PHYSICS NOTES FOR ‘O’ LEVEL

(S.3 WORK)

WAVES

A wave is a disturbance which travels through a medium and transfer energy from one point to another without causing any permanent displacement of the medium itself e.g. water waves, sound waves, waves formed when a string is plucked

WAVE MOTION

When a wave is set up on the medium, the particles of the medium from about a mean position as the wave passes. The vibrates are passed from one particle to the next until the final destination is reached

TYPES OFWAVES

Two broad types -:

a) progressive waves (stationary waves)
b) mechanical and electromagnetic waves).

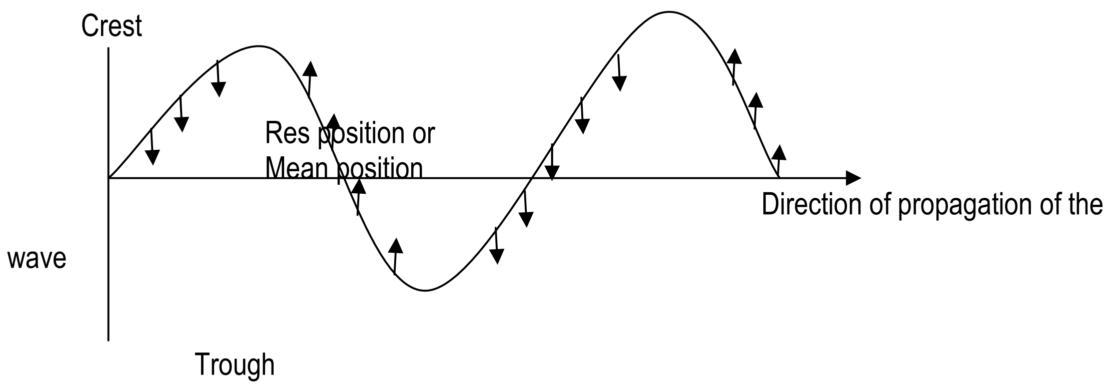
PROGRESSIVE WAVES

Is a wave which moves away from its source through a medium and spreads out continuously? There are two kinds of progressive waves namely:

i) Transverse waves
ii) Longitudinal waves

i) TRANSVERSE WAVES

These are waves in which particles vibrate perpendicular to the direction of propagation of the wave, e.g. water waves, light waves, waves formed when a rope is moved up and down.



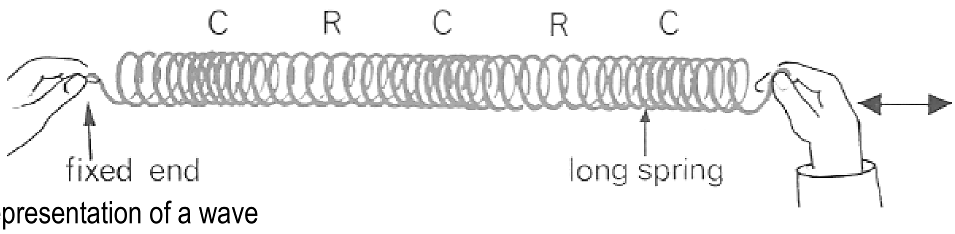
ii) LONGITUDINAL WAVES

These are waves in which the particles of media vibrate in the same direction as wave

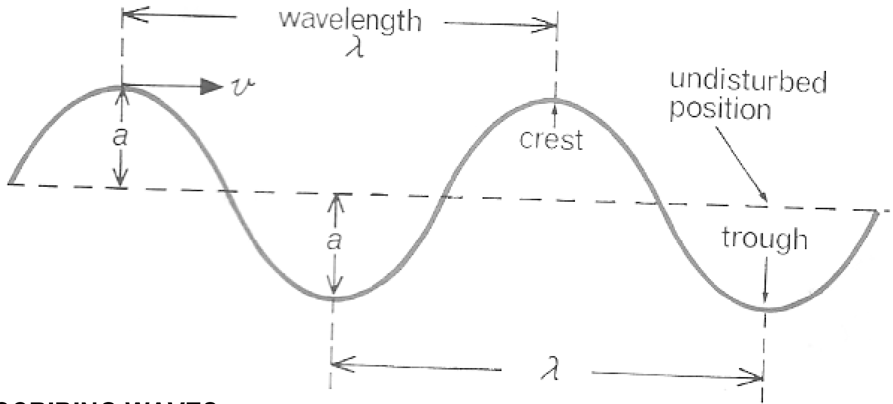
OR

These are waves in which the particles of the media vibrate parallel to wave motion e.g. sound waves, waves from a slinky spring.

Longitudinal waves travel by formation of compressions and rare factions. Regions where particles crowd together are called compressions and regions where particles are further apart are called rare factions.



General representation of a wave



TERMS USED IN DESCRIBING WAVES

1 **<u>Rest position (Mean position)</u>**

This is the line OQ where particles are stationary or displacement of a particle is 0

2 **<u>Amplitude (a)</u>**

This is the maximum displacement of a particle from the rest position.

3 **<u>Cycle</u>**

This is one complete oscillation of the wave.

4 **Wave length (λ)**

- This is the distance between two successive crests or two successive troughs. (Transverse wave)
- This is the distance covered by one complete cycle of a wave.
- This is the distance between two particles of a wave vibrating in phase e.g. x$ y or p $ Q.
- This is the distance between two successive compressions or rare factions.

5 **Period**

Is the time taken by a wave to perform one complete cycle, i.e. T= $\frac{t}{n}$ where n is number of cycle.

6 **Frequency**

This is the number of cycles a wave completes in one second i.e. F= $\frac{n}{t}$ S.I. unit = Hertz (H_z)

7 **Wave front**

Is any line or section taken through an adversing wave in which all the particles are in the same phase.

8 **Crest**

It is the maximum displaced point a above the line of 0 (zero) disturbance.

9 **Trough**

It is the maximum displaced point below line of zero disturbance.

10 **Wave velocity**

It is the distance which the wave travels in one second in a given direction. S.I unit m/s.

THE WAVE EQUATION

From the wave speed v= $\frac{d}{t}$ …..(i)

If the wave describes n cycles in time t_1

Then the distance covered d= nλ…. (ii)

Substituting for d in … (i) → v= $\frac{d}{t}$

$$V=\frac{n\lambda}{t}$$

But f= $\frac{n}{t}$ hence v= fλ wave equation

Examples

A radio station produces waves of wave length 10m. If the wave speed is 3×10^8 m/s, calculate

(i) Frequency of radio wave.

(ii) Period t

(iii) Number of cycles completed in 10^8

(i) λ = 10m , v= 3×10^8 m/s t= 10s

$v = f\lambda \rightarrow f = \frac{v}{\lambda}$

$= \frac{3\times 10^8}{10}$

$= 3\times10^{-1}\ H_z$

(ii) period $T = \frac{1}{f} = \frac{1}{3\times10^{-1}}$

$= \underline{3.3\times10^{-8}}$

(iii) Number of cycles $\rightarrow f = \frac{n}{t} \rightarrow n = f\,t$

$= 3\times10^{-1}\times 10$

$= \underline{3\times10^8 \text{ cycles}}$

2 The distance between 10 consecutive crests is 36cm. Calculate the velocity of the wave. If the frequency of the wave is $12H_z$.

V= f λ   but   d = (n – 1) λ

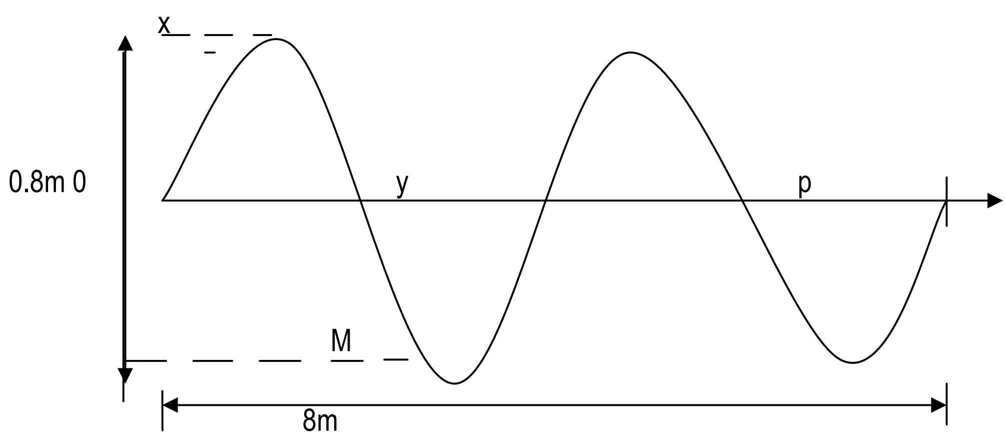
= 12×0.04   = (10- 1) λ

= 0.48m/s   0.36 = 9 λ

λ = $\frac{0.36}{9}$

= <u>0.04m</u>

3. The diagram below shows a wave travelling in water.



(a) Name (i) Any two points on the wave which are in phase

(ii) Labeled m and x

(b) (i) Determine the amplitude of the wave.

(ii) If the speed of the wave is 80m/s. Determine the frequency of the wave.

Questions

A vibrator produces waves which travel 35 m in 2 seconds. If the waves produced are 5cm from each other, calculate;

(i) the wave velocity

(ii) wave frequency

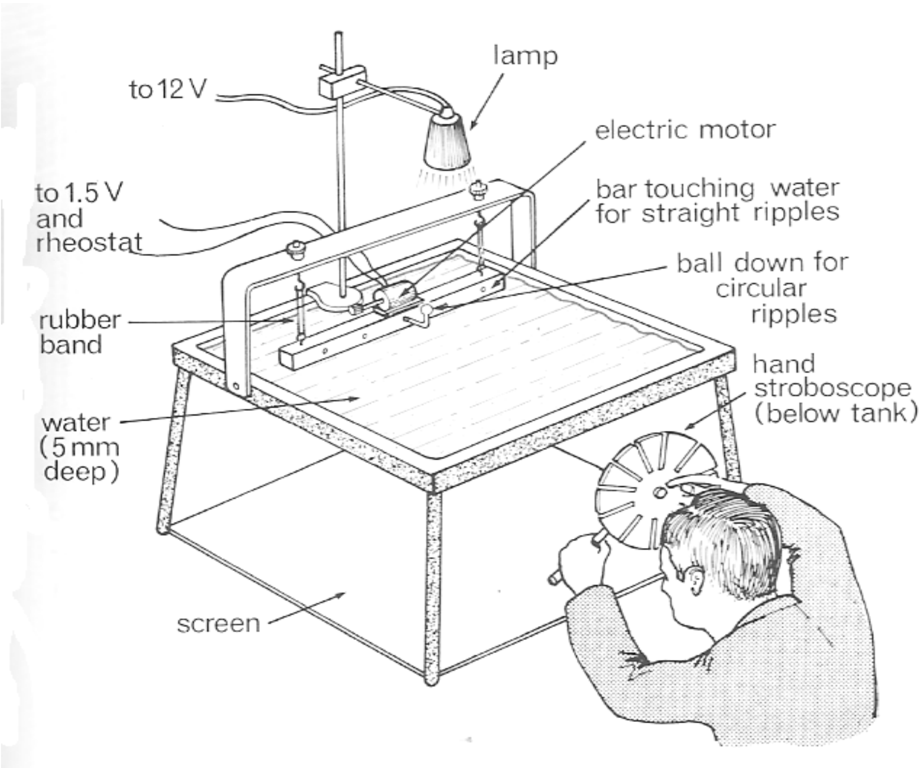
(i) v= f λ $\longrightarrow$ f = $\frac{v}{\lambda}$ = $\frac{35}{2}$

= $\frac{14.7}{1}$ = $\frac{v}{5}$

14.7 × 5 = v

<u>7^3 .5m/s = v</u>

THE RIPPLE TANK



A ripple tank is an instrument used to study water wave properties. It is a shallow glass trough which is transparent. The images of the wave are projected on the screen which is placed below it.

