 = 1.0 \times 10^{-5}m^2$

   Pressure exerted $P = \frac{F}{A} = \frac{F}{1.0\times10^{-5}} = 1.0 \times 10^8$

   Force exerted by the man $F = 1.0 \times 10^8 \times 1.0 \times 10^{-5} = 1.0 \times 10^3 = 1000N$

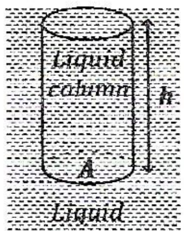
Pressure in liquids

Liquids exert pressure on the containers in which they are held.

A column of water of mass m, height h and cross-sectional area A and weight $W = mg$ is considered.

Pressure at the bottom of the column is due to its weight above

$P = \frac{weight\ of\ liquid}{cross\text{-}sectional\ area} = \frac{W}{A} = \frac{mg}{A}$



Volume of liquid column $V = Ah$ (in shape of a cylinder)

Mass of liquid column $m = \rho V = \rho Ah \quad \Rightarrow P = \frac{\rho Ahg}{A} = h\rho g$

Thus pressure in liquid at a depth h is $P = h\rho g$

Since g is constant, pressure in liquids

- Increases with its depth below the liquid surface
- Increases with liquids with high density

Examples

1. A liquid of density $1000kgm^{-3}$ is poured into a box of dimensions $6cm \times 3cm \times 4cm$. Calculate the pressure exerted on the box by the liquid.

   Solution:

   Height of liquid in a box $h = 4cm$, *Liquid pressure exerted* $P = \frac{4}{100} \times 1000 \times 10 = 400Pa$

2. A metal cylinder contains a liquid of density $1100kgm^{-3}$. The area of the base of the cylinder is $0.005m^2$ and the height of the liquid is $5m$. Calculate the force exerted by the liquid on the base of the cylinder.

   Solution:

   Height of liquid $h = 5m$, *pressure exerted* $P = 5 \times 1100 \times 10 = 55{,}000Pa$

   But $P = \frac{F}{A} \Rightarrow F = P \times A = 55{,}000 \times 0.005 = 275N$

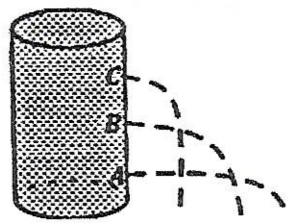
3. What is the pressure 100m below the surface of sea water of density $1150kgm^{-3}$? [$1{,}150{,}000\ Pa$]

4. Calculate the pressure at the bottom of a beaker when filled with water to a level 12cm high. (Density of water is $1gcm^{-3}$) [$1{,}200\ Pa$]

5. A drum 85cm high and base radius 37.5cm is three-quarters full of paraffin of density $800kgm^{-3}$. Find the
   (i) volume of paraffin in the drum [$0.2805m^3$]
   (ii) force it exerts at the base of the drum. [$4.0 \times 10^{-3}N$]

Variation of pressure in liquids

1. ***Pressure in liquids increases with depth.***



- Three holes, A, B and C of the same diameter are punched on a container at different heights from the bottom.
- Using masking tape, the holes are covered.
- water is poured into the container up to full capacity
- Masking tape is removed from the holes at the same time.

It is observed that water jet lands farthest from lower hole A followed by hole B and then C.

This shows that pressure at A is greater than that at B and C hence pressure increases with depth below the liquid surface.

Question: Explain briefly why walls of electrical dams are made thicker at bottom than at top.

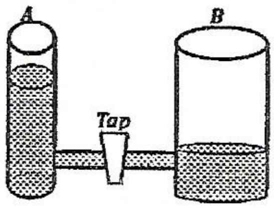
In liquids, pressure increases with depth so there is large water pressure exerted at the bottom than at the top. Walls at bottom are therefore made ticker to withstand this great pressure.

2. ***Pressure at the same points(depth) is the same and acts equally in all directions***

   Holes D, E and F if made at the same height and opposite to the holes A, B and C respectively, the jets A and D, B and E and C and F land at equal distances from the container. This shows that pressure is same at the same level and acts equally in all directions.

3. ***A liquid finds its own level***

- Water is poured in two cylinders of different cross-sectional areas with the tap closed
- When the tap is opened, because of high pressure in A, water flows from cylinder A to B until the levels are same in both cylinders.



Thus water finds its own level regardless of the shape of the container.

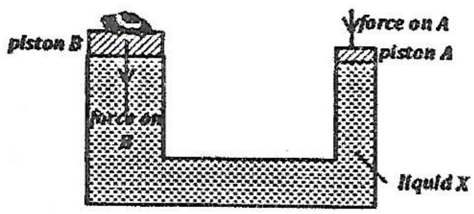
Transmission of pressure

When a fluid is completely enclosed and pressure applied to it, pressure is transmitted equally to all parts of the fluid. This is called Principle of transmission of pressure in fluids or Pascal's law. This principle is applied in hydraulic brake system, hydraulic presses, hydraulic car jacks.

(a) The hydraulic press

A hydraulic press uses the principle that liquids are incopressible (their volumes are not reduced by compressing).

A force applied at a piston A of small area produces a greater pressure that is transmitted to the larger piston B to overcome a large mass placed on larger piston



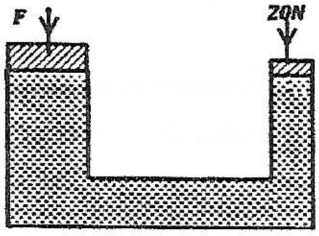
$i.e\ pressure\ applied\ at\ smaller\ piston = pressure\ on\ large\ piston$

$$\frac{force\ on\ A}{area\ of\ A} = \frac{force\ on\ B}{area\ of\ B}$$

Hydraulic presses are used in mordern garages to hoist cars. Car jacks use the same principle.

Example:

1. In a hydraulic press a force of 20N is applied to a piston of area $0.2m^2$. The area of the other piston is $2m^2$. What is the



   (i) pressure transmitted through the liquid?

   (ii) force exerted on the other piston

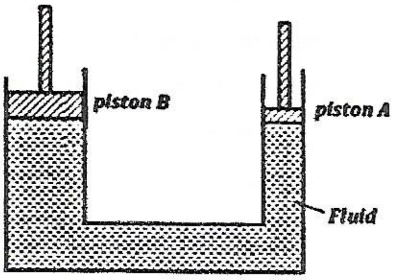
   solution:

   (i) pressure exerted on small piston is the pressure transmitted

   $P = \frac{F}{A} = \frac{20}{0.2} = 100Pa$

   (ii) pressure exerted on large piston $P = \frac{F}{A} = \frac{F}{2} = 100 \Rightarrow F = 200N$

2. In the figure, piston A has a diameter of 14cm while B has a diameter of 280cm. If a force of 77N is exerted on piston A, calculate the force exerted by piston B.



   Solution: radius of A $r = \frac{14}{2} = 7cm$ *radius of B* $R = \frac{280}{2} = 140cm$

   $Area\ of A = \pi r^2 = \frac{22}{7} \times 7^2 = 154cm^2 and\ Area\ of B = \pi R^2 = \frac{22}{7} \times 140^2 = 61{,}600cm^2$

   Pressure exerted on A = pressure exerted on B

   $P = \frac{F}{A} = \frac{77}{154} = \frac{F}{61{,}600} \Rightarrow F = 30{,}800N.$ *Force exerted on B is 30,800N*

3. The areas of the pistons in a haydraulic press are $0.01m^2$and $5m^2$. If a body of mass 1000kg is being overcome, find the value of the force applied on a small piston.

   Solution: force on large piston $= mg = 1{,}000 \times 10 = 10{,}000N$

   Pressure exerted on small piston = pressure exerted on large piston

   $P = \frac{F}{A} = \frac{F}{0.01} = \frac{10{,}000}{5} \Rightarrow F = 20N.$ *Force exerted on small piston is 20N*

4. (a) In a hydralic press, the area of the piston to which the effort is applied has an area of $5cm^2$. If a force of 400N is applied to the piston, what is the pressure transmited to the fluid in the the hydraulic press?

   (b) If the press can raise a weight of $2k$N when an effort of 400N is applied, what is the area of the piston under the load?

   Solution: area of the piston $5cm^2 = 5 \times 10^{-4}m^2$

   $(a)\ P = \frac{F}{A} = \frac{400}{5\times10^{-4}} = 800{,}000Pa$

   (b) *weight to raise* $= 2k\text{N} = 2{,}000\text{N}$

Pressure on this piston $P = \frac{F}{A} = \frac{2,000}{A} = 800,000 \Rightarrow A = \frac{2,000}{800,000} = 2.5 \times 10^{-3} m^2$

Area of the piston under the load is $2.5 \times 10^{-3} m^2$

5. The diameters of the pistons of a hydraulic press are 4cm and 80cm respectively. A force of 22N is applied to the small piston. Calculate the
   (i) pressure on the effort piston
   (ii) pressure on the load piston
   (iii) force applied on the load piston

Radius of small piston $r = \frac{0.04}{2} = 0.02m$

radius of large(load) piston $R = \frac{0.80}{2} = 0.40cm$

Area of small piston $= \pi r^2 = 3.14 \times 0.02^2 = 1.256 \times 10^{-3} m^2$ *and*

Area of large (load) piston $= \pi R^2 = 3.14 \times 0.40^2 = 0.5024m^2$

(i) Pressure exerted on effort piston $= \frac{F}{A} = \frac{22}{1.256 \times 10^{-3}} = 17,515.92Pa$

(ii) Pressure exerted on load piston = pressure exerted on effort piston $= 17,515.92Pa$

(iii) Pressure exerted on load piston $P = \frac{F}{A} \Rightarrow 17,515.92 = \frac{F}{0.5024}$

$\Rightarrow F = 17,515.92 \times 0.5024 = 8,799.998 \approx 8,800N$

Force applied on the load piston is $8,800N$

Hydraulic press as simple machine

This consists of the lever system and the hydraulic press.

Taking moments about the povot,

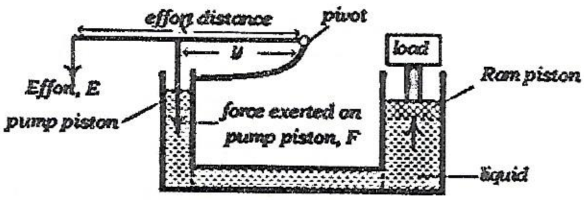
effortx effort distance = F × load distance

$E \times x = F \times y$

V.R of lever system $= \frac{effort\ distance\ x}{load\ distance\ y}$ and

V.R of press $= \frac{area\ of\ ram\ piston\ A_2}{area\ of\ pump\ piston\ A_1}$

V.R of whole system $\frac{x}{y} \times \frac{A_2}{A_1}$



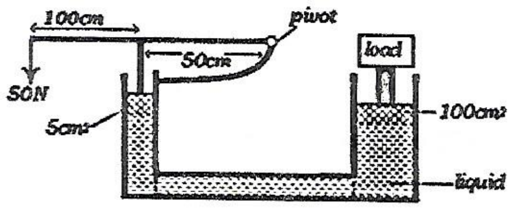
<u>Example 1:</u>

In the figure below, find the

(i) force exerted on the pump piston

(ii) pressure exerted on the liquid

(iii) V.R of the system

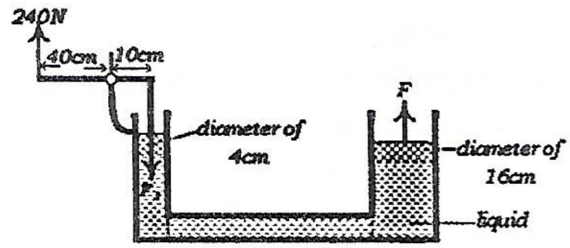


$(i) 50 \times 150 = F \times 50 \Rightarrow F = 150N$ $\quad$ *(ii)pressure on the liquid* $= \frac{F}{A} = \frac{150}{5 \times 10^{-4}} = 3.0 \times 10^5 Pa$

(iii) verocity of the system $= \frac{150}{50} \times \frac{100}{5} = 60$

Example 2.

In the figure the efficiency is 96%. Find the



(i) V.R of the system

(ii) M.A

(iii) Value of force F acting on the ram pistom

$(i)\ V.R\ of\ lever\ system = \frac{40}{10} = 4\ and$

$V.R\ of\ press\ = \frac{area\ of\ ram\ piston\ A_2}{area\ of\ pump\ piston\ A_1} = \frac{\pi R^2}{\pi r^2} = \frac{8^2}{2^2} = 16$

$V.R\ of\ whole\ system\ \ 4 \times 16 = 64$

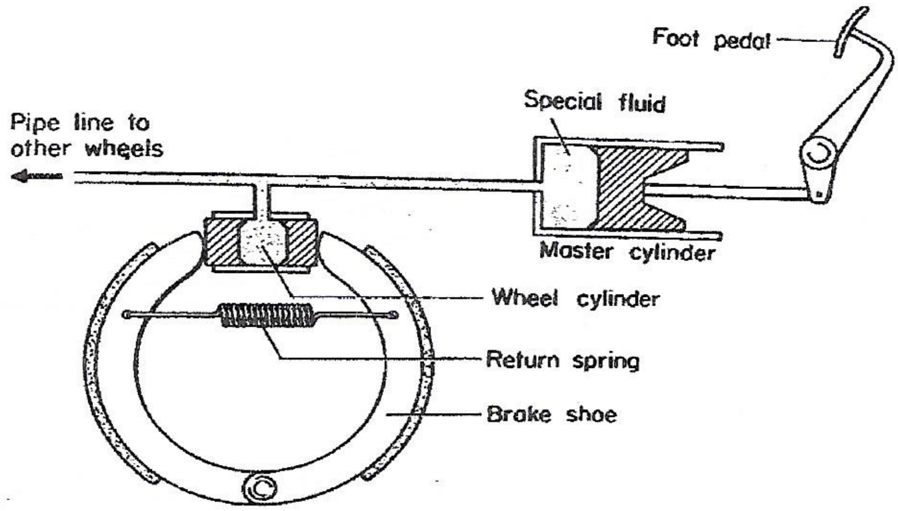
$(ii)\ eff = \frac{M.A}{VR} \times 100\% \Rightarrow 96\% = \frac{M.A}{64} \times 100\% \Rightarrow M.A = 61.44$

$(iii)\ force\ exerted\ on\ pump\ piston\ 240 \times 40 = F_1 \times 10 \Rightarrow F_1 = 960N$

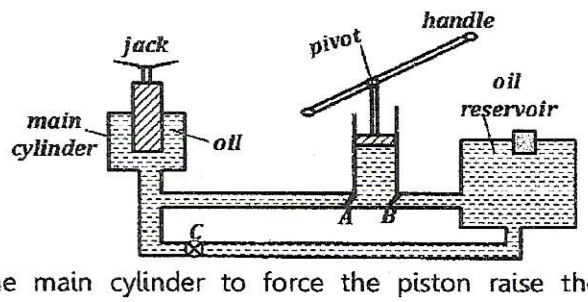
$by\ transmission\ of\ pressure;\ \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow \frac{960}{\pi(2)^2} = \frac{F}{\pi(8)^2} \Rightarrow F = 15{,}360N$

(b) The hydraulic brake system

When force is applied on the pedal, resulting pressure is transmitted equally to the slave/wheel cylinders. The liquid under pressure in the slave cylinders forces brake shoes against the wheels and the car finally stops.



(c) The hydraulic jack



Downward force applied on the handle forces valve A to open and B to close. Pressue applied on the handle is transmitted equally to the main cylinder to force the piston raise the jack.when the hande is lifted, A closes due to pressure in the main cylinder and valve B open allowing oil into the metal barrel.

Note: Valve C must be closed before using the jack.
To lower the jack, valve C is opened and oil is pushed back to the reservoir.

ATMOSPHERIC PRESSURE

This is the pressure exerted on all objects by the weight of air above.

At sea level, the atmospheric pressure is about $760mmHg$ or $76cmHg$ and density of air is about 1.3 kgm^{-3}.

The greater density at lower levels in the atmosphere is caused by the weight of air above which compresses the lower air layers.

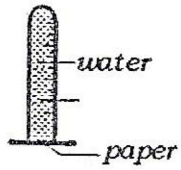
Pressure varies with latitude

In higher altitudes air is less dense and has less weight than at sea level. Thus atmospheric pressure decreases from sea-level to higher altitudes.

A person moving from a lower attitude to a higher altitude may experience nose bleeding since blood pressure will be greater than the atmospheric pressure.

Evidences of atmospheric pressure

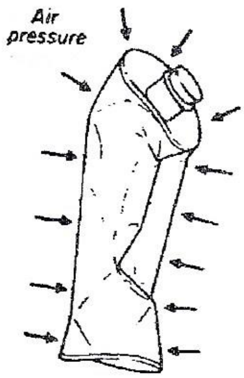
1. A test tube filled with water covered with a piece of paper is inverted and water does not pour out.



   Explanation:

   Air around the paper exerts a pressure called atmospheric pressure on the paper equal to the water pressure hence preventing water to pour out.

2. Crashing – can experiment
   - Small volume of water is boiled in a metal can for some time
   - The can is tightly closed and cold water poured on it.
     It will be observed that the can immediately crashes when cold water is poured on it.



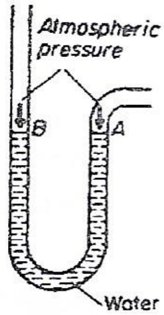
Explanation:

During heating, air inside is heated and become less. When the can is corked, air pressure inside is equal to the external atmospheric pressure. Cold water conducts heat away from the can making it cool. This too, cools hot air inside hence reduced air pressure. Atmospheric pressure now exceeds the air pressure inside forcing the can to crash inwards.

Measurement of pressure

1. Manometer

A manometer is a U – tube containing a liquid of known density. When both arms are open the liquid is subjected to same atmospheric pressure H. I.e Pressure at B = pressure at A (points on the same level have the same pressure)



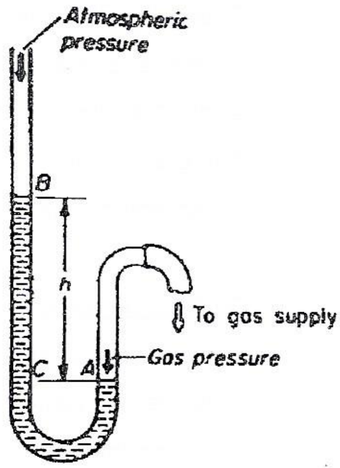
Measurement of gas pressure using a manometer

One arm of the manometer is connected to the gas supply whose pressure is to be measured.

The tap is opened and the rise h of the liquid of known density ρ in the other arm is measured as in the figure.

Thus gas pressure P is obtained from $P = h\rho g + H$

Where H is the value of atmospheric pressure.



Theory:

The gas pressure P at A is greater than atmospheric pressure at B

Pressure at C = gas pressure at A (points on the same level have the same pressure)

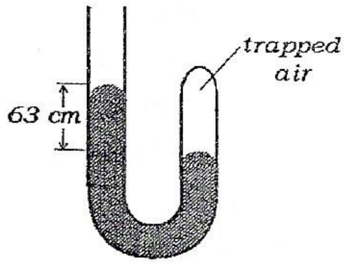
Pressure at C = pressure due to liquid column + pressure at B

$= h\rho g + H$

Thus gas pressure $P = h\rho g + H$

Examples:

1. The figure below shows a column of air trapped in a tube using mercury. Given that the atmospheric pressure is 76cmHg, calculate the air pressure.

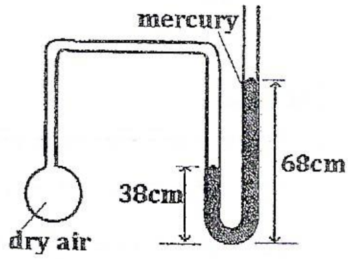


Air pressure $P = H + h\rho g$

$= \frac{76}{100} \times 13600 \times 10 + \frac{63}{100} \times 13600 \times 10$

$= 189040\ Pa$

2. In the figure, calculate the total pressure of air in the glass bulb if the atmospheric pressure is $76cm$ of mercury.



Solution:

Difference in mercury levels $h = 68 - 38 = 30cm$

Since mercury rises higher in right limb than left limb then gas pressure P is higher than atmospheric pressure;

$P - H = h\rho g$

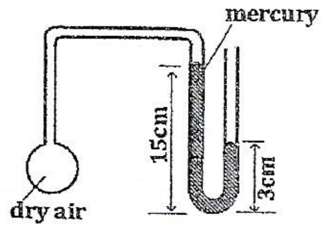
$P - 76cmHg = 30\ cmHg$

$\Rightarrow P = 30cmHg + 76cmHg = 106cmHg$

3. The diagram below shows a manometer connected to the gas bulb.

Given that the atmospheric pressure is $1.01 \times 10^5 Pa$, find the pressure of the gas.

[Density of mercury is $13600kgm^{-3}$]



Solution:

Difference in mercury levels $h = 15 - 3 = 12cm$

Since mercury rises higher in left limb than left limb then atmospheric pressure H is higher than the gas pressure P.

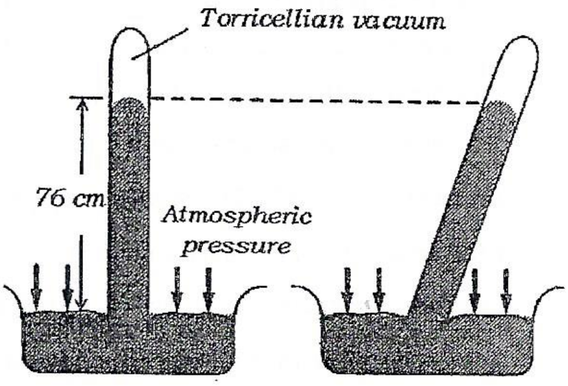
Pressure of the gas $P = H - h\rho g$

$\Rightarrow P = 1.01 \times 10^5 - \frac{12}{100} \times 13600 \times 10 = 84{,}680Pa$

2. **Simple barometer**: This is used to measure atmospheric pressure

Construction:

Mercury is filled into a one – metre long glass tube sealed at one end. With a finger placed on open end, the tube is inverted several times to collect small air bubble into a big one. More mercury is added to completely fill the tube. With a finger placed on open end again, the tube is inverted vertically into a dish of mercury. With the finger off, mercury falls and the difference h between mercury levels in the tube and the dish is measured. This difference is the atmospheric pressure.



Note:

- Standard atmospheric pressure is 76cm of mercury written as 76cmHg
- The space above the mercury in the tube is called Toricellian vacuum.

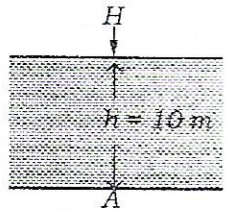
- When the tube is tilted the height of the mercury column remains constant up to when the top of the tube is less than 76 cm, that mercury completely fills the tube.

Example:

1. Express the standard atmospheric pressure (760mm) in Pa. [use density of mercury as 13600kgm^{-3}, acceleration due to gravity $g = 10ms^{-2}$]

   $Using\ P = h\rho g = \frac{760}{1000} \times 13600 \times 10 = 103{,}360Pa$

2. Calculate the pressure at the bottom of a lake of water of depth 10m, if the atmospheric pressure is $1.0 \times 10^5 Pa$. (density of water is $1000kgm^{-3}$)

   $Total\ pressure\ at\ the\ bottom\ of\ a\ lake\ P_A = pressure\ due\ to\ liquid\ column + H$

   $= H + h\rho g$

   $\Rightarrow P_A = 1.0 \times 10^5 + 10 \times 1000 \times 10 = 2.0 \times 10^5 Pa$

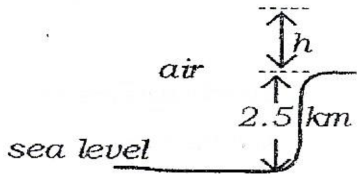
   $or\ \ pressure\ difference\ between\ A\ and\ water\ surface\ =\ pressure\ due\ to\ water\ column$

   $\Rightarrow P_A - H = h\rho g \quad \Rightarrow P_A - 1.0 \times 10^5 = 10 \times 1000 \times 10 \ \Rightarrow P_A = 2.0 \times 10^5 Pa$

3. A simple barometer is raised from sea level to a height of 2.5km. Given that the average density of air is 1.25 kgm^{-3} and that of mercury is 1.36×10^4 kgm^{-3}, calculate the new length of mercury in the barometer.

   $Pressure\ at\ sea\ level\ is\ 760mmHg = \frac{760}{1000} \times 13600 \times 10$

   $= 103{,}360\ Pa$

   $Pressure\ due\ to\ air\ column\ h\rho g = 2.5 \times 1000 \times 1.25 \times 10$

   $= 31250\ Pa$

   $Pressure\ of\ mercury\ at\ new\ level = h \times 13600 \times 10 = 136000\,h\ \ Pa$

   $Total\ pressure\ at\ sea\ level = pressure\ due\ to\ air\ column + pressure\ at\ new\ level$

   $103{,}360 = 31250 + 136000\,h \qquad \Rightarrow h = 0.53\ m$

   $New\ length\ of\ mercury\ in\ the\ barometer\ is\ 0.53\ m$

4. A mercury barometer reads 760 mm at sea level and 700 mm at the top of a mountain. If the density of mercury is 13600 kgm^{-3} and average density of air is 1.30 kgm^{-3} calculate the height of the mountain.

   $Pressure\ at\ sea\ level\ is\ 760\ mmHg = \frac{760}{1000} \times 13600 \times 10 = 103{,}360\ Pa$

   $Pressure\ due\ to\ air\ column\ h\rho g = h \times 1.3 \times 10 = 13\ h\ \ Pa$

   $Pressure\ of\ mercury\ at\ new\ level = \frac{700}{1000} \times 13600 \times 10 = 95200\ \ Pa$

   $Total\ pressure\ at\ sea\ level = pressure\ due\ to\ air\ column + pressure\ at\ new\ level$

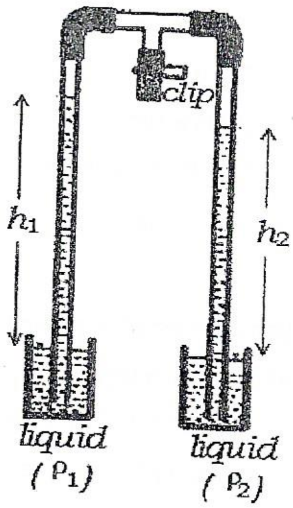
   $103{,}360 = 13\ h + 95200 \qquad 8160 = 13\ h \Rightarrow h = 627.69\ m$

   $Height\ of\ the\ mountain\ 627.69\ m$

Comparison of densities of liquids (Hare's apparatus)

Two long glass tubes dipped in liquids of densities ρ_1 and ρ_2 are connected with a clip

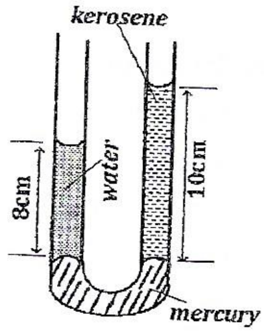
Some air is sucked thus lowering the air pressure in the tubes. The atmospheric pressure then forces the liquids to rise in the tubes until pressures at the base of liquid columns are each equal to atmospheric pressure. The heights h_1 and h_2 are measured and recorded. Pressure at base of each column is $P + h_1\rho_1 g = P + h_2\rho_2 g$ where P is the gas pressure above the liquids.



$$\Rightarrow h_1\rho_1 = h_2\rho_2 \Rightarrow \frac{\rho_1}{\rho_2} = \frac{h_2}{h_1}$$

Examples

1. The U – tube contains columns of water and kerosene. Find the density of kerosene if density of water is $1000kgm^{-3}$.



Solution:

Pressure at the same levels in a liquid is the same

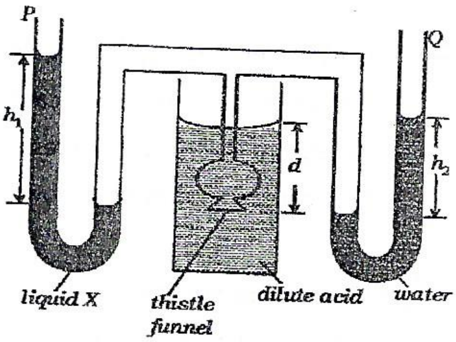
i.e Pressure of water column over mercury = pressure of kerosene over mercury

$$\Rightarrow H + \frac{8}{100} \times 1000 \times 10 = H + \frac{10}{100} \times \rho \times 10 \qquad \Rightarrow 800 = \rho$$

Density of kerosene is $800kgm^{-3}$

2. Two manometers P and Q contain a liquid X and water respectively at the same level. They are then connected to a thistle funnel covered with a rubber membrane as shown in the figure below.

   The thistle funnel is lowered into a beaker containing dilute acid of density $1200kgm^{-3}$ the heights h_1 and h_2 are 15cm and 12cm respectively.