The waves are produced by means of a dipper which is either a strip of a metal or a sphere. When the dipper is moved up and down by vibration of a small electric motor attached to it. The sphere produces circular wave fronts and the metal strip is used to produce plain waves.

A stroboscope helps to make the waves appear stationery and therefore allows the wave to be studied in detail.

N.B Therefore the speed of the wave in a ripple tank can be reduced by reducing the depth of water in the tank. The effect of reducing sped of waves is that wave length of water reduces but frequency does not. The frequency can only be changed by the source of wave.

WAVE PROPERTIES

The wave produced in a ripple tank can undergo.

(a) Refraction
(b) Reflection
(c) Defraction
(d) Interference

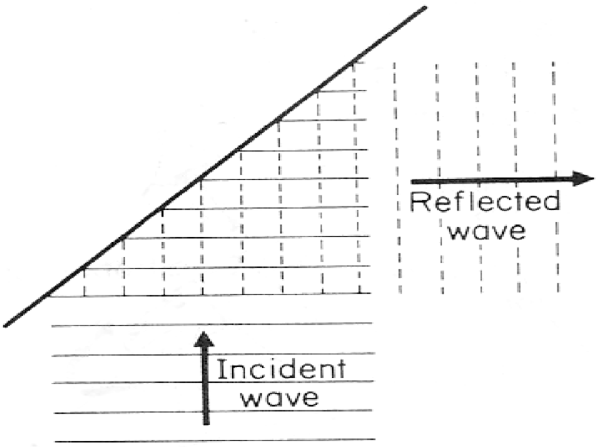
REFLECTION OF WAVES

A wave is reflected when a barrier is placed in its path. The shape of the reflected wave depends on the shape of the barrier.

The laws of reflection of waves are similar to the laws of reflection of light.

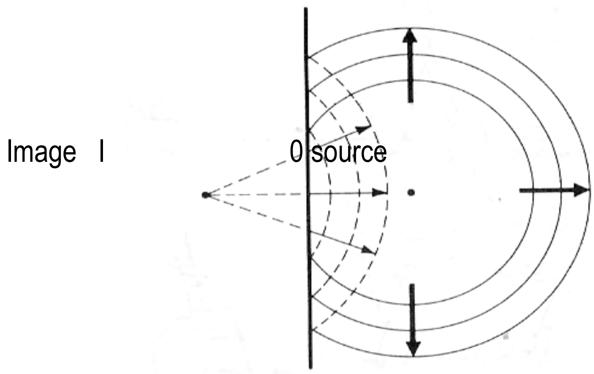
(i) <u>Reflection of plane wave</u>

(a) On a plane surface.



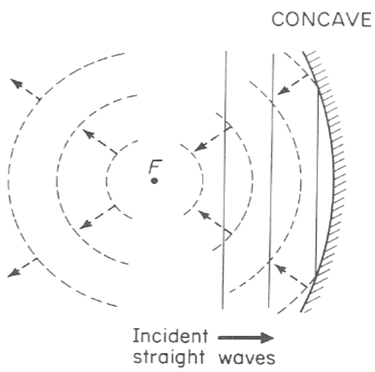
<u>Reflection of circular wave</u>

(a) **<u>On a plane surface</u>**



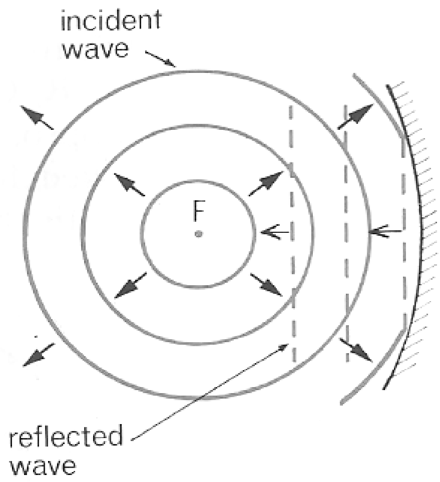
(i) **Reflection of plane wave**

(b) Concave reflector



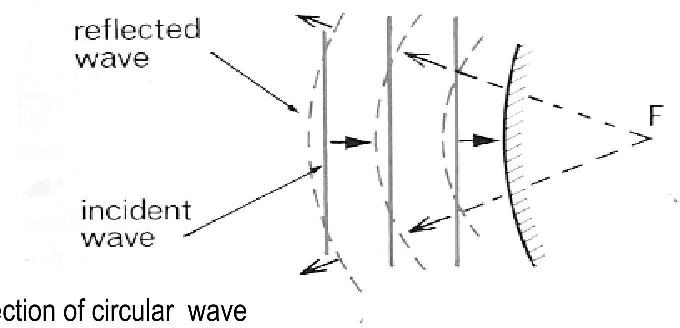
(ii) Reflection of circular wave

(b) Concave reflector



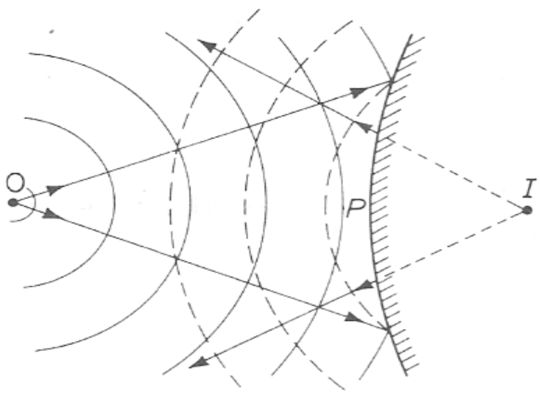
(i) Reflection of plane wave

(a) Convex reflector



(ii) Reflection of circular wave

(b) Convex reflector

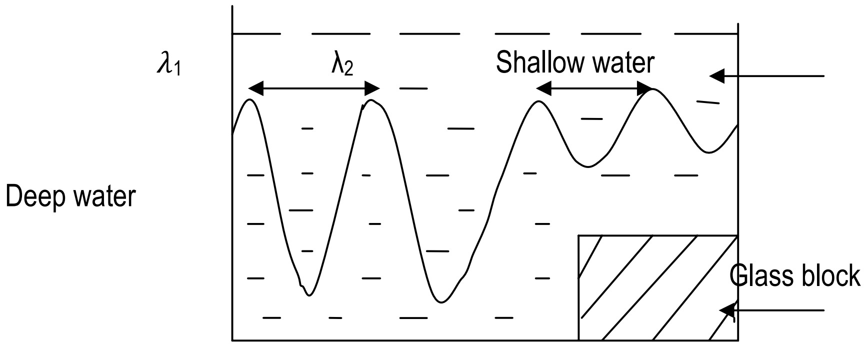


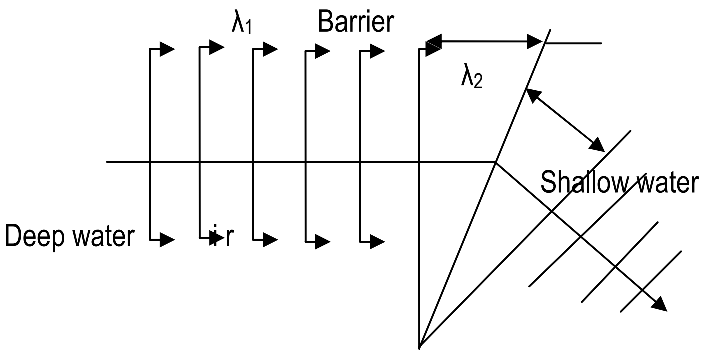
Note

During reflection of water waves, the frequency and velocity of the wave does not change.

REFRACTION OF WAVE

This is the change of in direction of wave travel as it moves from one medium to another of different depth. It is caused in change of wave length and velocity of the wave. However, the frequency and the period are not affected. In a ripple tank, the change in direction is brought about by the change in water depth.





λ_1 = wave length in deep water

λ_2 = wave length in shallow water

Note (i) $\lambda_1 > \lambda_2$

(ii) $v_1 = f\lambda$ and $v_2 = f\lambda_2$

(iii) $v_1 > v_2$ When f – is constant.

Refractive index n = $\frac{velocity\ in\ deep\ water}{velocity\ in\ shallow\ water}$

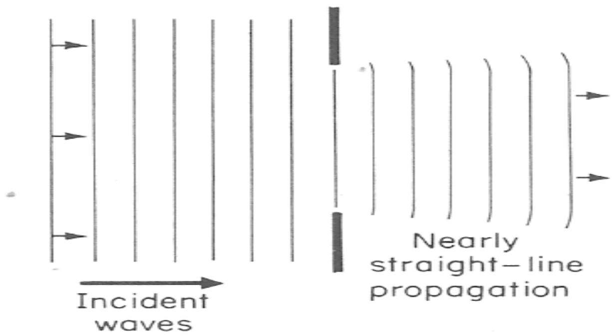
$= \frac{v_1}{v_2} = \frac{f\lambda_1}{f\lambda_2}$

n = $\frac{\lambda_1}{\lambda_2} = \frac{wave\ length\ in\ deep\ water}{wave\ length\ in\ shallow\ water}$

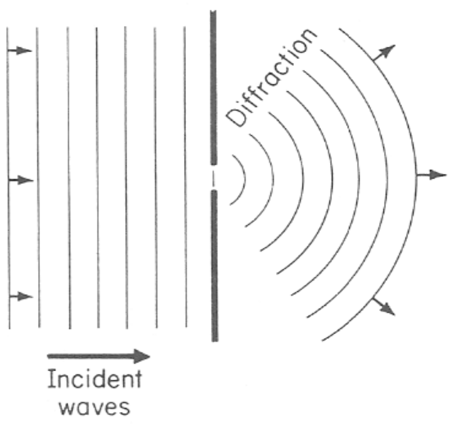
DEFRACTION OF WAVES

This is the spreading of waves as they pass through holes, round corners or edges of obstacle. It takes place when the diameter of the whole is in the order of wave length of the wave i.e. the smaller the gap the greater the degree of defraction as shown below.