   Find the

   (i) ratio of density of liquid X to that of water

   (ii) depth d of the thistle funnel below the surface of the dilute acid

   Solution:

   (i) Gas pressure in right limb of P = Gas pressure in left limb of Q

$H + \frac{15}{100}\rho_X \times 10 = H + \frac{12}{100} \times 1000 \times 10$

$\Rightarrow 1.5\rho_X = 1{,}200 \Rightarrow \rho_X = \frac{1{,}200}{1.5} = 800$

Ratio of density of liquid X to that of water $= 800:1{,}000 = 4:5$

(ii) Pressure at the bottom of the thistle funnel $= H + d\rho_A g = H + 12{,}000\ d$

This is the same pressure required to push the liquids in the manometers

$\Rightarrow H + 1{,}200 = H + 12{,}000\ d \Rightarrow d = \frac{12{,}000}{1{,}200} = 10\ cm$

Application of atmospheric and liquid pressure

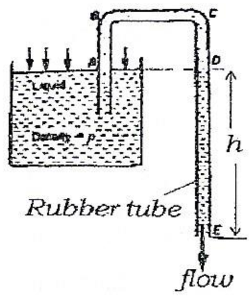
(a) The drinking straw

When one drinks using a straw, he sucks air in the straw thus reducing the air pressure in the straw. Atmospheric pressure acting on the liquid surface being greater than air pressure in the straw, forces the liquid up into the straw.

(b) The siphon

A siphon is often used to empty tanks that may not be emptied easily.

One end of a long rubber tube is inserted in a tank to be emptied and the other end, E placed below the surface of the liquid in the tank.The tube is filled with the liquid by sucking it and then clipped. When the clip is removed, the liquid flows continuously.

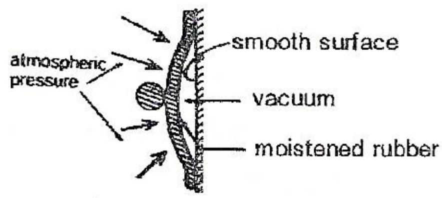


Explanation: sucking lowers the air pressure in the tube and atmospheric pressure forces the liquid into the tube because of pressure difference.

When clip is removed, excess pressure due to liquid column (DE) in the tube below the tank causes the liquid to flow out of the tube.

(c) The rubber sucker

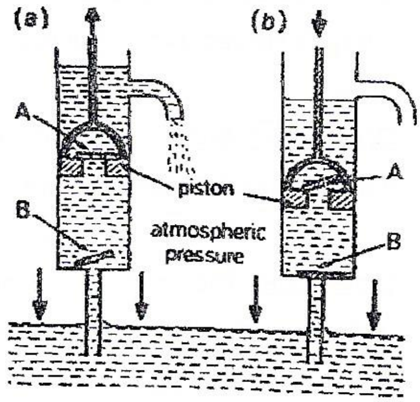
When a circular moistened rubber is pressed on a smooth flat surface, it flattens as air is squeezed out beneath it. Air pressure under rubber is reduced and great atmospheric pressure forces the sucker firmly onto the surface.



The rubber sucker is used to

- stick notices to shop glass windows,
- attach stickers, linceses to wind screens of cars.
- Lifting metal or glass sheets in industries
- Unblocking water sinks in homes

(d) The lift pump



A lift pump is used to raise water from wells.

On the *upstroke (fig a)*,valve A is closed due to weight of water above it. At the same time pressure in the barrel reduces and because of pressure difference atmospheric pressure acting on surface of water, pushes water up the pipe through valve B. Water above valve A is pushed out of the spout.

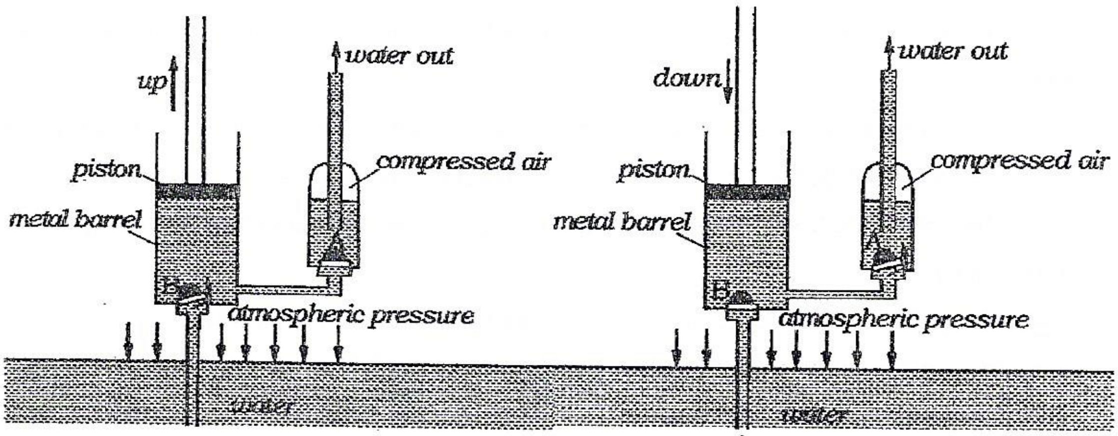
On the *down stroke (fig b)*, valve B closes by pressure of water above it and valve A opens allowing water above the pistons.

(e) The force pump

On the upstroke, valve A closes and atmospheric pressure forces water up into the barrel through valve B

On the downstroke, valve B closes due to pressure of water above it and water is forced through valve A.

Compressed air in the reservior expands and keeps the supply of water out from the spout.

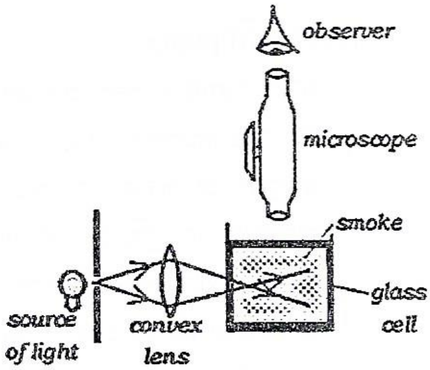


MOLECULAR PROPERTIES OF MATTER

Matter is anything that occupies space and has weight. It consists of small particles called atoms which take part in a chemical change. Groups of atoms joined together form molecules.

Brownian motion

Smoke particles are enclosed in an illuminated glass cell.
They are viewed using a microscope.



Observation: Bright specks of smoke particles are seen moving in a continuous random motion.

Explanation: The continuous random motion of smoke particles is due to invisible air molecules in a state of random motion colliding with the smoke particles.

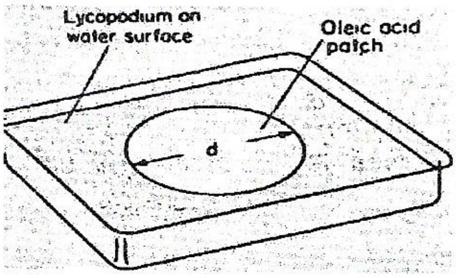
The jerky, erratic and continuous random movement of microscopic particles in a fluid is called Brownian motion.
The movement is caused by continuous irregular bombardment of suspended particles of the medium.

Note: increase in temperature of the smoke cell increases kinetic energy as well as their velocity and the bright specks are seen moving more rapidly.

Kinetic theory of matter

It states that matter is made up of tiny particles called molecules that are in random motion.
In solids, molecules are close together held by strong attractive forces which balance with repulsive forces between the neighboring molecules. Each molecule vibrates to and fro about the mean position. Therefore, solids have a regular and repeating pattern and have definite shape.
In liquids, molecules are further apart held by weak forces and so can flow.
In gases, forces between molecules are negligible and this makes them move in a continuous and haphazard motion.

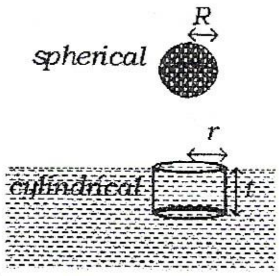
Determination of size/thickness of a molecule



- A dish full of water is allowed to stand until water is at rest.
- Lycopodium powder is lightly dusted on the surface of water.
- A known volume of oleic acid is dissolved in methanol and the mixture poured in a burette.
- A known volume, V of the mixture is run into the center of water surface forming a circular patch. [methanol evaporates leaving oleic acid to form a patch]
- The diameter d of the patch is measured and recorded.
- Thickness/size/diameter, t of the molecule of oleic acid is obtained from $t = \frac{V}{\pi r^2}$ where $r = \frac{d}{2}$ is the radius of patch.

Note: Lycopodium powder is used to reduce the surface tension effects and to enable the edge of the patch seen clearly. [*Surface tension to be discussed later*]

Assumptions



- All the solvent (methanol) has evaporated or dissolved
- The patch formed is cylindrical of volume $\pi r^2 t$
- The patch formed is one molecular thick
- A drop of the mixture is spherical
- Molecules of oleic acid are spherical [$V = \frac{4}{3}\pi R^3$]
- There are no air spaces between acid molecules in the patch.
- Volume of the patch = volume of the oleic acid in the drop.

Question: Describe an experiment to determine the thickness of an oil drop

- *Water is poured in a container and allowed to settle*
- *A known volume, V of oil is run into the center of water surface forming a circular patch.*
- *Diameter d of the patch is measured and recorded.*
- *Thickness t of the molecule of oleic acid is obtained from* $t = \frac{V}{\pi r^2}$ *where* $r = \frac{d}{2}$ *is the radius of patch.*

Calculations

1. A very dilute solution of oil has volume $0.1cm^3$. The drop makes a patch of area $1.0cm^2$. Estimate the thickness of the oil patch.

   $Volume\ of\ oil = volume\ of\ the\ patch,\ V = \pi r^2 t,\quad area\ of\ patch\ A = \pi r^2 = 1.0cm^2$

   $\Rightarrow 0.1 = 1.0t \Rightarrow t = \frac{0.1}{1.0} = 0.1cm$

2. A small oil drop of volume $0.001cm^3$ spreads to form a patch of radius 0.4cm on the water surface. Calculate the thickness of one molecule of oil. [0.002cm]

   $Volume\ of\ drop = volume\ of\ the\ patch,\ V = \pi r^2 t$

   $0.001 = 3.14 \times 0.4^2 t \Rightarrow t = \frac{0.001}{3.14 \times 0.4^2} = 0.0019cm.$

3. In an experiment to determine thickness of an oil molecule, a drop of radius 0.4mm formed a patch of diameter 0.2m. Calculate the thickness of oil patch.

   $R = \frac{0.0004}{2} = 0.0002m\quad r = 0.1m$

   $Volume\ of\ oil\ drop = volume\ of\ the\ patch,\ \frac{4}{3}\pi R^3 = \pi r^2 t,$

   $\Rightarrow \frac{4}{3} \times 0.0002^3 = 0.1^2 t \Rightarrow t = 1.07 \times 10^{-9} m.$

Questions

1. An oil drop of volume $1.8 \times 10^{-4}\ cm^3$ spreads to form a patch of area $150cm^2$. Calculate the molecular thickness of the oil patch.

   $Volume\ of\ oil\ drop = volume\ of\ the\ patch$

   $\Rightarrow 1.8 \times 10^{-4} = 150\,t \Rightarrow t = 1.2 \times 10^{-6}\ cm.$

2. 100 identical drops of oil of density $800kgm^{-3}$ are found to have a mass of $2.0 \times 10^{-4}kg$. One of the drops is placed on a large clean water surface and it spreads to form a uniform film of area $0.2m^2$.

   Find

   (a) mass of one drop

   (b) volume of one drop

   (c) thickness of the oil film.

   $Mass\ of\ one\ oil\ drop = \frac{2.0 \times 10^{-4}}{100} = 2.0 \times 10^{-6}\ kg,$

   $Volume\ of\ one\ oil\ drop = \frac{2.0 \times 10^{-6}}{800} = 1.5 \times 10^{-9} m^3$

   $Volume\ of\ oil\ drop = volume\ of\ the\ patch \Rightarrow 1.5 \times 10^{-9} = 0.2\,t \Rightarrow t = 7.5 \times 10^{-9}\ m.$

   $Thickness\ of\ the\ film = 7.5 \times 10^{-9}\ m$

3. An oil drop spreads on water surface forming a patch of diameter 28 cm. If the volume of the oil drop is $4.0 \times 10^{-3}\ cm^3$, estimate the diameter of the oil molecule.

   $Volume\ of\ oil\ drop = volume\ of\ the\ patch$

   $V = \pi r^2 t;$

   $4.0 \times 10^{-3} = 3.14 \times \left(\frac{28}{2}\right)^2 t\quad \Rightarrow t = 6.499 \times 10^{-6}\ cm.$

   $Diameter\ of\ the\ oil\ molecule\ is\ 6.499 \times 10^{-6}\ cm$

4. In an experiment to determine the size of a molecule, the following were done
   (a) $1cm^3$ of oil was dissolved in $9cm^3$ of ether and $1cm^3$ of solution was diluted to $400cm^3$.
   (b) $0.2cm^3$ of diluted solution was dropped onto the water surface.
   (c) Radius of the oil film was measured to be 10cm.

   From the above data, estimate the size of the molecule.

   Solution

   $Volume\ of\ mixture = (1 + 9)cm^3 = 10cm^3$

   $10cm^3 of\ mixture\ contain\ 1cm^3 of\ oil \Rightarrow 1cm^3 of\ mixture\ contains\ \frac{1}{10} = 0.1\ cm^3\ of\ oil$

   $On\ dilution;\ 400cm^3 of\ solution\ contain\ 0.1cm^3 of\ oil$

   $\Rightarrow 0.2cm^3\ of\ solution\ contain\ \frac{0.1}{400} \times 0.2 = 5.0 \times 10^{-5} cm^3 of\ oil$

   This is the volume the patch formed as the ether is dissolved and evaporated.

   Thus $5.0 \times 10^{-5} = \pi r^2 t$ *where t is the size of the molecule.*

   $\Rightarrow 5.0 \times 10^{-5} = 3.14 \times 10^2 t \quad \Rightarrow t = \frac{5.0\times10^{-5}}{3.14\times10^2} = 1.59 \times 10^{-7} cm$

   Size of oil molecule is $1.59 \times 10^{-7} cm$

5. $1cm^3$ of oil is dissolved in $999cm^3$ of ether and $1cm^3$ of solution is dropped onto the water surface sprinkled with Lycopodium powder. A patch of diameter 14cm was formed. Calculate the thickness of the oil molecule.

   Solution

   $Volume\ of\ solution = 1 + 999 = 1000cm^3$

   $1000cm^3 of\ solution\ contain\ 1cm^3 of\ oil$

   $\Rightarrow 1cm^3 of\ solution\ contains\ \frac{1}{1000} = 0.001\ cm^3\ of\ oil$

   This is the volume the patch formed as the ether is dissolved and evaporated.