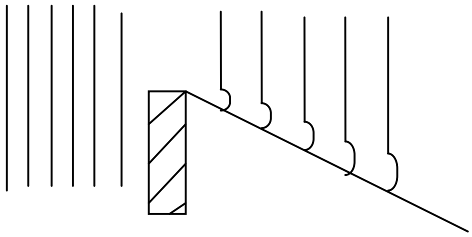
(a) Wide gap



(b) Narrow gap



(c) Edge of obstacle



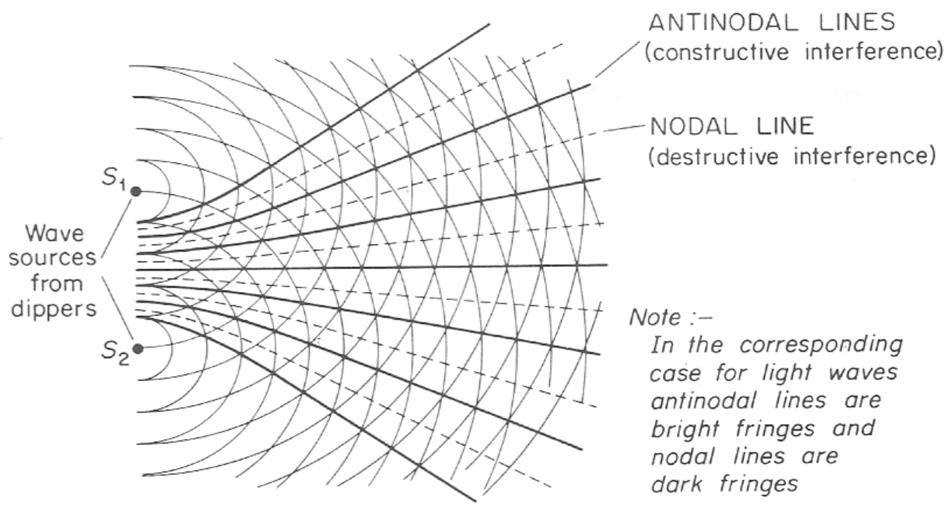
Sound waves are more defrosted than light waves because the wave length is greater than that of light. Therefore sound can be heard in hidden corners.

N.B - When waves undergo defraction, wave length and velocity remain constant.

INTERFERENCE OF WAVES

This is the super imposition of two identical waves travelling in the same direction to form a single wave with a larger amplitude or smaller amplitude.

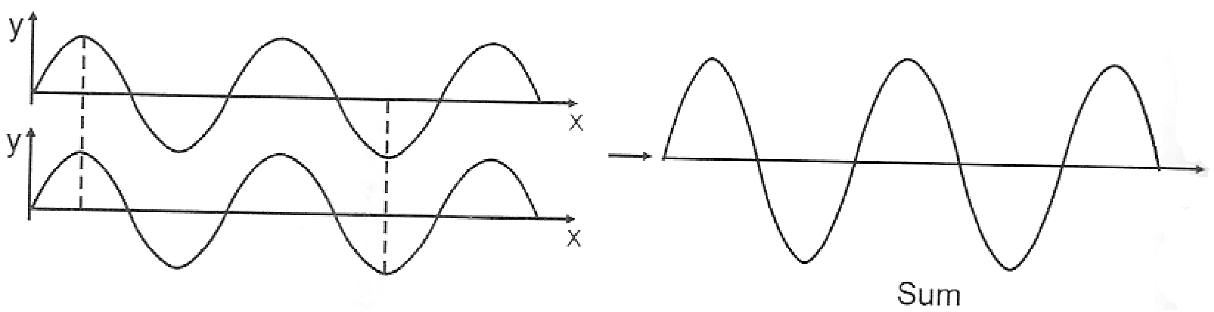
The two waves should be in phase (matching).



CONSTRUCTIVE INTERFERENCE

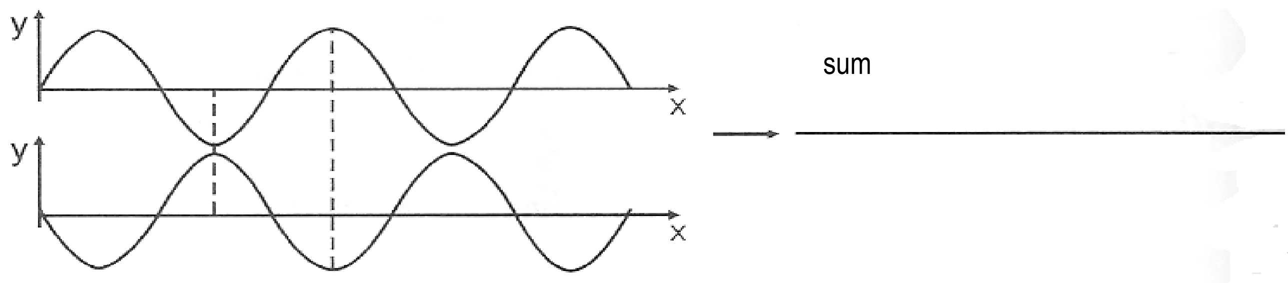
This constructive interference occurs when a crest from one wave source meets a crest from another source or a trough from one source causing reinforcement of the wave i.e. increased disturbance is obtained.

The resulting amplitude is the sum of the individual amplitudes.



DESTRUCTIVE INTERFERENCE

This occurs when the crest of one wave meets a trough of another wave resulting in wave cancelling i.e.



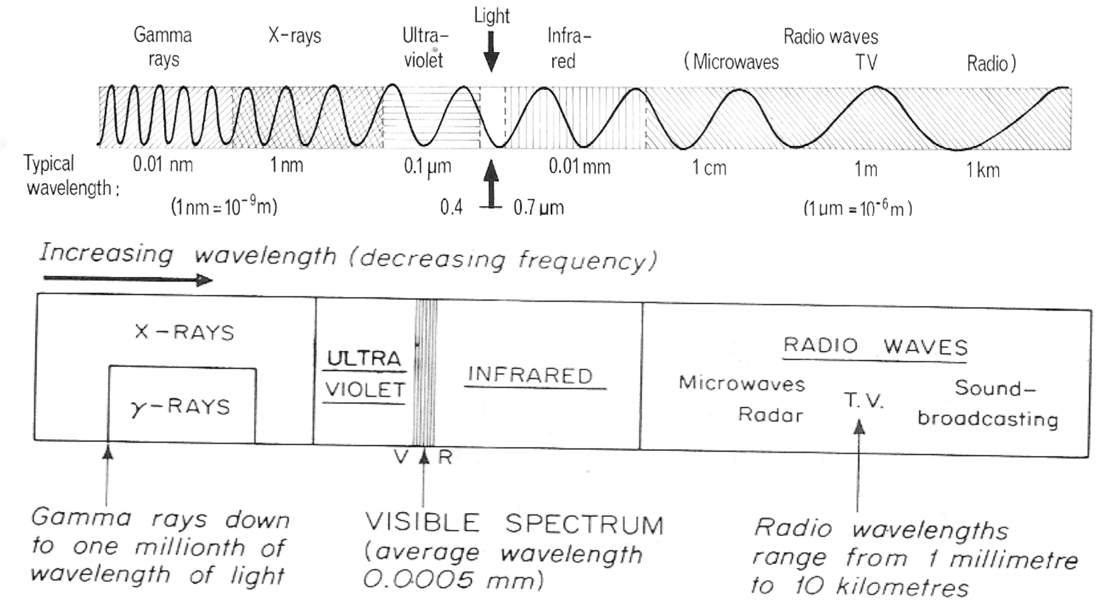
ELECTRO MAGNETIC WAVES

This is a family of waves which is made by electric and magnetic vibrations of very high frequency.

Electro magnetic waves do not need a material medium for transformation i.e. they can pass through a vacuum.

SPECTRUM OF ELECTRO MAGNETIC WAVES

In decreasing frequency



PROPERTIES OF ELECTRO MAGNETIC WAVES

- They are transverse waves.
- They can travel through vacuum.
- They travel at a speed of light (3.0×10^8 m/s).
- They can be reflected, refracted, defracted and undergo interference.
- They posses energy.

EFFECTS OF ELECTRO MAGNETIC WAVES ON METER

(a) Gamma rays.

- They destroy body tissues if exposed for a long time.
- They harden rubber solutions and lubricate oil to thickness.

(b) X- rays

- Causes curtains to give off electrons.
- Destroys body tissues if exposed for a long time.
- Used in industries to detect lickages in pipes and in hospitals to detect fractures of bones.

(c) Ultra violet

- Causes sun burn
- Causes metals to give off electrons by the process called photoelectric emission.
- Causes blindness.

(d) Visible light

- Enables us to see.
- Changes the apparent color of an object.
- Makes objects appear bent to refraction.

(e) Infrared

- Causes the body temperature of an object to rise.
- It is a source of vitamin D.

(f) Radio waves

- Induces the voltage on a conductor and it enables its presence to be detected.

Wave band	Origin	Source
Gamma rays	Energy changes in modes of atoms	Radio active substance
X- rays	Electrons hitting a metal target	X – ray tube
Ultra- violet	Fairly high energy changes in atoms	Very hot bodies Electron discharge Through gases especially mercury Vapour
Visible light	Energy changes in electron structure of atoms	Lamps, flames etc
Infrared radiation	Low energy changes in electrons of atoms	All matter over a wide range of temperature from absolute zero onwards.
Radio waves	High frequency Oscillating electric current Very low energy changes in electronic structures of atoms.	Radio transmission aerials.

SOUNDS WAVES (LONGTUDINAL WAVES)

Is a form of energy which is produced by vibrating objects e.g. when a tuning fork is struck on a desk and dipped in water, the water is splashed showing that the prongs are vibrating or when a guitar string is struck.

SPECTRUM SOUND WAVES

Frequency	$0H_Z$	$20H_Z$	$20{,}000H_Z$
Type of sound	Subsonic sound	Audible sound waves	Ultra sonic sound wave.

SUBSONIC SOUND WAVES

These are not audible to human ear because of very low frequency of less than $20H_Z$.

AUDIBLE SOUND WAVES

These are audible to human ear. This frequency ranges from

$20H_Z$- 20 KH_Z.

ULTRA SONIC SOUND WAVES

These are sound waves whose frequencies are above $20H_Z$. They are not audible to human ears. They are audible to whales, Dolphins, bats etc.

APPLICATION OF ULTRA SOUND WAVES

- They are used by bats to detect obstacles e.g. buildings a head.
- Used in spectacles of blind to detect obstacles.
- Used in radio therapy to detect cracks and faults on welded joints.
- Used in industries to detect rocks in seas using sonar.
- Used to measure the depth of seas and other bodies.

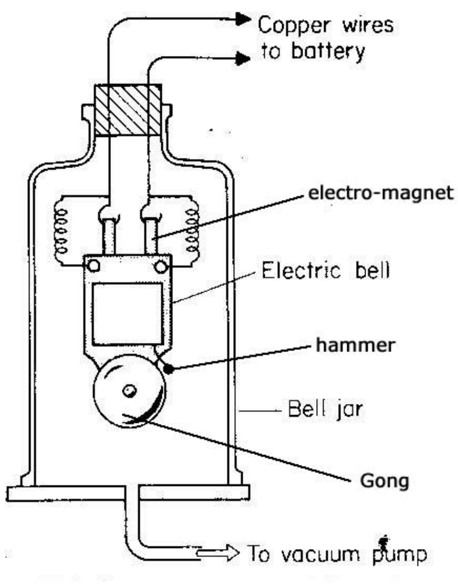
PROPERTIES OF SOUND WAVES

- Cannot travel in a vacuum because there is no metal needed.
- Can cause interference.
- Can be reflected, refracted, defracted, planes polarized and undergo interference.
- Travels with a speed V= 330m/s in air.

TRANSMISSION OF SOUND.

Sound requires a material medium for its transmission. It travels through liquid, solids and gases, travels better in solids and does not travel through vacuum.

EXPERIMENT TO SHOW THAT SOUNDS CAN NOT PASS THROUGH A VACCUM.



- Arrange the apparatus as in the diagram with air, in the jar.
- Switch on the electric bell, the hammer is seen striking the gong and sound is heard.
- Gently withdraw air from the jar by means of a vacuum pump to create a vacuum in the jar.
- The sound produced begins to fade until it is heard no more yet the hammer is seen striking the gong.

- Gently allow air back into the jar, as the air returns, the sound is once again heard showing that sound can not travel through vacuum.

Note: The moon is sometimes referred to as a silent planet because no transmission of sound can occur due to lack of air (metal medium).

The speed of sound depends on;

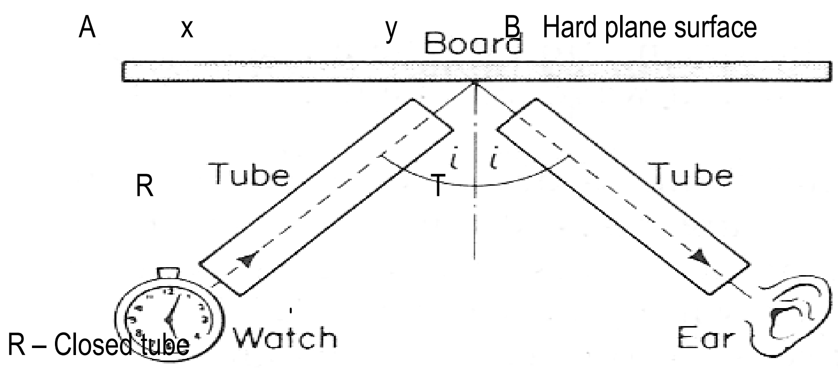
(i) Temperature
(ii) Wind
(iii) Density of medium.

Speed of sound is more in denser medium than in less dense.

Increase in temperature increases the speed of sound i.e. sound travels faster in hot air than in cold air. Speed of sound is increased if sound travels in the same direction as wind.

Change in pressure of air does not affect speed of sound because density is not affected by change in pressure.

EXPERIMENT TO VERIFY THE LAWS OF REFLECTION OF SOUND



T – Open tube

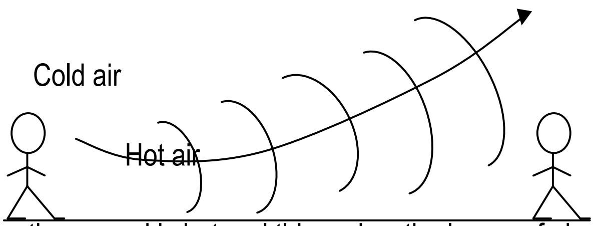
- Put a ticking clock in tube R on a table and make it to face a hard plane surface e.g. a wall.
- Put tube T near your ear and move it on either sides until the ticking sound of the sound is heard loudly.
- Measure angle i and r which are the angles of incidence and reflected.

- From the experiment, sound is heard distinctly due to reflection.
- Angle of incidence (i) and angle of reflection (r) are equal and lie along XY in the same plane.
- This verifies the laws of reflection.

REFRACTION OF SOUND WAVES

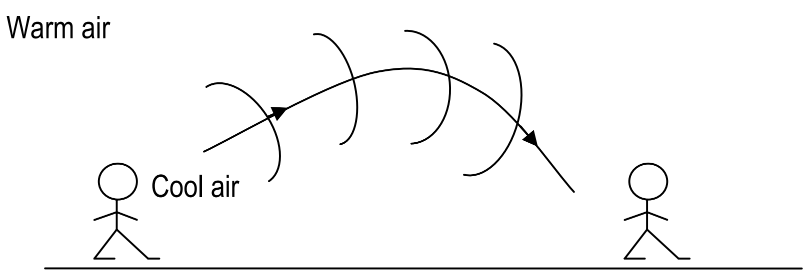
Refraction occurs when speed of sound waves changes. The speed of sound in air is affected by temperature. Sound waves are refracted when they are passed through areas of different temperature. This explains why it is easy to hear sound waves from distant sources at night than during day.

REFRACTION OF SOUND DURING DAY.



During day, the ground is hot and this makes the layers of air near the ground to be hot while that above the ground is generally cool. The wave fronts from the source are refracted away from the ground.

REFRACTION OF SOUND DURING NIGHT



During night, the ground is cool and this makers layers of air near the ground to be cool while above to be warm. The wave fronts from the source are refracted towards the ground making it easier to hear sound waves over long distances.

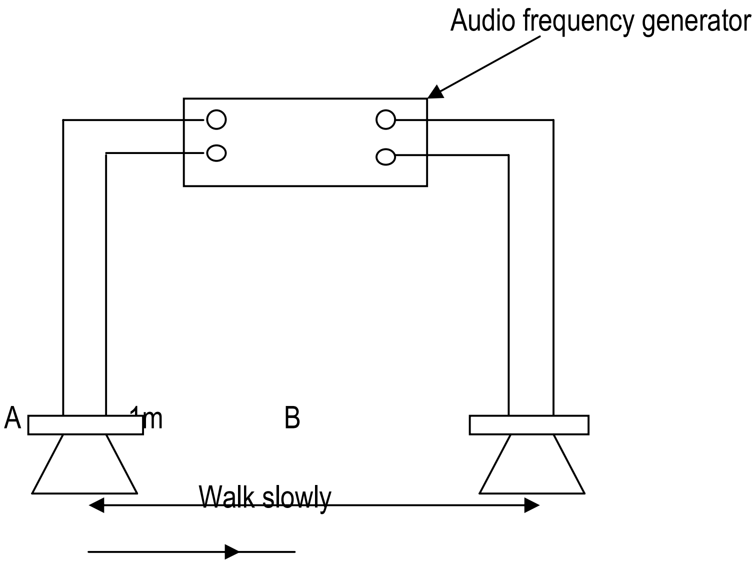
DEFRACTION OF SOUND

This refers to the spreading of sound waves around corners or in gaps when sound waves have wave length similar to the size of the gap. They are defracted most. It is due to refraction that a person behind the house can hear sound from inside.

INTERFERENCE OF SOUND

When two sound waves from two different sources overlap, they produce regions of loud sound and regions of quiet sound. The regions of loud sound are said to undergo constructive interference while regions of quiet are said to undergo destructive interference.

EXPERIMENT TO SHOW INTERFERENCE OF SOUND



ECHOES

An echo is a reflected sound. Echoes are produced when sound moves to and fro from a reflecting surface e.g. a cliff wall. The time taken before an echo arrives depends on the distance away from the reflecting surface.

In order for a girl to hear the echo; sound travels a distance of 2d.

Velocity = $\frac{distance}{time}$

For an echo; velocity of sound = $\frac{2d}{t}$

$V = \frac{2d}{t}$

Examples

1 A girl stands 34m away from a reflecting wall. She makes sound and hears an echo after 0.2 seconds. Find the velocity of sound.

$$V = \frac{2d}{t}$$

$$= \frac{2 \times 34}{0.2}$$

$$= 340\text{m/s}$$

2 A person standing 99m from a tall building claps his hands and hears an echo after 0.6 seconds. Calculate the velocity of sound in air.

$$V = \frac{2d}{t} = \frac{2 \times 99}{0.6} = \frac{198}{0.6} = \underline{330\text{m/s}}$$

3 A gun was fired and an echo from a cliff was heard 8 seconds later. If the velocity of sound is 340m/s, how far was the gun from the cliff?

$$V = \frac{2d}{t}$$

$$8 \times 340 = \frac{2d}{8} \times 8$$

$$\frac{8 \times 340}{2} = \frac{2d}{2}$$

$$1360 = d$$

$$d = 1360\text{m}$$

4 A student is standing between two walls. He hears the first echo after 2 seconds and then another after a further 3 seconds. If the velocity of sound is 330m/s, find the distance between the walls.

$V = \frac{2d_1}{t}$ $\quad$ $V = \frac{2d_2}{t}$ $\quad$ $\frac{distance\ btn\ walls}{d_1 + d_2}$

$330 = \frac{2 \times d_1}{2}$ $5 \times 330 = \frac{2 \times d_2}{5} \times 5$ $= 330 + 825$

$\underline{d_1 = 330m}$ $\frac{5 \times 330}{2} = \frac{2d_2}{2}$ $= \underline{1155m}$

$= 825$ m

5 A man is standing midway between two cliffs. He claps his hands and hears an echo after 3 seconds. Find the distance between the two cliffs.

(Velocity of sound = 330m/s)

$V = \frac{2d_1}{t}$ $d_1 = d_2$

$3 \times 330 = \frac{2d_1}{3} \times 3$ $d_1 + d_2 = 495 + 495$

$\frac{3 \times 330}{2} = \frac{2d_1}{2}$ $\underline{= 990m}$

$3 \times 165 = d_1$

$495 = d_1$

$d_1 = 495m$

MEASUREMENT OF VELOCITY OF SOUND USING AN ECHO METHOD

Method;

A person stands a certain distance d from the reflecting surface, then measure that distance.

Make a sharp clapping sound by banging two blocks of wood together.

Report the sound at regular time intervals to coincide exactly with the echo.

Count the number of claps in a given time t

Find the time taken for one clap i.e. $\frac{t}{N}$

$$\text{Velocity} = \frac{2 \times distance}{time}$$

$$\text{Velocity} = \frac{2 \times d}{\frac{t}{N}}$$

$$V = \frac{2dN}{t}$$

Example

A student made 50 claps in one minute. If the velocity of sound is 330s, find the distance between the student and the wall.

$$V = \frac{2dN}{t}$$

$$60 \times 330 = \frac{2 \times d \times 50}{60} \times 60$$

$$\frac{60 \times 330}{100} = \frac{100d}{100}$$

$$198 = d$$

$$\underline{d = 198m}$$

REVERBERATION

In a large hall where there are many reflecting walls, multiple reflections occur and cause or create an impression that sound lasts for a longer time such that when somebody makes a sound; it appears as if it is prolonged. This is called reverberation.

Definition of Reverberation

Reverberation is the effect of the original sound being prolonged due to multiple reflections.

ADVANTAGES OF REVERBERATION

In grammar, reverberation is used in producing sound. Complete absence of reverberation makes speeches inaudible.

DISADVANTAGES OF REVERNERATION

During speeches, there is a nuisance because the sound becomes unclear.

PREVENTION OF REVERBERATION

The internal surfaces of a hall should be covering the sound absorbing material called acoustic materials.

WHY ECHOES ARE NOT HEARD IN SMALL ROOMS?

This is because the distance between the source and reflected sound is so small such that the incident sound mixes up with the reflected sound making it harder for the ear to differentiate between the two.

Question

Outline four properties of electro magnetic waves.

Distinguish between (i) sound waves and light waves.