   Thus $0.001 = \pi r^2 t$ *where t is the size of the molecule.*

   $\Rightarrow 0.001 = 3.14 \times 14^2 t \quad \Rightarrow t = \frac{0.001}{3.14\times7^2} = 6.499 \times 10^{-6} cm$

   Size of oil molecule is $6.499 \times 10^{-6} cm$

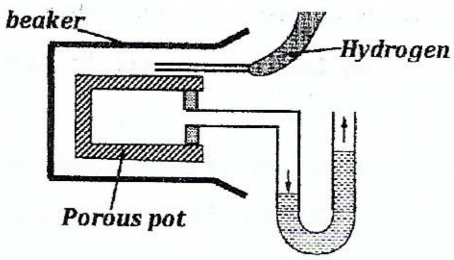
Diffusion

This is the spreading of molecules of a substance on their own from a region of high concentration to a region of low concentration.

Diffusion in gases

When hydrogen surrounds the porous pot, the liquid in a U – tube moves in the directions as in the figure.

Explanation: Lighter and faster hydrogen molecules diffuse faster into the porous pot than the heavier slower air molecules which diffuse out. The pressure inside the pot therefore increases forcing liquid in the manometer to move in the indicated direction.



Diffusion in liquids

Blue copper sulphate crystals are gently placed at the bottom tall beaker containing water using a long glass tube.

Copper crystals will dissolve forming dense blue copper solution at the bottom.

After a long period of time, the blue copper solution gradually spreads throughout the water.

Factors affecting rate of diffusion

- Temperature; increase in temperature increases rate of diffusion
- density of diffusing molecules; more dense molecules diffuse slowly
- concentration of molecules; concentrated molecules diffuse faster

Question: Give one reason why the rate of diffusion is higher in gas than in liquid at the same temperature.

Response: The intermolecular forces of gas molecules are negligible while in liquids the intermolecular forces are appreciable. Increase in temperature increases molecular speed in a substance, thus gas molecules move at higher rate when heated than liquid molecules at the same temperature.

Application of diffusion

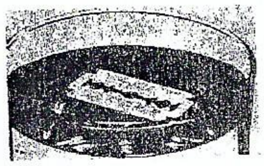
- spraying rooms or clothes with perfumes
- spraying chemicals in houses to kill mosquitoes, house flies, bed bugs
- mothballs are added to the toilets and urinal places to suppress stench
- spreading of chemical pollutants in water bodies
- spraying of teargas to disperse rioters

Surface tension

Liquid surface molecules are more widely spaced compared to those inside it. As a result, surface molecules experience unbalanced inward pull and are always in a state of tension.

Experiment to demonstrate surface tension

- Clean water is poured in a beaker and allowed to settle.
- A razorblade on a blotting paper is gently placed on water surface.



- After some time, the paper absorbs water and sinks leaving the razorblade floating on water surface though more dense than water. This shows existence of surface tension.

Explanation:

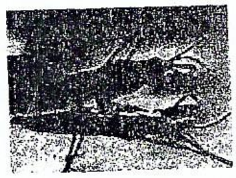
The water surface acts as an elastic skin covering the water and is able to support the weight of the razorblade or pin.

The property of water surface which enables it to support the razorblade is called surface tension.

For the same reason,

- a drop of water formed at the end of the tap is spherical
- soap films formed are spherical
- brush hairs are held together when removed from bucket of paint

Application of surface tension



- Small insects are able to walk on water surfaces
- Ships and boats are able to float on water
- Water-repellant garments are covered with wax-like substances to allow cohesion in water to pull water into spherical drops.

Definition: surface tension is defined as a tangential force in the surface of a liquid acting normally per unit length across any line in the surface.

Factors affecting surface tension

- Increasing temperature of the liquid decreases the intermolecular forces in the liquid hence reducing surface tension.
- Soap solution or detergents added on liquid surface reduce surface tension.

  For this reason, in the above experiment, if detergents or soap solutions are added on water surface, the razorblade or pin sinks.

Adhesion and cohesion forces

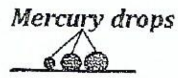
Cohesion forces: These are forces of attraction between molecules of the same substances. Forces between water molecules only are cohesion.

Surface tension is as a result of cohesion forces in a liquid.

Adhesion forces: These are forces of attraction between molecules of different substances. Forces between water molecules and glass molecules are adhesion.

Substances in which adhesion forces are greater than cohesion forces always cause wetting. Adhesion forces of water to glass molecules are stronger than cohesion forces of water molecules therefore water spreads into a thin film when spilled on glass.

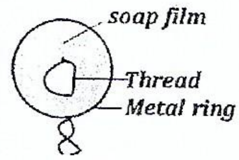
Cohesion forces of mercury are greater than adhesion forces of mercury and glass molecules therefore mercury forms small spherical drops when spilled on glass.



Note: Large drops of liquids because of their weight tend to flatten when poured on clean surfaces.

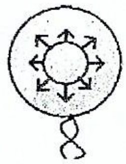
Question

The figure shows a metallic loop dipped in soap solution and then removed. A loop of thread is gently placed on the soap film.



With the aid of a diagram explain what happens if a sharp metal pierces in the middle of the thread.

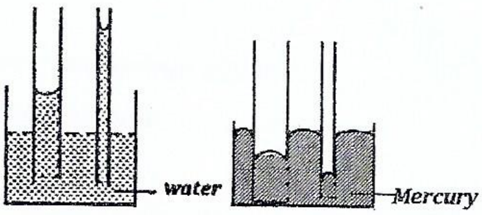
Before piercing, surface tension forces act equally on the soap film. After piercing in middle, surface tension forces act only on one side of the thread stretching it into a circular loop.



Capillarity attraction

Capillarity is a process by which liquids rise or fall in substances.

Glass tubes of different diameters one at a time are inserted into dishes of water and mercury.



It will be observed that

- water rises higher in smaller tubes compared to large tubes than outside level in a dish.

  Explanation: Strong adhesion forces between water and glass molecules result in the rise of water in the tubes. For the same reason, its meniscus curves inwards (concave).

- mercury falls more in smaller tubes compared to large tubes than outside level in a dish.

  Explanation: Cohesion forces of mercury molecules are greater than adhesion forces between mercury and glass molecules. It is for this reason that mercury meniscus curves upwards (convex).

Applications of capillarity

- Rising paraffin in wicks whose fibres provide fine tubes where paraffin rises.
- Drying our bodies by towels whose fibres provide fine tubes where water rises.
- Mopping using rugs which provide fine tubes where water rises.
- Rising of mineral salts in plants whose tissues provide fine tubes where salts rise.

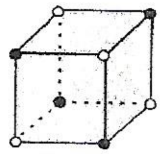
Capillarity causes dampness in buildings. This is prevented by covering damp-course using damp proof papers.

Crystalline solids

Crystals are hard solids with straight edges and flat sides. Molecules in a crystal are arranged in a regular pattern giving it a permanent and fixed shape.

Crystals of the same substance have the same shape irrespective of the size.

Example; sodium chloride has a cubic shape



A crystal with ordered structure is formed when a liquid cools slowly allowing particles of the liquid time to arrange. Metals and rocks are formed in such way.

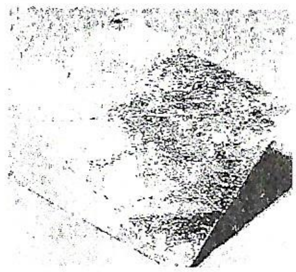
Rapid cooling produces amorphous structure. Glass is formed in such way.

Growing of crystal

Sugar/salt is mixed in water up to saturation point.

It will be found that threads hanging in the solution for about three days will contain sugar/salt crystals when removed.

Mineral/crystal cleavage



Cleavage is the tendency minerals have to break or split along the planes of their crystal structure.

This sample of fluorite shows a smooth cleavage face on the left where the mineral broke along the plane of its cubic crystal structure.

ELASTICITY

This is the ability of a material to regain its original size, length and shape when a stretching force is removed.

Some terms used

1. Extension is the increase in length of a substance when stretched.
2. Elastic deformation: This is when the material regains its shape or length when the applied force is removed.
3. Plastic deformation: This is when the material does not regain its shape or length when the applied force is removed.

Application of elasticity

- Making spring balances, spring beds and seats
- Rubber is used in making catapults, seatbelts
- Concrete is strong under compression and weak under tension is used in construction of concrete pipes and building
- Bridges are made of strong and stiff materials to minimise bends when loaded car pass over.
- Wires and other desired shapes are made from ductile materials.

Hooke's law

The extension, e of elastic material is directly proportional to the force, F applied provided elastic limit is not exceeded.

$F \propto e$ Thus $F = ke$ or $k = \frac{F}{e}$ where k is called spring constant. S.I units of spring constant are Nm^{-1}.

Spring constant is defined as the measure of stiffness of a spring when a force is applied at its ends.

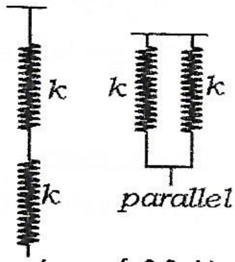
Calculation: A mass of 100 g suspended on a spring, caused an extension of 2.0 cm. Find the spring constant

$$F = mg = \frac{100}{1000} = 0.1\ N\ Extension\ e = \frac{2.0}{100} = 0.02\ m$$

$$Spring\ constant\ k = \frac{F}{e} = \frac{0.1}{0.02} = 50\ Nm^{-1}$$

Note: Experiments show that spring constant of two identical springs

- in series is half of spring constant of one spring $k_T = \frac{k}{2}$.
- in parallel is twice the spring constant of one spring $k_T = 2k$



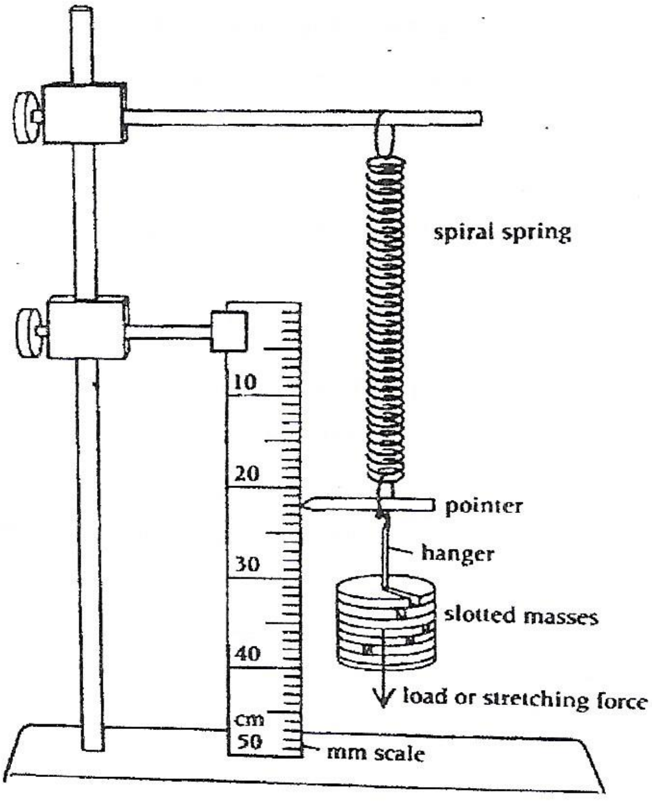
Calculation: A spring produces an extension of 6mm when a force of 0.3 N is applied to it. Calculate the spring constant for the system when the two springs are arranged in series and in parallel.

Spring constant on one spring $k = \frac{F}{e} = \frac{0.3}{0.006} = 50\ Nm^{-1}$

For two springs in series $k_T = \frac{K}{2} = \frac{50}{2} = 25\ Nm^{-1}$

For two springs in parallel $k_T = 2K = 2 \times 50 = 100\ Nm^{-1}$

Experiment to verify Hooke's law

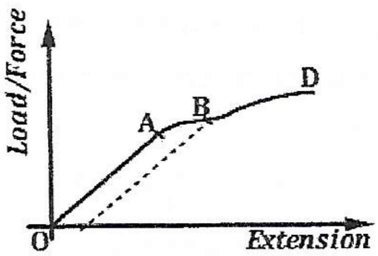


- A spring with a pointer is clamped alongside a metre rule.
- Initial pointer reading p_0 is recorded.
- A known mass, M of weight $W = 10M$, is hung on a clamped spring and new pointer reading p_1 recorded.
- Extension x of the spring is obtained from $x = p_1 - p_0$
- Experiment is repeated with increasing masses.

- A graph of x against W is a straight line showing that extension is proportional to weight hence Hooke's law verified.

Special graphs

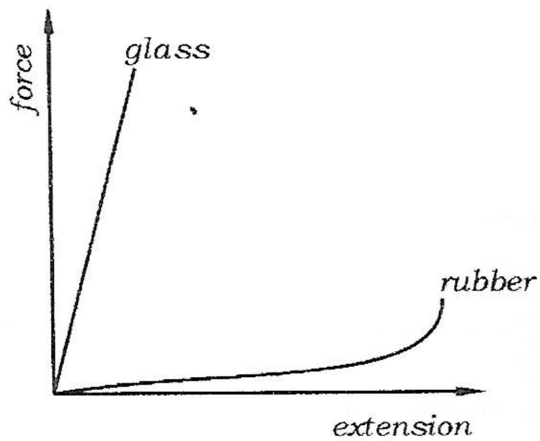
1. A graph of force, F against extension, e of a metallic wire (ductile material) is drawn.



Features of the graph

i. Between OA, increasing values of F increase values of e. Elastic deformation occurs and Hooke's law is obeyed. Point A is proportional / elastic limit.
ii. Beyond A up to B, layers of atoms slide over each other. Plastic deformation occurs and greater extensions occur than before. Point B is the yield point.
iii. Beyond B; layers of atoms slide further apart and more plastic deformation occurs until when the material breaks. Point D is the breaking point.

2. A graph of force, F against extension, e of other materials is drawn



Rubber; a small force causes a very large extension. Rubber does not obey Hooke's law.

Glass; a large force causes a small extension. Glass does not obey Hooke's law. Glass just breaks when its elastic limit is exceeded.

Calculations

- for different forces, $\frac{F_1}{e_1} = \frac{F_2}{e_2}$ or and
- for different masses, $\frac{m_1}{e_1} = \frac{m_2}{e_2}$

1. A spring of natural length 5 cm extends by 2 mm when a force of 1.8 N acts on it. Calculate the extension when a force of 10 N is applied to the spring.

Using $\frac{F_1}{e_1} = \frac{F_2}{e_2} \Rightarrow \frac{1.8}{2} = \frac{10}{e_2} \Rightarrow e_2 = 11.1\ mm = 1.11\ cm$

Extension caused is $1.11\ cm$

2. A vertical spring of length 30 cm is stretched to 36 cm when an object of mass 100 g is placed in a pan attached to it. The spring is stretched to 40 cm when a mass of 200 g is placed in the pan. Find the mass of the pan.