(iii) sound waves and water waves

A man standing midway between two cliffs makes a sound. He hears the first echo after 3s. Calculate the distance between the two cliffs (Velocity of sound in air = 330m/s)

Musical notes

Music

This is an organized sound produced by regular vibrations.

Noise

This is a disorganized sound produced by irregular vibrations.

Musical note

This is a single sound of a certain pitch made by a musical instrument or voice.

Characteristics of musical notes

Pitch

This is the loudness or softness of sound. It depends on the frequency of sound produced, the higher the frequency the higher the pitch.

Timber

This is the quality of sound produced, it depends on the number of overtones produced, the more the number of overtones, the richer and the sweeter the music and therefore the better the quality.

Overtone

This is a sound whose frequency is a multiple of a fundamental frequency of the musical note.

Beat

This refers to the periodic rise and fall in the amplitude of the resultant note.

Loudness

This depends on the amplitude of sound waves and sensitivity of the ear.

Amplitude

This is the measure of energy transmitted by the wave. The bigger the amplitude, the more energy transmitted by the wave and the louder sounder sound produced.

Sensitivity of the ear.

If the ear is sensitive, then soft sound will be loud enough to be detected and yet it will not be detected by the ear which is insensitive.

Pure and impure musical notes.

Pure refers to a note without overtones. It is very boring and only produced by a tuning fork.

Impure refers to a note with overtones. It is sweet to the ear and produced by all musical instruments.

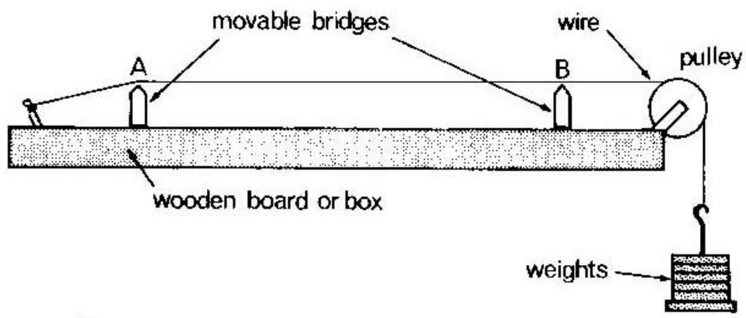
VIBRATION IN STRINGS

Many musical instruments use stretched strings to produce sound. A string can be made to vibrate plucking it like in a guitar or in a harp putting it in pianos. Different instruments produce sounds of different qualities even if they are of the same note.

Factors affecting the frequency of the stretched string.

(a) Length

For a given tension of the string, the length of the string is inverse the proportion to the frequency of sound produced. This can be demonstrated by an instrument called sonometer as shown below.



A- Fixed bridge

B- Movable bridge

C- Wheel

D- Stretched

R-Load

By moving bridge B_2, higher frequency can be obtained for a short length AB and lower frequency for a long length AC. The relation can be expressed as F ∂ $\frac{1}{l}$

(b) Tension

Adding weights or removing them from its ends at load R the tension of the higher sonometer wire. It will be noted that the higher the tension, the higher the frequency of the note produced.

(c) Mass per unit length (m)

Keeping length (l) and tension (t) constant, the frequency of sound produced depends on the mass per unit length of the string. Heavy strings produce low frequency sounds. This is seen in instruments such as guitar, base strings are thicker than solo stings. If the tension and length are kept constant, the frequency of sound is inversely proportional to the mass of the strings thus a thin short and taut string produces high frequency sound. (F ∂ $\sqrt{\frac{1}{m}}$)

Example

A musical note has frequency of 420H_z and length (l), if the length of the string is reduced by $\frac{1}{2}$, find the new frequency.

$$F \partial \frac{1}{l} \rightarrow f = \lambda \frac{1}{l} \rightarrow fl = k \text{ (constant)}$$

$$f_1 l_1 = f_2 \, l_2$$

$$420k = f_2 \times \frac{1}{2}$$

$$f_2 = 420 \times 2$$

$$= 840 \; H_z$$

Vibrating strings

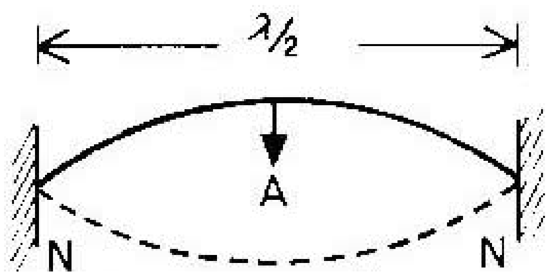
The ways in which a string vibrates are called harmonics. The sound is produced when notes are performed at both ends of a stationary wave.

A stationary wave is a wave formed when two progressive waves of the same frequency and wave length travelling in opposite direction meet producing nodes and antinodes.

Progressive wave is a wave in which energy is transmitted from one place to another and is not stores.

(i) Fundamental note (1st harmonics) string plucked midway.

Diagram

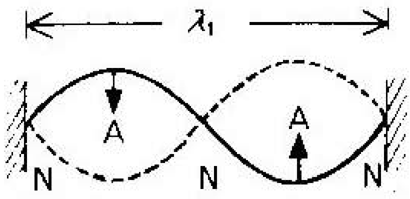


Let V = velocity of sound in air and l- the vibrating length of the string.

L = $\frac{1}{2}$ λ ⟶ λ = 2L

but f_0 = $\frac{V}{\lambda} = \frac{V}{2l}$ - fundamental frequency $f_o = \frac{V}{2l}$

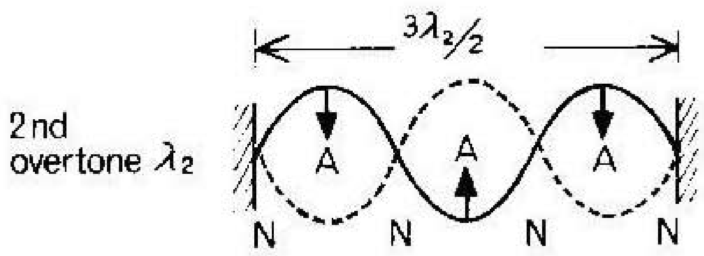
(ii) 2nd harmonics (1st overtone): string plucked $\frac{1}{4}$ way



$$L = \lambda$$

$$f_1 = \frac{V}{l} = f_1 = 2f_o$$

(iii) 3rd harmonics (2nd overtone): string plucked $\frac{1}{6}$ way from one end.



$$L = \frac{3\lambda}{2} \longrightarrow \lambda = \frac{2l}{3}$$

$$f_2 = \frac{V}{\lambda} = \frac{V}{\frac{2}{3l}} = \frac{3v}{2l}$$

$$f_2 = 3f_o$$

Thus harmonics obtained from vibrating strings are f_o,$2f_o$, $3f_o$ etc. hence both even and odd harmonics are obtained.

A- Antinodes- these are points that are permanently at rest. No disturbance occurs at these points.

RESONANCE

This is when a body is set into vibrations with its own natural frequency by another near by body which vibrates with the same frequency.

Applications of Resonance.

- In determining the speed of sound in air using a tuning fork and the resonance tube.
- In tuning strings of a musical instrument e.g a guitar and tuning electrical circuits which include indicators.

Dangers of Resonance

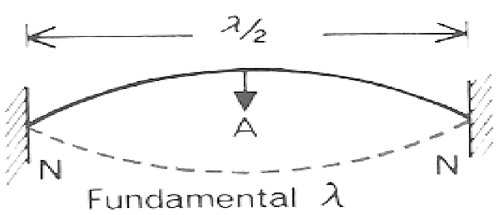
- Causes bridges to collapse as soldiers match across them. This can be prevented by stopping the matching.
- Causes buildings to collapse due to earthquake.
- Chimneys can also collapse due to strong resonance.

Vibrations of air in pipes.

(a) When a wave of a particular wave length and frequency is sent into a closed pipe, reflection of the wave occurs at the bottom of the pipe. The reflected wave will interfere with the incidence when the length of the wave is adjacent so that a node is reflected at the reflected surface, a standing wave is produced.

The air column is now forced to vibrate at the same frequency as that of the source of the wave which is a natural frequency of the air column.

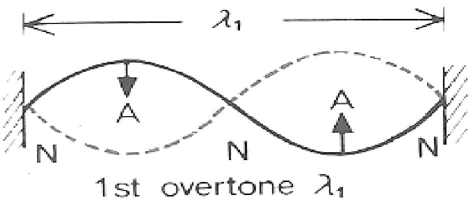
1st harmonic vibration



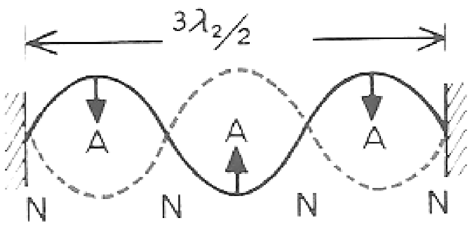
In 1st harmonics $\frac{1}{4}\lambda$ = L + c $\rightarrow$ λ = (L + c0 fundamental frequency

$$f_o = \frac{V}{\lambda} = \frac{V}{4(l+c)} \text{.......(i)}$$

2^{nd} harmonics



3^{rd} harmonics



In clos tc) are obtained because of the presence of odd harmonics, closed pipes are not as rich as open pipes.

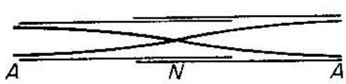
In closed pipes, nodes are formed at closed ends and antinodes at open end.

Open pipes

In open pipes, standing waves resulting into resonance are created when the incident waves are reflected by the air molecules at the other end. Possible ways in which waves travel are shown below:

In open pipes, the sound nodes are produced when antinodes are formed at both ends.

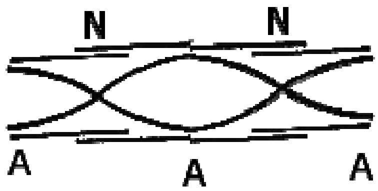
1^{st} harmonic



$$L= \frac{1}{2}\lambda \rightarrow \lambda = 2L$$

$$f_o = \frac{v}{\lambda} = \frac{v}{2l}.........(i)$$

2nd harmonic

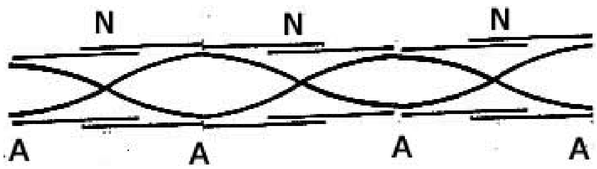


$$L = \lambda$$

$$\text{Frequency } f_1 = \frac{v}{\lambda} = \frac{v}{2l}$$

$$f_1 = 2f_0$$

3rd harmonic

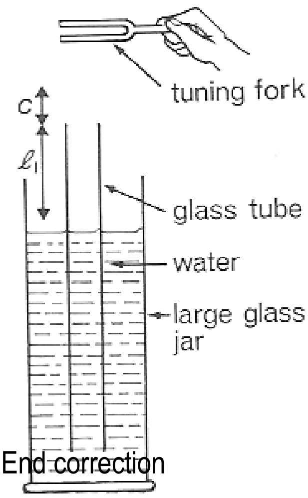


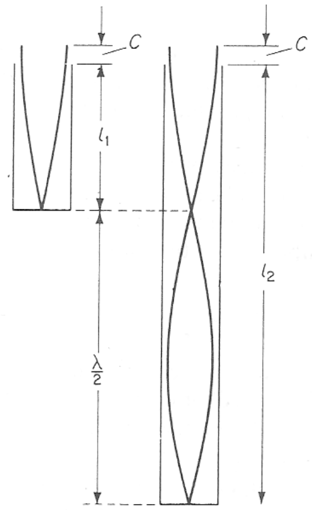
$$L = \frac{3}{2\lambda} \quad \rightarrow \lambda = \frac{2l}{3}$$

$$f_2 = \frac{v}{\lambda} = 3\left(\frac{v}{2l}\right) \rightarrow f_2 = 3\,f_0$$

Open pipes are preferred to closed pipes because they give both odd and even harmonics hence better quality sound.