Let m be mass of pan

Total mass is $m + 100$ *Extension* $e_1 = 36 - 30 = 6\ cm$

Total mass is $m + 200$ *Extension* $e_2 = 40 - 30 = 10\ cm$

Using $\frac{m_1}{e_1} = \frac{m_2}{e_2} \Rightarrow \frac{m+100}{6} = \frac{m+200}{10} \Rightarrow m = 50g$ *Mass of the pan is* 50 g

Practice questions

1. A mass of 0.2 kg produces an extension of 8 cm in a spring. What is the force required to produce an extension of 6 cm?

$F_1 = mg = 0.2 \times 10 = 2N$ *Using* $\frac{F_1}{e_1} = \frac{F_2}{e_2} \Rightarrow \frac{10}{8} = \frac{F_2}{6} \Rightarrow F_2 = 7.5N$

Required force is $7.5N$

2. A force of 100 N stretches an elastic spring by 2 cm. What force would stretch the same spring by 3.5 cm?

Using $\frac{F_1}{e_1} = \frac{F_2}{e_2} \Rightarrow \frac{100}{2} = \frac{F_2}{3.5} \Rightarrow F_2 = 175\ N$

Required force is $175N$

3. When a mass of 100 g is suspended on a spiral spring, an extension of 2.0 cm is produced. Calculate the
   (i) spring constant and
   (ii) force that extends the spring by 3.0 cm.

$F_1 = mg = \frac{100}{1000} \times 10 = 1\ N,\ e = \frac{2.0}{100} = 0.02\ m$

Using $F = k\,e \Rightarrow 1 = k \times 0.02 \Rightarrow$ *spring constant* $k = 50\ Nm^{-1}$

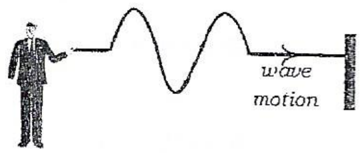
From $\frac{F_1}{e_1} = \frac{F_2}{e_2} \Rightarrow \frac{1}{0.02} = \frac{F_2}{0.03} \Rightarrow F_2 = 1.5\ N$

Required force is $1.5N$

WAVES

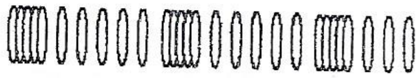
A wave is a disturbance which transfers energy from one point to another without causing any permanent displacement of the medium itself.

A wave consists of particles which are in constant oscillation.

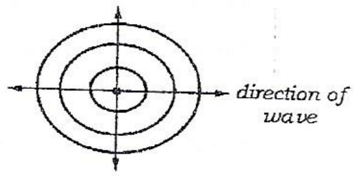


A wave can be seen when

- a rope is moved up and down
- a long slinky spring is stretched and released.



- a stone is dropped in a pond



Classes of waves

Waves are classified as mechanical and electromagnetic

A mechanical wave is a periodic disturbance which requires a material medium for its propagation.

Electromagnetic waves are waves produced by both electric and magnetic vibrations of very high frequencies.

Mechanical waves	Electromagnetic waves
- Need a medium to travel through - Brought about by a disturbance of the medium	- Do not need a medium to travel through - Originate from hot bodies

Types of mechanical waves

Mechanical waves are of two types; **progressive waves** and **stationary waves**.

Progressive waves:

A progressive wave is the one which propagates only in one direction and carry energy with it through a medium.

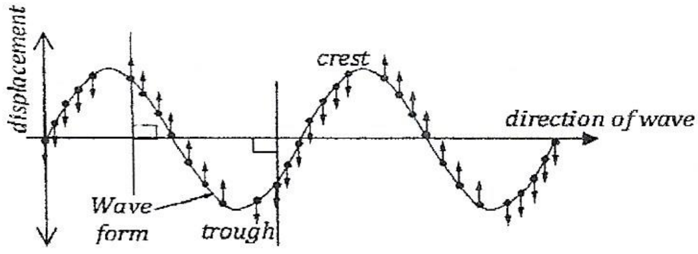
Example: Water waves carry energy to toss ships and wash away cliffs, Light waves

Progressive waves are either transverse or longitudinal.

i. **Transverse wave:** It is the one in which direction of the vibrating particles is perpendicular to that of the wave travel.

Examples of transverse waves include: Water waves, Light waves, Electromagnetic waves, Waves in a string

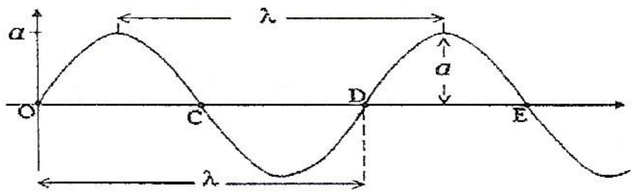
A transverse wave is represented as in the figure below



A transverse wave comprises of two regions; the crests and the troughs

A crest is a region of maximum upward displacement of the vibrating particles in a transverse wave. A trough is a region of minimum downward displacement of the vibrating particles in a transverse wave.

Terms used in wave motion



1. Rest/mean position ($\overline{OE}$): this is the resting position of the particles in a wave after the vibrations have ceased.
2. Amplitude (a): this is the maximum displacement of vibrating particles from the mean position.
3. Oscillation/cycle: it is a to and fro complete motion of the vibrating particles
4. Wavelength (λ): it is a distance between two successive particles in phase. Particles in phase move with the same direction and occupy the same distance from the mean position.
5. Period (T): it is the time taken for a wave to complete one cycle. Or it is the time taken for a wave to travel a full wavelength.
6. Frequency(f): it is the number of complete cycles made in one second.
   Its units are **hertz (Hz).**
   Other units are kilohertz(kHz) and megahertz (MHz) where $1kHz = 1000Hz$ and $1MHz = 1{,}000{,}000Hz$. $f = \frac{1}{T}$
7. Wave velocity (V): it is the displacement of the vibrating particles in a given time.
   In one cycle, distance covered is wavelength, λ and time taken is period, T
   $\Rightarrow V = \frac{\lambda}{T} = \frac{\lambda}{1} \times \frac{1}{T} = \lambda \times f$ $\quad\quad \Rightarrow V = \lambda f$

Calculations:

1. A radio station produces radio waves of wavelength 10m and velocity of $3.0 \times 10^8\ ms^{-1}$. Calculate

   (i) The frequency

   (ii) Period

   Solution: $V = 3.0 \times 10^8\ ms^{-1},\ \lambda = 10\ m$

   (i) From $V = \lambda f, \Rightarrow 3.0 \times 10^8 = 10f \Rightarrow f = \frac{3.0\times10^8}{10} = 3.0 \times 10^7 Hz$

   Thus the frequency of the waves is $3.0 \times 10^7 Hz$

   (ii) Period $T = \frac{1}{f} = \frac{1}{3.0\times10^7} = 3.3 \times 10^{-8}\ s$

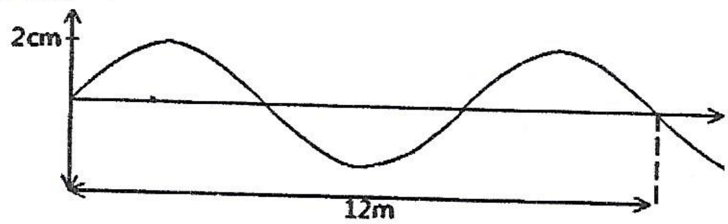
2. A vibrator produces waves which travel a distance of 35 m in 2 seconds and the distance between two successive crests is 5 cm. Calculate the wave velocity and the frequency.

   Solution: $distance = 35\ m\ \ in\ time\ t = 2s,\ \lambda = 5cm = 5.0 \times 10^{-2}\ m$

   $V = \frac{distance}{time} = \frac{35}{2} = 17.5ms^{-1},$

   From $V = \lambda f, \Rightarrow 17.5 = 5.0 \times 10^{-2} f \Rightarrow f = \frac{17.5}{5.0\times10^{-2}} = 350Hz$

3. The figure below represents a wave travelling from left to right with a velocity of $330\ ms^{-1}$.



Find

(i) the peak value (amplitude)

(ii) wavelength

(iii) frequency

Solution:

From the graph,

(i) amplitude $= 2cm = 2.0 \times 10^{-2} m$

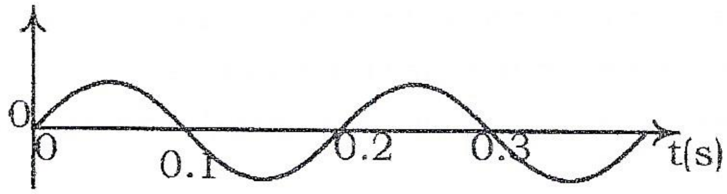
(ii) distance to cover $1\frac{1}{2}$ cycles is $12m$

Distance to cover 1 cycle (wavelength) is $\frac{12}{1.5} = 8m$

Or $1\frac{1}{2}\lambda = 12m \Rightarrow \lambda = 8m$

(iii) From $V = \lambda f, \Rightarrow 330 = 8f \Rightarrow f = \frac{330}{8} = 41.25Hz$

4. The figure below represents a wave travelling with a velocity of $2\ ms^{-1}$.



Find the wavelength of the wave.

Time taken for a full wavelength is $T = 0.2s \Rightarrow f = \frac{1}{0.2} = 5Hz$

From $V = \lambda f, \Rightarrow 2 = 5\lambda \Rightarrow \lambda = 0.4m$

5. A radio waves travel at a velocity of $3.0 \times 10^8\ ms^{-1}$ in air. Calculate wavelength in air of the radio waves when transmitted at a frequency of $150MHz$.

Solution: $V = 3.0 \times 10^8\ ms^{-1}, f = 150MHz = 150 \times 10^6 = 1.5\ \times 10^8 Hz$

From $V = \lambda f, \Rightarrow 3.0 \times 10^8 = 1.5\ \times 10^8 \lambda \Rightarrow \lambda = \frac{3.0\times10^8}{1.5\times10^8} = 2m$

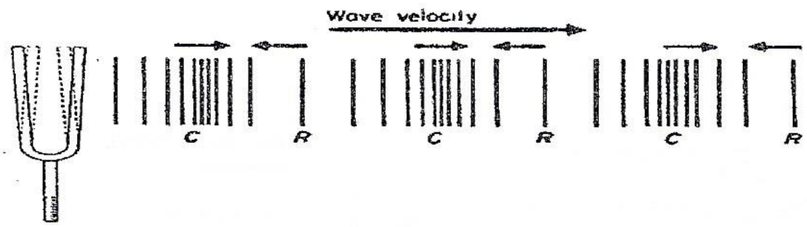
Thus the wavelength is $2m$.

ii. Longitudinal waves

A longitudinal wave is a wave in which direction of the vibrating particles oscillate in the same direction as the wave.

Examples of longitudinal waves include: sound waves, Waves in helical springs, Waves produced from pipes and string instruments, Waves produced when a tuning fork is hit at its prongs.

A longitudinal wave is represented as in the figure below



A longitudinal wave is comprised of two regions; compressions (C) and rarefactions (R). A compression is a region where the vibrating particles in a longitudinal wave are very close. In this region, pressure of particles of a medium is high hence high density.

A rarefaction is a region where the vibrating particles in a longitudinal wave are further apart. In this region, pressure of particles of a medium is low hence low density. Compressions and rarefactions are responsible for the energy transfer.

Note: a particle at the centre of compression moves through rest position in the same direction as the wave, while a particle at the centre of rarefaction moves through rest position in the opposite direction as the wave (*see figure above*).

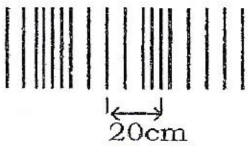
The distance between two successive compressions or rarefactions is the wavelength of a longitudinal wave.

Differences between longitudinal and transverse waves

Longitudinal waves	Transverse waves
- Direction of wave motion is same as that of vibrating particles - Have two regions; compressions and rarefactions	- Direction of wave motion is perpendicular to that of vibrating particles - Have two regions; crests and troughs

Calculations

1. The figure below shows a sound wave produced from a tuning fork vibrating at $800Hz$. Calculate the velocity of the wave.



$Distance\ between\ a\ rarefaction\ and\ compression\ is\ \frac{1}{2}\lambda = 20\ cm$

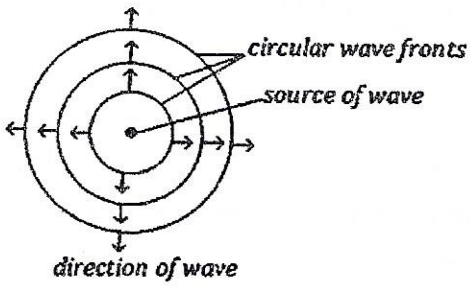
$\Rightarrow \lambda = 40cm = \frac{40}{100} = 0.40m$

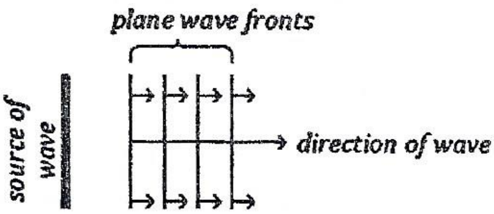
$V = \lambda f \Rightarrow V = 0.40 \times 800 = 320\ ms^{-1}$

Wave fronts

This is a surface of a wave form on which every particle transmitting the wave is at same distance from the source of the wave.

Wave fronts are either circular or plane.





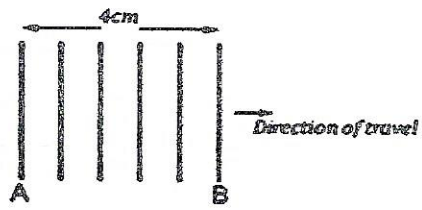
The distance between two successive wave fronts is called *wavelength* λ

Calculation: In the figure below,

i. find the wave length of wave fronts?

ii. If after 10 seconds A is in position B, calculate the frequency of the ripples

iii. What is the speed of the ripples?