Determination of velocity of sound by Resonance.





First and second positions of resonance

C – End correction

l_1 , l_2 - Length of air.

- Assemble the apparatus as in the diagram.
- Put a vibrating tuning fork just above the resonance tube.
- Gently lower the resonance tube until the 1st resonance (loud sound) occurs.
- Measure the length l_1 at which it occurs.
- $l_1 + c = \frac{1}{4}\lambda$...... (i)
- Raise the resonance tube until the 2nd resonance (loud sound) occurs.
- Measure $l_2 + c = \frac{3}{4}\lambda$...... (ii) as in diagram (b)
- Subtract equation (i) from (ii) to eliminate c
- $(l_2 - l_1) + (c-c) = \frac{3}{4}\lambda - \frac{1}{4}\lambda$
- $l_2 - l_1 = \frac{1}{2}\lambda$
- Wave length $\lambda = 2\,(l_2 - l_1)$...... (iii)

Hence the speed/velocity. $V= f\lambda$

$V= 2f\,(l_2 - l_1)$

Question.

In an experiment the velocity of sound in air using a resonance tube, the following results were obtained:

Length of 1st resonance = 16.1cm

Length of 2nd resonance = 51.1cm

Frequency of tuning fork = 480 H_z

(i) Calculate the wave length of sound produced.
(ii) The end correction of the resonance tube.
(iii) The velocity of sound in air.

(i) $\lambda = 2\ (l_2 - l_1)$

= (51.1 – 16.1)

= 70cm

= 0.07m

(ii) $l_1 + c = \frac{1}{4}\lambda$

$16.1 + c = \frac{1}{4} \times 70$

C = 17.5 – 16.1

= 1.4cm

(iii) V= 2f(l_2 - l_1)

= $2 \times 480\ (\frac{51.1-16.1}{100})$

= 33600cm

= 336m/s

2 The frequency of the 3rd overtone (4th harmonic) produced by an open pipe is 840H_z. Given that the velocity of sound in air is 330m/s, calculate;

(i) Length of the people
(ii) Fundamental frequency

3 A pipe closed at one end has a length of 10cm, if the velocity of sound is 340m/s; calculate the frequency of the fundamental note.

4 A tuning fork of $256H_z$ was used to produce resonance in a closed pipe. The first resonance position was 22cm and the 2nd resonance position was 97cm. Find the frequency of sound waves.

(b) An open tube produced harmonics of fundamental frequency $256H_z$, what is the frequency of the 2nd harmonics.

HEAT

MODES OF HEAT TRANSFER

Heat

It is a form of energy that changes the internal kinetic energy of a substance.
It is transferred in three different ways, conduction, convection and radiation

Conduction

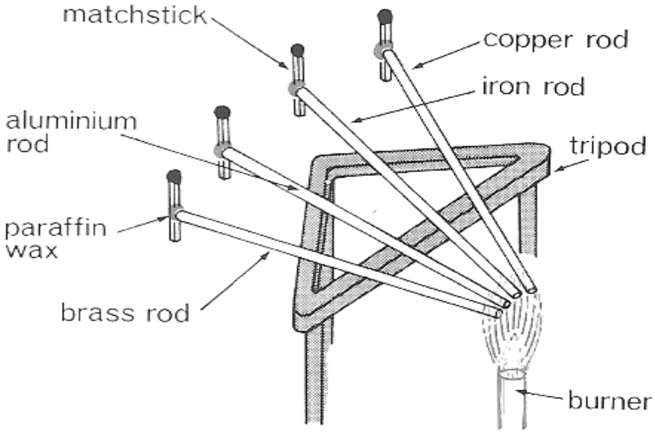
It is the flow of heat through a material that does not require movement of the material medium e.g. in metals when they are heated their molecules vibrates faster along their mean position and pass on the heat to the molecules on the cooler parts of the metals also electrons that are always moving about the metal transfer from the hot to the cold end.

Heat conduction is best in metals and worst in gases because of the distant spread of molecules in gases it is not highly possible to have heat transfer in gases

Factors affecting conduction in metals

- Increase in the cross section area of the metal increases the rate of conduction.
- Decrease in the length of the metal bar
- Increase in the temperature difference
- Different metals conduct heat differently.

Experiment to compare conduction in metals.



Procedures.

- The fix cork with wax at one end of each rod and place them on a tripod stand with their end put together
- Heat the ends with a Bunsen flame , heat is conducted along each rod towards the cork
- The cork drops off whenever the wax melts
- The best conductor will drop its cork first and the worst conductor drops its cork last or not at all.

Application of heat conduction

- Good conductors are used in frying and cooking
- Bad conductors are used on handles of frying pans i.e. handle are made of plastic, wood, rubber.

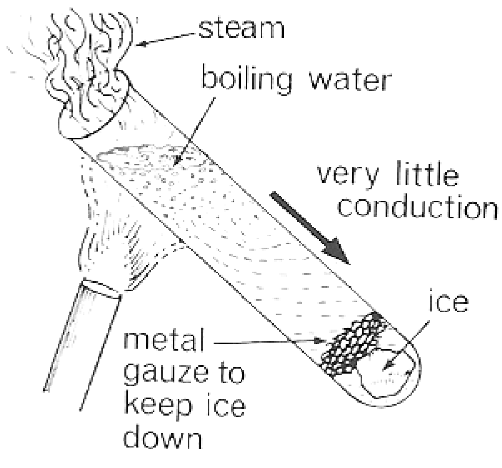
Explain why metals feel colder when touched than bad conductors

This is because metals carry heat away from the hands due to high degree of conduction while bad conductors do not conduct heat.

N.B

Liquids and conducts heat very slowly this is because their molecules are apart.

Experiment to show that water is a poor conductor of heat



Procedure

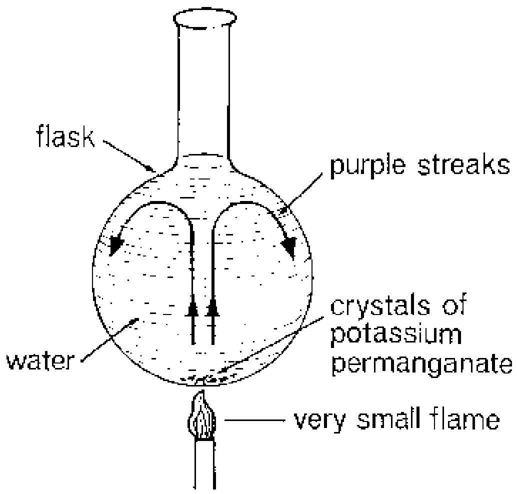
- Water is put in a test tube slanted as shown in the diagram above.
- The upper part of the tube is heated and convection currents are seen at the top of the tube, water begins to boil.
- Ice at the bottom remains not melted. This shows that water is poor conductor of heat.

Convection:

This is the heat transfer which involves bulk movement of molecules of the medium.

Convection cannot occur in vacuum because it requires a material medium. It occurs in fluids (liquid and gases) because they flow easily.

Experiment to demonstrate convection in liquids:



Proceure;

- Arrange the apparatus as in the diagram above.
- Use a straw and carefully put potassium permanganate crystals in water at the bottom.
- When heat is applied, purple streaks are observed moving upwards in the middle of the flask and down wards at the side of a flask in a circular form. The purple streaks show convection currents.

Explanation of convection currents:

When water at the bottom becomes hot, it expands and becomes less dense. It is therefore displaced by dense cold water from the top. In displacement of hot water by cold water, it sets up convection currents as observed by the purple loops.

Application of convection:

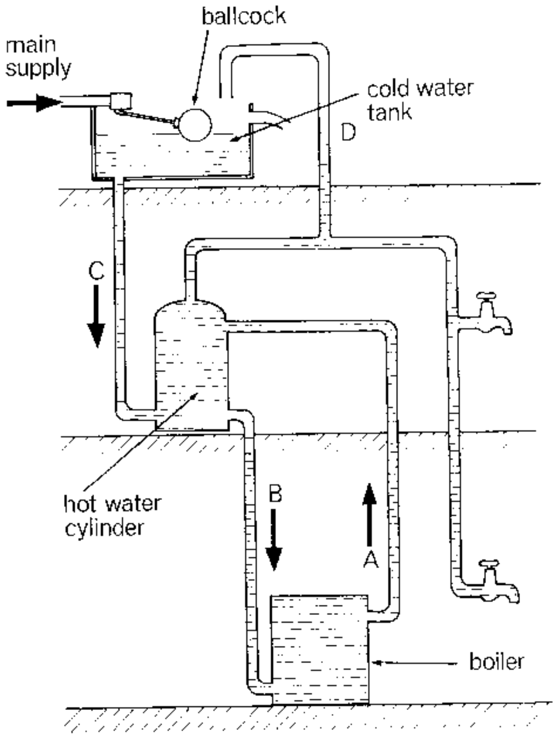
When warming a liquid, the heating element of an electronic kettle is placed at the bottom.

Domestic hot water system:

Cold water is supplied to the boiler along the cold water supply pipe. On warming, in the boiler the cold water warms up, expands and becomes less dense, so it rises up.

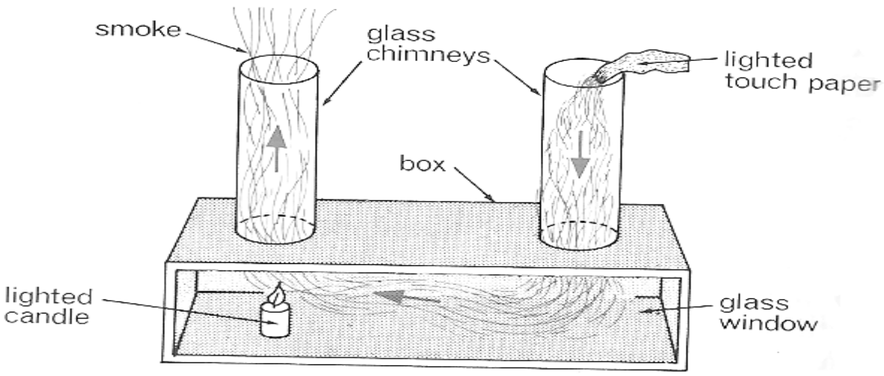
As more cold water is applied to the boiler, hot water is displaced upwards and supplied to the hot water taps along hot water pipes.