Distance between successive crests is wavelength i.e $5\lambda = 4cm$

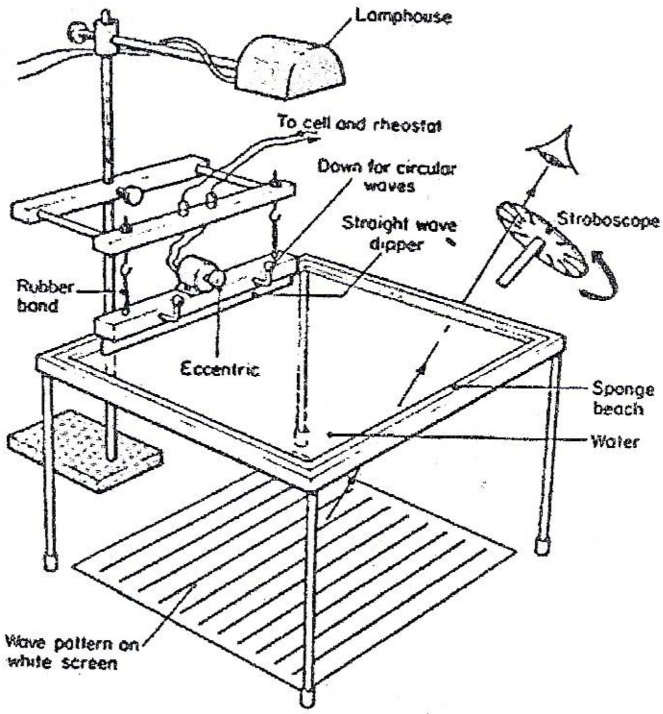
$\Rightarrow \lambda = \frac{4}{5} = 0.8\ cm = 8.0 \times 10^{-3}m$ *Time taken to travel a full wavelength is period*

i.e $5T = 10s \Rightarrow T = 2s \qquad f = \frac{1}{T} = \frac{1}{2} = 0.5Hz$

Speed $V = \lambda f = 8.0 \times 10^{-3} \times 0.5 = 4.0 \times 10^{-3}ms^{-1}$

Properties of waves

The properties of all types of waves can be obtained by studying the behavior of water waves in a ripple tank.



A ripple tank consists of a tray whose bottom is a transparent glass and its sides are sloppy and lined with a sheet of sponge in order to

- absorb energy of the ripples
- prevent deflection of waves by the sides

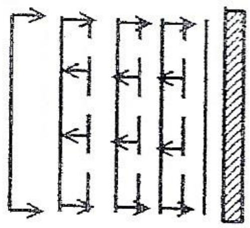
The shadow of the waves is formed on a white sheet of paper placed underneath.

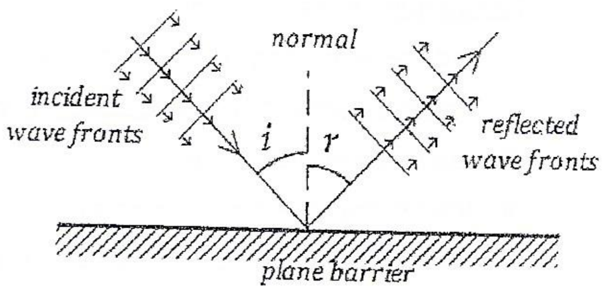
Circular wave fronts are produced by spherical ball attached and the plane wave fronts are produced by straight edged object attached to the bar.

The stroboscope when rotated is used to make waves appear stationary so that they are studied.

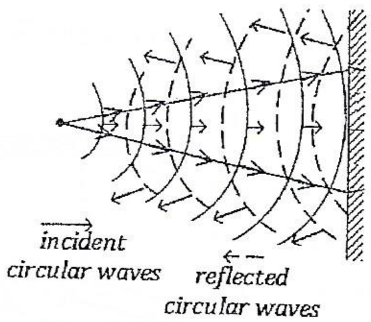
1. Reflection of waves: angle of incidence is equal to angle of refection of the wave fronts.

   (a) plane wave fronts incident at plane surfaces/obstacles/barrier

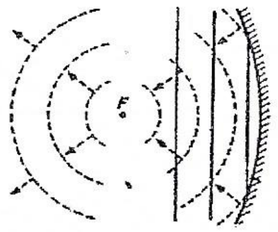


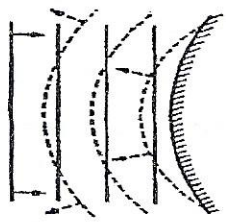


(b) circular wave fronts incident at plane surfaces/obstacles/barrier

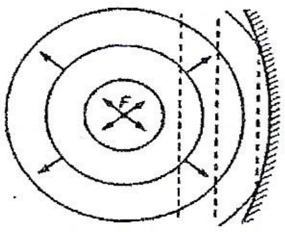


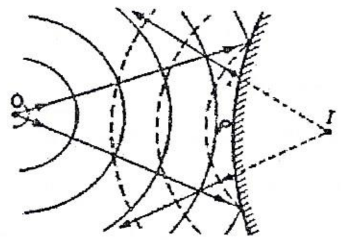
(c) plane wave fronts incident at curved obstacles:



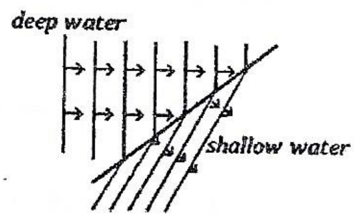


(d) circular wave fronts incident at curved obstacles:





2. <u>Refraction of waves</u>



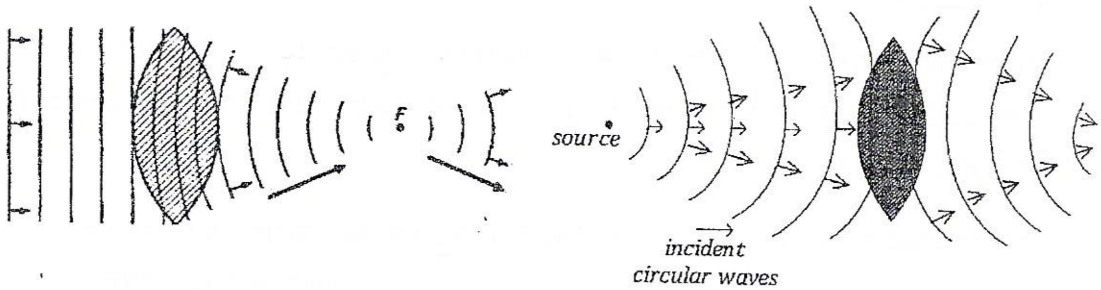
Refraction of waves at boundaries is caused by a change in wave speed as they travel from one medium to another medium of different densities.

(a) refraction on plane boundaries

Water waves are refracted at the boundary when travelling from deep to shallow water.

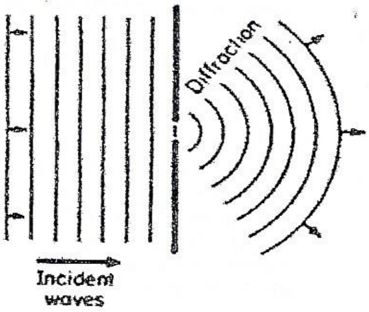
Wavelength and speed of water waves in shallow water reduces than in deep water.
The shallow water acts as a denser medium in which the speed of the wave is less.
Note: frequency of the waves remains constant as the wave travels from deep to shallow water.

(b) refraction on curved boundaries – lens shaped

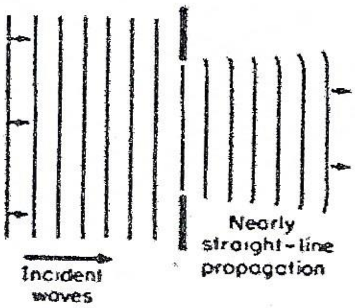


3. Diffraction of waves: This is the spreading of waves round edges of obstacles

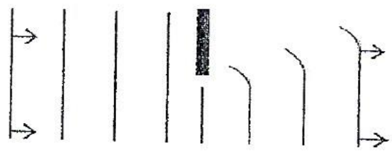
(a) At narrow gaps



(b) wider gaps



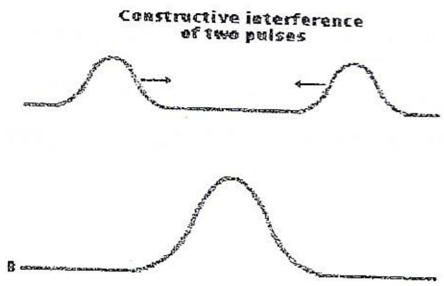
(c) single barrier

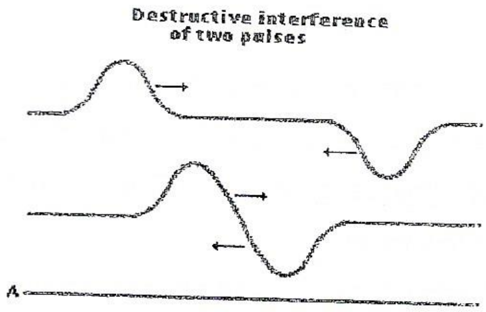


Note: The wavelength of light is exceedingly small and so diffraction of light waves is hardly seen.

4. Interference of waves:

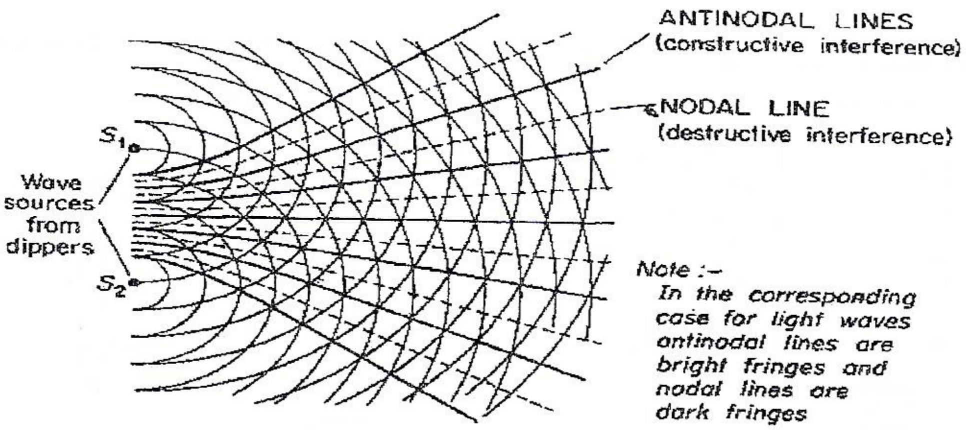
This is overlapping of two separate identical waves travelling in the same direction.
When two waves in phase are superposed i.e crests from one source arrive at the time as crests from the other source, a large crest is produced and constructive inference occurs.





When two waves out of phase are superposed i.e crests from one source arrive at the time as troughs from the other source, a zero disturbance is produced and destructive inference occurs.

Interference can also be seen when two sources are placed near each other.



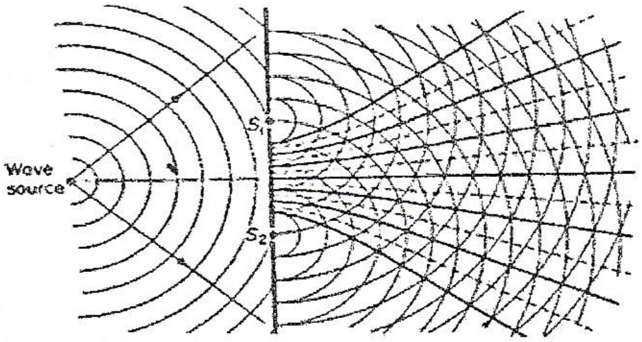
Antinodal lines are lines of increased disturbance and it is where constructive interference occurs.

Nodal lines are lines of zero resultant disturbances and it is where destructive interference occurs.

Note:

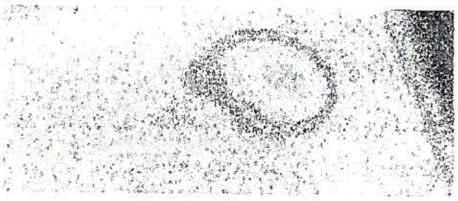
- When distance between the sources is reduced, points of maximum (Antinodal points) and zero disturbances (nodal points) are further apart.
- When the frequency of the source increases antinodal points come so close to each other. Nodal points too, become so close.

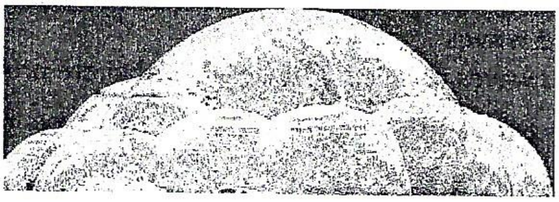
Similar interference pattern is obtained when straight or circular waves are incident to a barrier with two narrow gaps.



Note: If a light source is used, we observe increased brightness along the antinodal lines and increased darkness along the nodal lines.

The rainbow colors of a film of oil on water are a result of different wavelengths of visible light interfering with each other at that point on the bubble's surface.



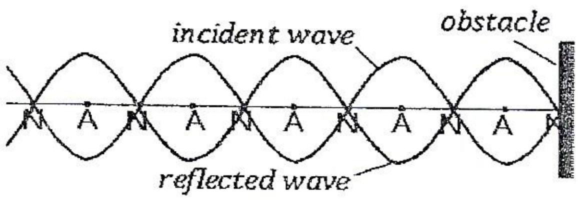


A stationary/standing wave

This is a wave that is formed when two progressive waves of equal amplitude, wavelength and frequency travelling in opposite directions overlap.

Examples of stationary waves are waves on stringed instruments (guitar), waves inside pipes or wind instruments (flute), light waves inside a laser.

Stationary waves are represented by the figure below



A stationary wave has two points – nodes (N) and antinodes (A).

Nodes are points on a stationary wave where particles are permanently at rest and their amplitude is zero.

Antinodes are points on a stationary wave where particles vibrate with maximum amplitude.

The distance between two successive nodes or antinodes is $\overline{AA} = \overline{NN} = \frac{\lambda}{2}$

Example: The distance between two successive antinodes on a standing wave is 3cm. If the distance between the source and the reflector is 24cm, find

(i) the wavelength of the wave

(ii) number of loops

Solution:

(i) *distance between two successive antinodes* $\overline{AA} = \frac{\lambda}{2} = 3 \Rightarrow \lambda = 6\ cm$

$Thus\ wavelength = 6\ cm$

(ii) a complete wavelength corresponds to 2 loops

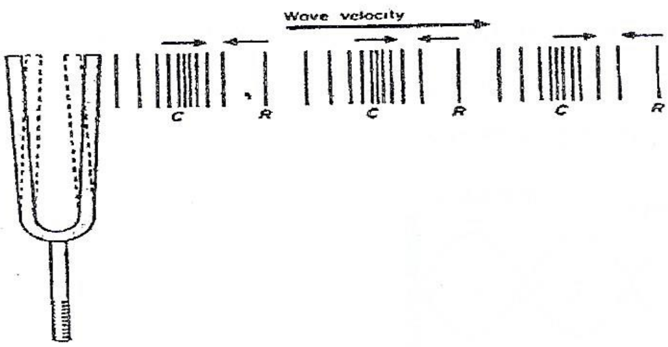
$i.e\ \ 6cm \rightarrow 2\ loops \Rightarrow 24\ cm \rightarrow \frac{2}{6} \times 24 = 8\ loops$ *Number of loops are 8*

Sound waves

Sound waves are longitudinal waves that are produced when a medium vibrates.