The ventilation pipe is used to release steam.



Convection in gases

Experiment to demonstrate convection in gases:



A lighted piece of paper will produce smoke at point A. The movements of smoke from A to B across point X and out through C shows convection.

Explanation of how smoke moves:

Smoke moves by convection because;

- The air above the candle warms up, becoming less dense and then rises up through C.
- The dense cold air from the paper (smoke) enters X through chimney A to replace the risen air (smoke) causing convection currents.

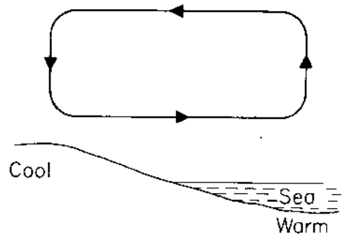
Application of convection in gases:

- Chimneys in kitchens and factories
- Ventilation pipes in VIP latrines
- Ventilators in houses
- Land and sea breezes

Land breeze;

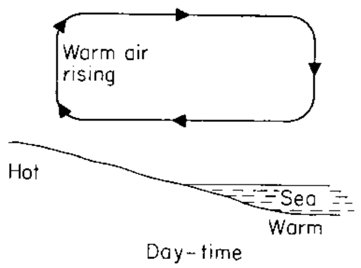
It occurs at night. At night land loses heat faster than sea water causing land to be cooler than the sea. As a result, causing air above the sea to become warm and less dense, so it rises.

The air above the land which is cold, replaces the warm air resulting in the land breeze.



Sea breeze:

Sea breeze occurs during day. During day the land absorbs more heat from the sun than the sea water. The land becomes warmer than the sea. So warm air rises which is replaced by the cold air from the sea.



VENTILATION:

Air inside a room, air gets heated up on hot days. Rooms are usually provided with ventilators above the floor, through which warm air find its way outside while fresh air enter through the doors and windows. In this way a circulation of air convection is set up.

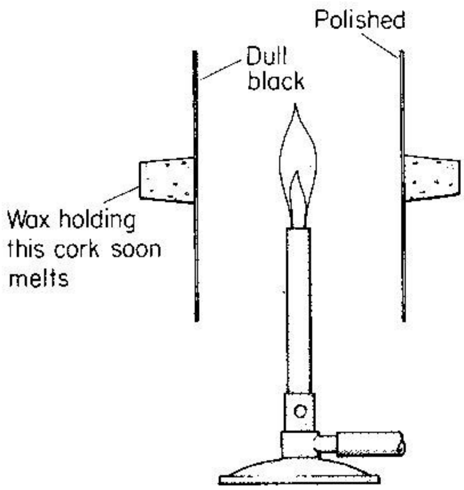
RADIATION:

This is the process of heat transfer in which the transfer of heat does not require a material medium.

Radiant heat is mainly comprised of infrared which makes the skin feel warm. It travels as fast as light and it is the fastest means of heat transfer. It can travel through a vacuum.

Good and bad absorbers of heat radiation:

Some surfaces absorb heat radiation better than others as illustrated below;



The polished surfaces stay cool and the wax on it, is not melted. After a few minutes the wax on the dull or black surface begins to melt. And cork eventually falls off.

A dull black surface is a good absorber of heat radiation while a polished surface is a poor absorber of heat radiation because shine surfaces reflect heat radiation instead of absorbing it.

Comparison of radiation of different surfaces:

Requirements: - A Leslie tube

- Thermopile (instrument that converts heat to electrical energy).

Hot water metre

Leslie tube

Thermopile

One side of the tube is dull black, the other is dull white and the last one is made shiny polished.

The tube is filled with hot water and radiation from each surface is detected by a thermopile.

When the radiant heat falling on the thermopile is much, it registers a large deflection of the point.

With different surfaces of the tube made to face the thermopile one at a time. The following results are obtained:

- The greatest deflection at the pointer is obtained when dull dark surface faces the thermopile.
- The least deflection is obtained a highly polished shiny surface faces the thermopile.
- The dull surface is a good radiator or emitter of heat radiation while a polished shiny surface is a poor emitter of heat radiation.

Laws of radiation:

- Heat radiation travels in a straight line.
- Good absorbers of heat radiation are also good emitters.
- Temperature of the body remains constant when the rate at which absorbs heat radiation is equal to the rate at which radiates heat energy.
- Bodies only radiate heat when their temperatures are higher than those of the surroundings and absorb heat from the surroundings if their temperatures are low.

Application of radiation:

a. Thermos/vacuum flasks
b. Black and dull surfaces

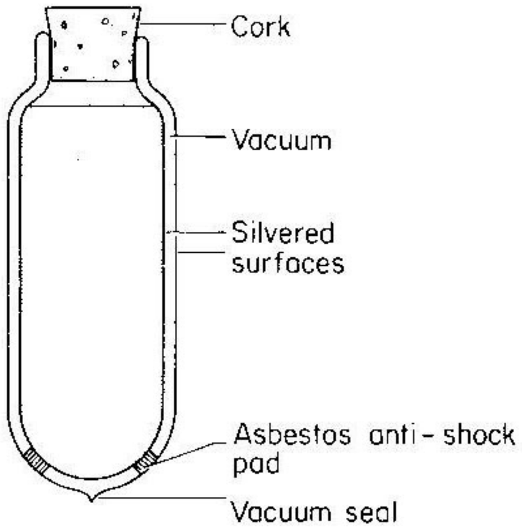
i) Car radiators are painted black to easily emit heat
ii) Cooling fins of a refrigerator are black to easily emit heat.
iii) Solar plates or panels are black to easily emit heat.

c. Polished and white surfaces

i) White washed buildings keep cool in summer.
ii) Roots and petro tanks are aluminum painted to reflect radiant heat.
iii) White coloured clothes are won in summer to keep us cool.
iv) Silver tea pots, kettles and saucepan retain heat for a long time.

The vacuum flask:

It keeps hot liquids hot and cold liquids cold. It is very difficult for heat to travel in or out of the flask.



How flasks minimizes heat loss

The double walled glass vessel with a vacuum between the walls minimizes heat transfer by conduction and convection.

Silvered surfaces reduce heat loss by radiation.

The small amount of heat radiation from the hot substance inside the wall is reflected back across the vacuum by slivering on the outer wall

However the flask can lose heat through radiation, this radiation is reduced by slivered inner walls.

The cork prevents heat loss by conduction since it is a bad conductor of heat.

NB

The thermos flask becomes useless when the vacuum seal breaks, because the vacuum will no longer exists and heat loss by conduction and convection will occur.

Choice of dress

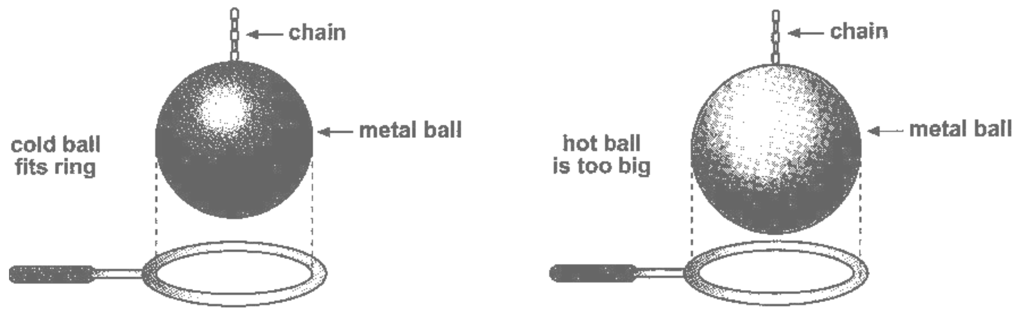
The choice of dress one puts on depends on conditions of the environment. On hot days, a white dress is preferable because it reflects most of the heat radiations falling on it.

On cold days a dull black woolen dress is preferred because it absorbs most of the heat incident on it and can retain for a longer time.

EXPANSION OF SOLIDS.

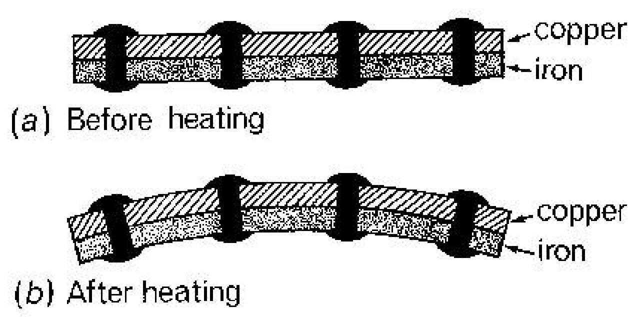
Expansion is an increase in size of a substance. When heated they increase in size in all directions.

Expansion of solids can be illustrated using a metal ball with a ring as shown below.



The metal ball passes through the ring when it is cold, but when heated, the ball doesn't pass through the ring any more, showing that it has expanded. It passes through the hole again when it cools, meaning that the metal contracts when it loses heat.

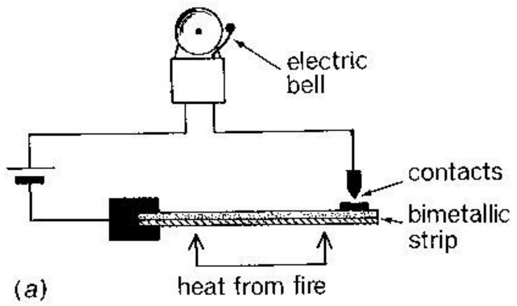
Different metals expand at different rates when equally heated, this can be shown using a metal strip made of two metals such as copper and iron bounded tightly together (bi- metallic strip) when the bi metallic strip is heated, the copper expands more than iron and the strip bends as shown.



Uses of a metallic strip (application of expansion of solids)

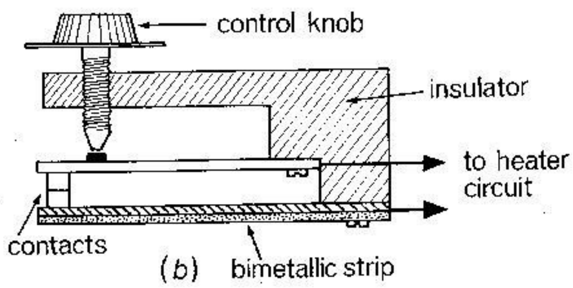
a) **Fire alarm**

Heat from the source makes the bi metallic strip bend and completes the electric circuit and the bell rings.



b) **Thermostat**

This is a device that makes temperature of appliances or room constant. The thermostat shown below uses a bi metallic strip in the heating circuit of a flat iron.



-When flat iron reaches, the required temperature.
-The strip bends and breaks the circuit at the contact and switch off the heater.
-The strip makes contact again after cooling a little and the heater is on again.

A nearly steady temperature results. If the control knob screwed, the strip has to bend more to break the circuit and this reads higher temperature.

Disadvantages of expansion

Expansion can cause a number of problems:

- Contraction of railway lines, bridges, oil pipes and putting up electrical transmission wires. Therefore allowance must be for expansion.

Railway lines are constructed with gaps left in between consecutive on hot days when the rails expand; they have enough room for expansion.