When a prong of a tuning fork is hit, air layers it to vibrate. This in turn causes next air layer to vibrate. As a result a series of compressions and rarefactions of invisible air molecules around it reach the ear drum causing it to vibrate at the same frequency as that of a tuning fork. Consequently, sound is heard.

In this example, energy from the source of vibration is propagated through the air by the vibration if air layers.



Properties of sound waves

- They require a medium for their transmission
- They are longitudinal in nature.
- They undergo reflection, refraction, diffraction and interference.
- They travel at a lower speed of $330ms^{-1}$ in air than light.

Experiment to show interference of sound waves

- Two loud speakers of the same power rate are placed fairly nearby each other, so that they send out sounds of equal intensity.

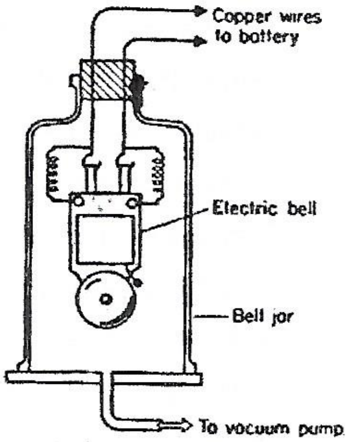
- The observer walks along a line parallel to the speakers and hears loud and soft sounds alternately.

  When loud sound is heard constructive interference has occurred and when soft sound is heard destructive interference has occurred.

Experiment that shows that sound needs a medium for its transmission

- Air is pumped out of the glass jar containing ringing electric bell.
- Disappearing sound is heard though the hammer is still seen hitting the gong.
- When all air is pumped out no sound is heard and the hammer is still seen hitting the gong.

  This shows that sound needs a medium for its transmission.



Factors affecting speed of sound in gases

- Temperature of gas: at constant pressure, increase in temperature of the gas decreases its density hence increase in speed of sound in it. [$c \propto \sqrt{T}$ where T is the temperature of the gas in kelvins and c is the speed]
- Density of gas: at constant pressure sound travels faster in gases of lower density.

  [$c \propto \sqrt{\frac{pressure}{density}}$
- Humidity: water vapour is less dense than oxygen and nitrogen thus moist air is slightly less dense than dry air. Therefore speed of sound is greater in moist air than in dry air.
- Wind : speed of sound increases if it moves in the same direction as wind.

In solids and liquids

Any medium that has particles that can vibrate transmits sound. Sound travels more quickly through a medium in which the atoms are strongly bound together since sound waves tend to travel long distances before they die away.

Therefore sound travels faster in solids than in liquids and air. [$330ms^{-1}$ in air, $1500ms^{-1}$ in water and $5000ms^{-1}$ in steel]

Limits of audibility

Human ear can hear sounds of frequency between 20 Hz – 20 kHz. Above 20 kHz the waves are called ultrasound. Dogs detect these sounds of higher frequencies. Bats emit and detect ultrasounds and can locate and dodge obstructions when flying in the dark.

Applications of ultrasounds

- They are used in quality control i.e to detect the level of liquid, powder or any material in a container. A pulse of ultrasound is transmitted from a sensor fixed at a height. If the level of the content in the container is lower than normal, the time between transmission and reception of the ultrasound pulse is increased, and the container is rejected.
- They are used in pre-natal scanning i.e to examine the development of a fetus by sending ultrasound pulses into the body through a transmitter. The echoes reflected from any surface within the body are received, and the depth of the reflecting surface within the body may be known. A real-time image of the fetus can be produced.
- in measuring the depth of the water by echo method
- to detect tumors, damage, or abnormalities in the liver, kidney, ovaries, eyes, and other organs.

Echoes

An echo is a reflected sound wave from obstacles.

Conditions for the formation of Echoes

(i) The minimum distance between the source of sound and the reflecting body should be at least 17.2 metres.

(ii) The wavelength of sound waves should be less than the height of the reflecting body.

(iii) The intensity of sound should be sufficient so that it can be heard after reflection.

Note: When the obstacle is nearer the source of sound waves, echo joins the original sound. This makes the original sound appears to be prolonged (persistence of sound after its production is stopped). This effect is called ***reverberation***.

Reverberation is the effect caused when the incident and reflected sound occur almost at the same time creating an impression of a prolonged incident sound.

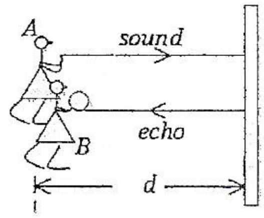
Reverberation time is the time taken for sound of specific intensity to die away until it becomes inaudible.

Reverberation is minimized by; cushioning seats, covering walls with soft materials such as cotton clothes and blankets or using carpets. These materials absorb sound avoiding echoes which would result from reflected sound.

This however, makes music or speeches appear to be weaker. Some reverberation is useful

- it prevents a hall from being acoustically dead [music not amplified]
- improves the hearing obtained in all parts of the building

Measurement of speed of sound by echo method



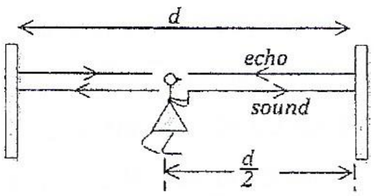
- Two people A and B stand at the same point and at a known distance, d, from the tall building.
- A claps and at the same time B starts timing with using a stop clock.
- When echo is heard, B stops timing and the time taken, t, is recorded.
- Speed, V, of the wave is obtained from $V = \frac{2d}{t}$

Calculation

1. A person stands at a distance of 990m away from a tall building and makes a loud sound. He hears echo after 6 seconds. Calculate the speed of sound.

   $V = \frac{2d}{t} = \frac{2 \times 990}{6} = 330ms^{-1}$

2. A girl standing midway between two cliffs makes a loud sound. She hears the first echo after 3 seconds. Calculate the distance between the cliffs if the velocity of sound in air is $330ms^{-1}$



   Solution *Let distance between cliffs be d,*

   Distance traveled by sound for to and fro $= \frac{d}{2} \times 2 = d$

   Speed of sound after the first echo; $330 = \frac{d}{3} \quad \Rightarrow d = 990m$

   [Since the girl was standing midway sound travelled equal distance in same time]

3. A student standing between two vertical walls of cliff and 480m from the nearest cliff shouted. He heard the first echo after 3seconds and the second echo after 5seconds. Calculate the velocity of sound in air and the distance between the cliffs.

Solution: *after the first echo*; $V = \frac{2\times480}{3} = 320ms^{-1}$

Let distance between cliffs be d,

After the second echo, distance traveled by sound for to and fro

$$= 2 \times (d - 480) = 2d - 960$$

Thus speed of sound after the second echo; $320 = \frac{2d-960}{5} \Rightarrow d = 1280m$

Questions

1. A boy standing 300 m away from a high vertical wall makes a loud sound of frequency 60 Hz. Calculate the wavelength of the sound waves if the boy hears the echo after 2 seconds.
2. Echo sounding equipment on a ship receives sound pulses reflected from the sea bed 4 seconds after they were sent from it. The speed of sound in water is 1500 ms^{-1}. Calculate the depth of water.
3. A child stands between two cliffs and makes a loud sound. If the child hears the first echo after 1.5 s and then the second echo after 2 s, find the distance between the two cliffs (velocity of sound in air is $320ms^{-1}$) [560 m]

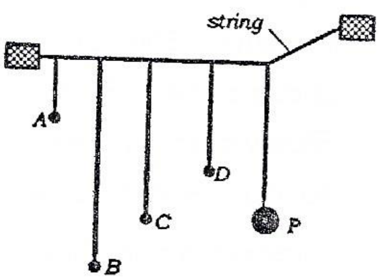
Resonance: is a phenomenon where vibrations of one body are caused by vibrations of another body by which both bodies vibrate with the same natural frequency.

Or: This is a phenomenon in which a body is set to vibrate at its own natural frequency due to impulses from another body vibrating at the same frequency

If a body is set into resonance, it oscillates with maximum amplitude.

Experiment to show resonance

- Pendulum bobs A, B, C and D of different lengths are suspended on a string as in the figure below.
- A pendulum bob, P, of length as C is set swinging in a perpendicular plane containing other bobs.
- It is observed that all other bobs vibrate but C, swings with a larger amplitude.



Note: Small impulses in the string reach C at equal intervals to its own natural period.

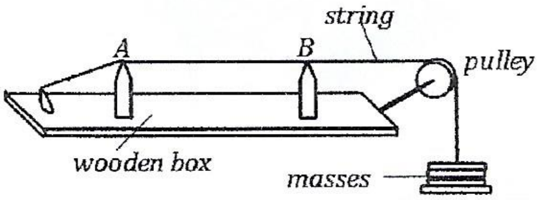
Resonance may lead to collapse of tall buildings, bridges when they resonate with strong winds or earthquakes.

Examples of resonance

1. Tuning a radio changes the frequency of the radio waves until it is exactly same as frequency of the waves at a transmitting station.
2. If a heavy vehicle is passing by a house, windows shake.
3. In cars, drumming sound is made due to resonance between the car's body and the engine vibrations.

Factors affecting frequency of vibrating string

These factors can be demonstrated by using a sonometer.



- Length of string: a short string of AB produces waves of high frequencies $f \propto \frac{1}{l}$
- Force in the string (tension): a highly stretched string produces waves of high frequencies $f \propto \sqrt{T}$
- Thickness (mass per unit length) of string: a thick string produces waves of low frequencies $f \propto \frac{1}{d}$

Sound characteristics

1. Pitch: this is highness or lowness of sound reaching the ear. Sounds of low wavelength have higher frequencies and high pitch. Children's voice has a high pitch.

2. Loudness/intensity: this is the magnitude of sound energy reaching the ear per second. Louder sounds have larger amplitudes. Loudness decreases with distance from the source of sound waves.

   Intensity increases with density of the medium in which it vibrates. Loud music is heard at night than in the day since cool air is denser than warm air.

3. Quality: this is characteristic of a note that distinguishes it from another note of same pitch and loudness. This is due to the presence of a group of higher pitched notes called overtones that accompany the main note.

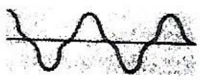
A note or tone is defined as a sound of regular frequency. Music is an artful arrangement of sound

The number and strength of overtones decides the quality of a note of sound from particular instruments.

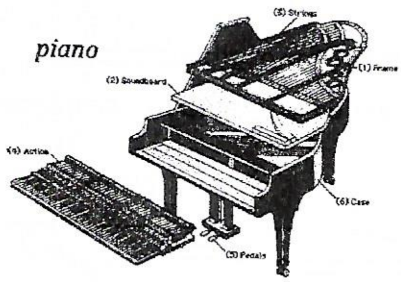
A violin for example, has more and stronger higher overtones than a piano.

Violin

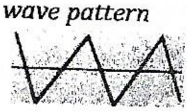
wave pattern



piano



wave pattern



Similarities of sound waves and light waves

- They both carry energy and
- They both undergo reflection, refraction, diffraction and interference.

Differences between sound waves and light waves

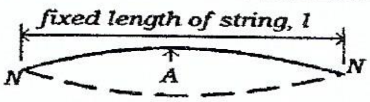
Sound waves	Light waves
- they are longitudinal waves	- they are transverse wave
- they need a medium for transmission	- they travel in vacuum
- they can't be polarised	- they can be polarised
- they are produced by vibration of matter	- they are caused by both electric and magnetic vibrations
- travel at lower speeds($330\ ms^{-1}$) in air.	- they travel at higher speeds ($3 \times 10^8 ms^{-1}$) in vacuum.

Standing waves on a stretched string

When a tight string is plucked in the middle, transverse waves are produced and a loud sound is heard. First resonance occurs and a strongest audible tone of frequency called *fundamental frequency* $\left(f_1 = \frac{V}{\lambda}\right)$ is heard.

When vibrations are vigorous, sounds of different notes, frequencies and wavelengths are produced but the speed of sound waves remains constant.

The distance between two successive nodes or antinodes is $\frac{\lambda}{2}$.

Fixed length of string	Wavelength	Frequency	Harmonic number
 $l = \frac{\lambda}{2}$	$\lambda = 2l$	$f = \frac{c}{\lambda} \Rightarrow f_1 = \frac{c}{2l}$ (1st resonance)	1
 $l = \lambda$	$\lambda = l$	$f_2 = \frac{c}{l} = 2 \times \frac{c}{2l}$ $\Rightarrow f_2 = 2f_1$ (2nd resonance) (1st overtone)	2
 $l = 3\frac{\lambda}{2}$	$\lambda = \frac{2}{3}l$	$f_3 = \frac{c}{\frac{2}{3}l} = 3 \times \frac{c}{2l}$ $\Rightarrow f_3 = 3f_1$ (3rd resonance) (2nd overtone)	3

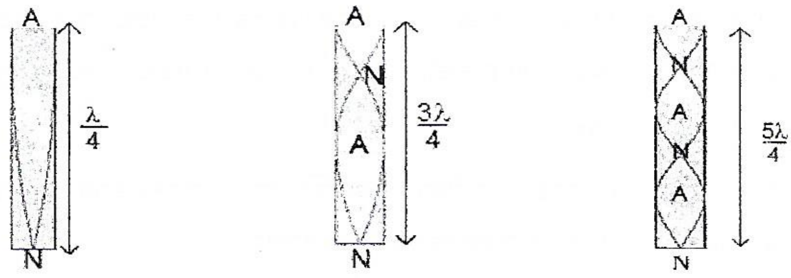
A series of frequencies that are exact multiples of the fundamental regular frequency is called harmonics/overtones.

Standing waves in pipes and tubes

A disturbance of air at one end of pipes and tubes causes sound waves to reflect from the other end forming standing/stationary waves.

The distance between successive nodes or antinodes is $\frac{\lambda}{2}$ and thus distance between a node and antinode is $\frac{\lambda}{4}$.

(a) Closed tube at one end



First resonance second resonance third resonance

(b) Open pipe

First resonance second resonance

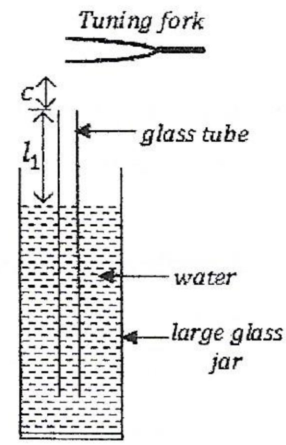
Example

A person blows hard across the mouth of an open pipe of length 0.3m. Find the fundamental interval frequency. (Speed of sound in air is $330ms^{-1}$)

Solution: for fundamental frequency, $l = \frac{\lambda}{2} = 0.3 \Rightarrow \lambda = 0.6m$

From $f = \frac{v}{\lambda}, \Rightarrow f = \frac{330}{0.6} = 550Hz$. *Fundamental frequency is* $550Hz$

- Experiment to determine speed of sound in air by resonance tube



- A vibrating tuning fork of known frequency f is held near and above a short air column in a tube dipped in water.
- The tube is raised slowly until a loud sound is heard (first position of resonance is reached).
- Length, l_1 of air column is measured.
- The tube is raised further until a second position of resonance is obtained.
- Length, l_2 of air column is measured.
- The speed of sound in air is calculated from $V = 2f(l_2 - l_1)$

Alternatively

- A vibrating tuning fork of known frequency f is brought near the mouth of a long tube full of water.
- A tap is opened slowly until a first loud sound is heard
- Length, l_1 of air column is measured and recorded.
- A tap is again opened slowly until a second loud sound is heard
- Length, l_2 of air column is measured and recorded.
- The speed of sound in air is calculated from $V = 2f(l_2 - l_1)$

Theory

At first position of resonance, $\frac{\lambda}{4} = l_1 + c \dots\dots\dots (i)$

Where c is end correction (since antinode is not exactly at the top of the tube some distance c is added on l_1)

At second position of resonance, $\frac{3\lambda}{4} = l_2 + c \dots\dots\dots (ii)$

Subtracting the two equations $\Rightarrow \frac{3\lambda}{4} - \frac{\lambda}{4} = l_2 - l_1 \Rightarrow \frac{\lambda}{2} = l_2 - l_1 \Rightarrow \lambda = 2(l_2 - l_1)$

From $V = \lambda f \Rightarrow V = 2f(l_2 - l_1)$

Example

1. A long tube is partially immersed in water and a tuning fork of frequency 425Hz is sounded and held above it. If the tube is gradually raised, find the length of air column when resonance first occurs. (Neglect the end correction, speed of sound in air= $340\ ms^{-1}$).

   Solution: $V = 340\ ms^{-1}, f = 425Hz;$

   From $V = \lambda f \Rightarrow 340 = 425\lambda \Rightarrow \lambda = \frac{340}{425} = 0.8m$

   At first position of resonance, $\frac{\lambda}{4} = l \Rightarrow l = \frac{0.8}{4} = 0.2\ m.$ *The length of air column*$= 0.2m$

2. A tuning fork of frequency 550Hz is sounded and placed near the mouth of a closed resonance tube containing water. The first loud sound is heard when the length of the air column above the water level in resonance tube is 15 cm. Calculate the speed of sound in air.

   Solution: $V = ?\ ms^{-1}, f = 550Hz;$

   At first position of resonance, $\frac{\lambda}{4} = l \Rightarrow \lambda = 4l = 4 \times 0.15 = 0.6\ m$

From $V = \lambda f \Rightarrow V = 550 \times 0.6 = 330ms^{-1}$

Speed of sound in air is $330ms^{-1}$

3. A vibrating tuning fork is held above the open end of a tube which is partially immersed in water. A loud sound is obtained from the tube when the length from the open end to water is 28.5 cm and again when it is 94.0 cm. If the frequency of the tuning fork is 256 Hz, calculate the speed of sound in air.

At first position of resonance, $l_1 = 28.5\ cm = 0.285\ m$

At second position of resonance, $l_2 = 94.0\ cm = 0.940\ m$

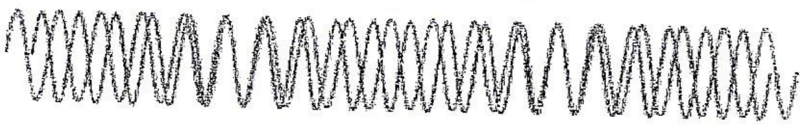
Using $V = 2f(l_2 - l_1) = 2 \times 256(0.940 - 0.285) = 335.36\ ms^{-1}$

BEATS

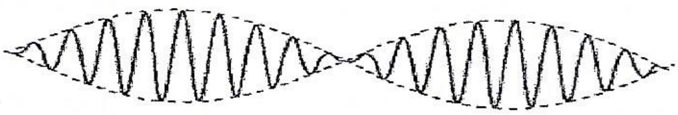
When two notes of nearly equal pitch are both sounded together, a regular rise and fall occurs in the loudness of the tone heard.

Beats are the periodic alternations in loudness due to superposition of two notes of nearly same frequencies.

The beat frequency is equal to the difference in frequency of the two waves.



The resulting wave is shown in the figure below



Questions

1. (a) Give two differences between transverse waves and longitudinal waves

(b) Two identical sources are made to produce circular waves in a ripple tank.

(i) Explain with aid of a diagram how interference fringes may be obtained

(ii) What happens when distance between the sources is reduced?

(d) A vibrator of frequency 5Hz produces circular waves in a ripple tank. If the distance between any two successive crests is 3cm, what is the speed of the waves?

(e) (i) Explain why echoes are not heard in small rooms

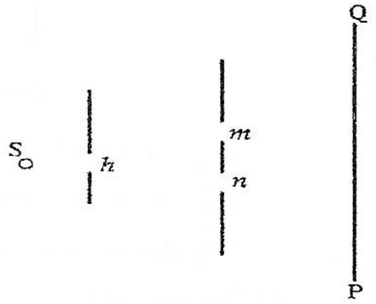
(ii) Describe a simple method of determining the speed of sound in air.

2. A person standing from a vertical wall beat drum and hears the echo after 2s. Calculate the distance between the person and the wall. [speed of sound in air is $330ms^{-1}$]

3. (a) Define constructive interference as applied to sound waves

(b) The figure below shows a source, S, of sound behind a barrier with single hole, h, another barrier of two holes m and n.

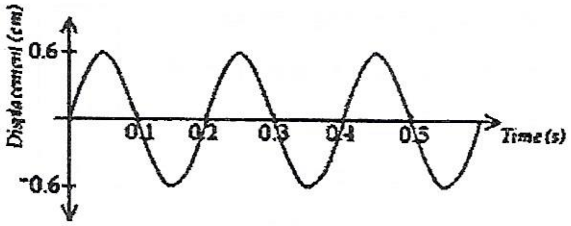
A sound detector is moved a line PQ.



(i) With the aid of a diagram explain what is detected

(ii) What is the significance of m and n ?

(e) The figure below shows a displacement – time graph of a wave travelling through water with a velocity of $2.5mms^{-1}$.



Find the

(i) Amplitude (ii) Period

(iii) Wavelength of the wave.

(f) What are the conditions for the formation of a standing wave with the wave in (c) above?

4. (a) Explain the following observations

(i) Sound from a distant place is louder at night than during the day time.

(ii) An observer can hear sound from a source which is behind a building

(iii) Speed of sound is higher in solids than in air.

(b) Draw a diagram to show how circular water ripples are reflected from the concave and convex reflectors

(c) (i) What is meant by a stationary wave?

(ii) Give two conditions for stationary waves to be formed

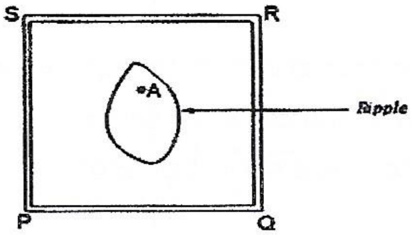
(iii) Name one musical instrument which produces stationary waves.

5. (a) state the changes detected when listening to a sound note if the

(i) amplitude is raised (ii) frequency is increased

(b) Give three differences between light waves and sound waves

(c) The figure below shows a ripple tank PQRS whose one side is raised. A ripple started by touching the water at A and after one second it had the shape shown.

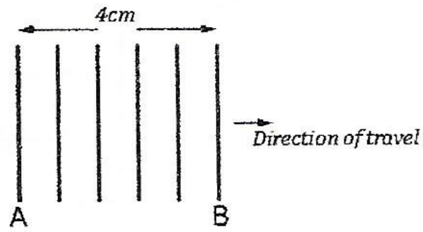


(i) State which side of the tank is raised*(SR)*

(ii) Explain the shape of the ripple.

(Ripples travel more slowly towards SR than PQ thus R is shallower than PQ)

(d) The lines in the figure below show crests of straight ripples formed in a ripple tank



(i) What is the wave length of the ripples?

(ii) If after 10seconds A is in position B, calculate the frequency of the ripples

(iii) What is the speed of the ripples?

Distance between successive crests is wavelength

i.e $5\lambda = 4cm \quad \Rightarrow \lambda = 8.0 \times 10^{-3}m$

Time taken to travel a full wavelength is period i.e $5T = 10s \Rightarrow T = 2s$

$f = \frac{1}{T} = \frac{1}{2} = 0.5Hz$ *Speed* $V = \lambda f = 8.0 \times 10^{-3} \times 0.5 = 4.0 \times 10^{-3}ms^{-1}$

6. (a) State two differences between sound waves and light waves

(b) (i) Describe an experiment to show that sound waves are mechanical

(ii) Explain why the speed of sound is higher in solids than air

(iii) Two students P and Q stand in a straight line at distances 330m and 660m respectively from a high wall. Find the time interval taken by P to hear the first and the second sounds when Q makes a loud sound. (Speed of sound in air $330ms^{-1}$])

(c) A tuning fork is held over a tube containing water. If the frequency of the tuning fork is 320Hz and the speed of the sound in air is $330ms^{-1}$, find the

(i) wavelength of the sound wave produced

(ii) shortest length for which resonance occurs.

7. (a) (i) Draw a diagram to show how plane waves incident from a concave reflector are reflected.

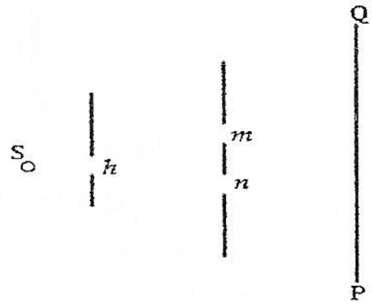
(ii) If the velocity of the waves is $320ms^{-1}$and the distance between two successive crests is 10cm, find the period of the waves.

2. A person standing from a vertical wall beat drum and hears the echo after 2s. Calculate the distance between the person and the wall. [speed of sound in air is $330ms^{-1}$]

3. (a) Define constructive interference as applied to sound waves

   (b) The figure below shows a source, S, of sound behind a barrier with single hole, h, another barrier of two holes m and n.

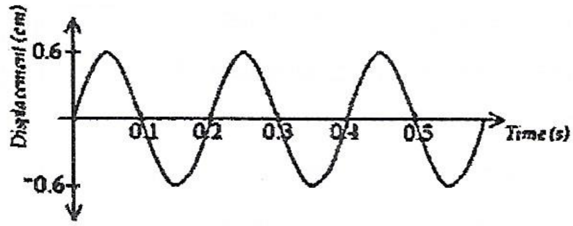
   A sound detector is moved a line PQ.



   (i) With the aid of a diagram explain what is detected

   (ii) What is the significance of m and n ?

   (e) The figure below shows a displacement – time graph of a wave travelling through water with a velocity of $2.5mms^{-1}$.



   Find the

   (i) Amplitude (ii) Period

   (iii) Wavelength of the wave.

   (f) What are the conditions for the formation of a standing wave with the wave in (c) above?

4. (a) Explain the following observations

   (i) Sound from a distant place is louder at night than during the day time.

   (ii) An observer can hear sound from a source which is behind a building

   (iii) Speed of sound is higher in solids than in air.

   (b) Draw a diagram to show how circular water ripples are reflected from the concave and convex reflectors

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   (ii) Give two conditions for stationary waves to be formed

   (iii) Name one musical instrument which produces stationary waves.

5. (a) state the changes detected when listening to a sound note if the

   (i) amplitude is raised (ii) frequency is increased

   (b) Give three differences between light waves and sound waves (b)(i)Describe a simple echo method for determining the speed of sound in air.

(ii) An echo – sounding equipment on a shop receives sound pulses reflected from the sea bed 0.02s after they were sent out from it. If the speed of sound waves in water is $150ms^{-1}$, calculate the depth of the water under the ship.

8. (a)(i) Describe a simple experiment to determine the velocity of sound in air.

(ii) What factors would affect the velocity of sound obtained from the experiment above?

(b) Explain why a musical note played on a piano sounds different from that played from a guitar.

(c)(i) Calculate the wavelength of sound waves of frequency $3.3kHz$ and speed of $330ms^{-1}$.

(ii) State four differences between sound and radio waves.

9. (a) State three differences between sound waves and light waves

(b) (i) Explain how stationary waves are formed.

(ii) State three main characteristics of stationary waves

(c) (i) Define the terms frequency and wavelength as applied to sound.

(ii) Describe an experiment to demonstrate resonance in sound

(d) A vibrator of frequency 5Hz produces circular waves in a ripple tank. If the distance between 10 successive crests is 37.8 cm, what is the;

(i) wavelength of the waves?

(ii) velocity of the waves

10. (a) Define the following terms as applied to wave motion: frequency and wavelength

(b) What are transverse waves?

(c) A radio station transmits signals at a frequency of 103.7MHz. Find the wavelength of the signals and state any assumption made.

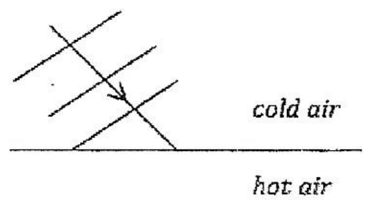
(d) Draw a diagram to show the pattern for a straight water wave passing through a narrow slit.

(e) Describe an experiment to demonstrate that sound waves require a medium for their propagation.

Explain how sound waves travel through air.

11. (a) What is meant by the following: pitch and audio – range?

(b) The figure below shows sound waves travelling from a region of cold to a region of hot air.



(i) Copy and draw the wave pattern in hot air showing the direction of travel.

(ii) Name the wave phenomenon shown by the wave

(iii) Explain why the wave behaves the way you have drawn in the hot air

(c) A student observed the time interval between the lightning flash from a distant storm and the accompanying thunder as 4 beats of his pulse. If his pulse rate is 72 beats per minute, determine the

(i) time in seconds taken for him to hear the thunder from the instant he sees the flash.

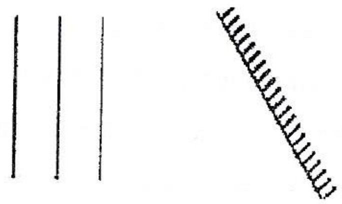
(ii) distance of the storm from the observer.

(Take the speed of sound in air as $330ms^{-1}$)

12. (a)(i) What is meant by sound?

(ii) State two factors that affect the motion of sound waves

(c) Plane waves move towards a reflector as shown in the figure below



Copy and complete the diagram to show the motion of the waves after reflection

(d) State the effect of constructive interference of

(i) sound waves

(ii) light waves

(g) Describe an experiment to demonstrate resonance in a closed pipe