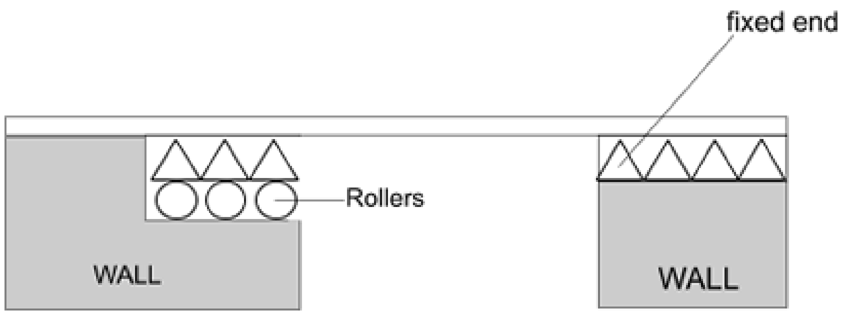
Cold days Hot days

If no gap is left in the rails, they bend on hot days.

Cold days hot days

Steel bridges

Those are constructed in such a way that one end os rested on rollers and the other end is normally fixed. This is to ensure that the structure can contact and expand freely at various temperatures without damaging the bridge.



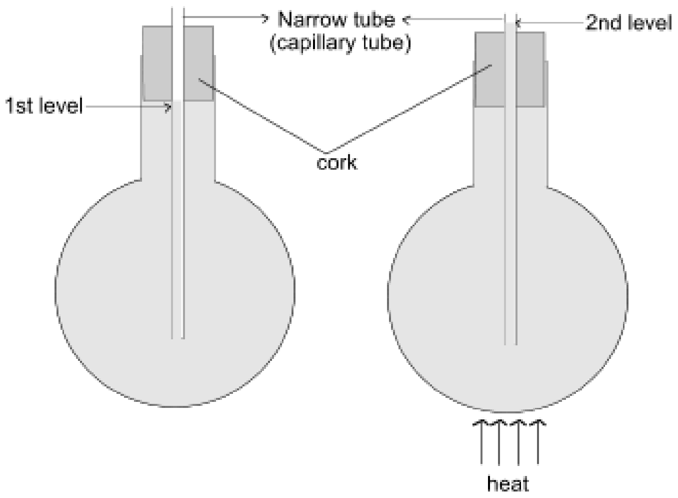
Transmission cables

Wires or cables in transmission or telephone cables are normally not pulled tightly during installation in order to allow room for expansion and contraction during extreme weather conditions.

EXPANSION IN FLUIDS

When liquids or gases (fluids) get hot , they expand just as solids do, but their expansion is greater than that of solids for the same amount of heat.

Experiment to demonstrate expansion in liquids



Procedure

- Fill the flask completely with colored water. Pass the narrow tube through the hole of the cork and fix the cork tightly to the flask.
- Note the first level of water on a narrow tube
- Heat the bottom of the flask and observe the new level of water on the capillary tube.
- Therefore liquids expand when heated since there was a rise in the levels of water in the capillary tube.

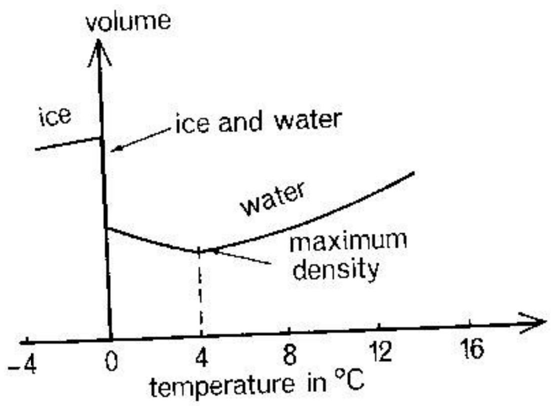
Application of expansion property of liquids

This property is used in thermometer; the liquids used include alcohol and mercury.

Anomalous expansion of water

When water is heated over the temperature of 0 -4^{0}C it contracts instead of expanding and this is what is called anomalous (unusual) expansion of water.

The volume of water is minimum at 4^{0}C and its density is maximum beyond 4^{o}C the volume of water increases i.e. expands increase in temperature.

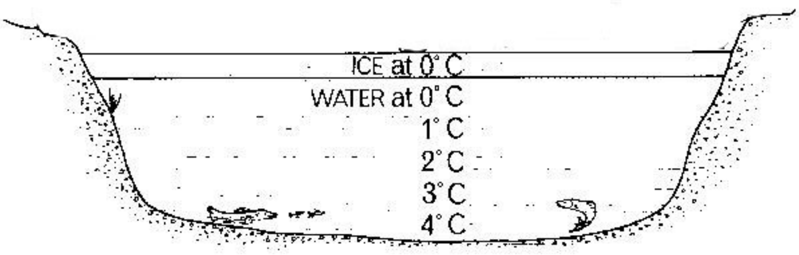


Application of anomalous behavior of water.

It is used to preserve aquatic life during cold weather.

As the temperature of the pond or lake fall the water contracts it becomes denser and sinks. a circulation is thus set up until all the water reaches its maximum density at 4^0c if furth cooling occurs any water below 4^0c will stay at the top due to its lighter density thus ice format the top of water.

The lower layer of water at 4^0c can only loss heat by conduction. So in deep water there will be always water beneath the ice in which fish and other creatures can live.



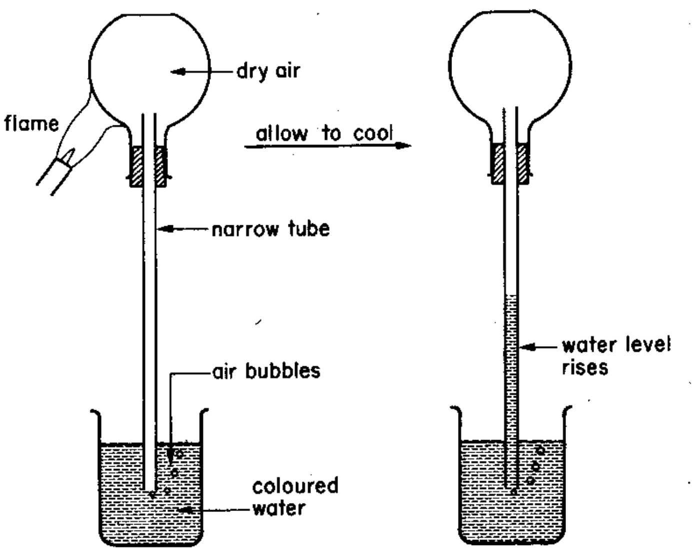
Disadvantages of anomalous behavior of water.

- it causes weathering of rocks due to its expansion and contraction
- it can cause water pipes to bust due to formation of ice inside the pipe
- it can have a satisfactory thermometer with water as the thermometric liquid.

EXPANSION OF GASES

A gas expands when heated almost 10,000 times more than solids this is due to the fact that cohesive exist between molecules are extremely weak.

Experiment to demonstrate expansion in gases



- In the above set up the flask is slightly heated.
- Air bubbles will be seen coming out from the other end of the tube
- This shows that air expand when heated.
- In the second set up, when the surface of heat is removed and the flask is allowed to cool by pouring cold water, the level of water will rise. This shows that air contacts when cooled.

Application of expansion of air.

1) Hot air balloon

Expansion of air is used in hot air balloon. When air in the balloon is heated, it expands and becomes less dense and as a result the balloon rises up.

THERMOMETRY

Thermometers: these are instruments used for measuring temperatures

Thermometric properties

A thermometric property is a property of a substance which continuously change with temperature and may be used for temperature measurements, these include:

- Increase in length.
- Change in difference
- *Change in volume*
- Change in pressure.

THERMOMETER SCALES.

There are 3 thermometer scales commonly used

1) Celsius / centigrade scale(^{0}C)
2) Fahrenheit (^{0}F)
3) Kelvin/ absolute(k)

a) Relation between Celsius and Fahrenheit

$F = \frac{9}{5}C + 32$

If Celsius scale reads ^{0}0c then $F = \frac{9}{5}\theta + 32$

And if Celsius scale reads 100^{0}c then $F = \frac{9}{5} X100 + 32$

$= 212^0F$

b) Converting from Fahrenheit to Celsius.

The formula is $C = \frac{5}{9}(F-32)$

$C = \frac{9}{5}(212 - 32)$

$= 100^0C$

c) Relationship between Celsius scale and Kelvin scale.

K = 273 + C where C is temperature in Celsius scale and is temperature in Kelvin scale.

d) Convert 0^0C to Kelvin scale

$K = 273 + \theta$

$= 273K.$

Convert 100^0C to Kelvin scale (Absolute scale)

$K = 273 + 100$

$= 373K$

To obtain a standard scale on a thermometer. Two fixed points must be marked out on it. The upper and lower fixed points.

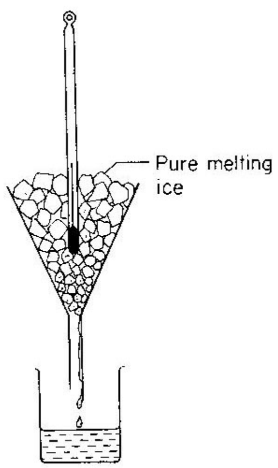
LOWER FIXED POINTS:

This is the temperature of pure melting ice at standard atmospheric pressure.

76cm Hg or 760mm Hg and – On Fahrenheit scale = 32^0F

- On Celsius scale = 0^0C
- Kelvin scale = 237K

DETERMINATION OF LOWER FIXED POINTS:



Procedure;

-support the funnel on a retort stand as shown above.

-put the thermometer in funnel packed with pure melting ice.

- Adjust the thermometer so that the mercury thread is clearly seen.

-mark the points where the level of mercury stops is the lower fixed point.

UPPER FIXED POINT:

This is the temperature as steam above the boiling water of standard atmospheric pressure.

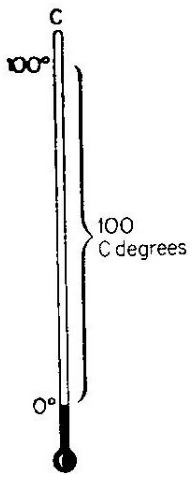
On Celsius scale is 100^0C

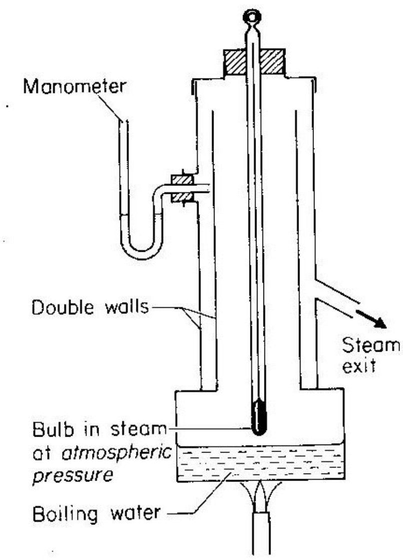
On Kelvin scale is 373K

On Fahrenheit scale is 212^0F.

Determination of upper fixed point using a hypsometer.

A hypsometer is a two walled vessel made out of a round bottom flask.





Procedure;

-Partly fill vessel with water and arrange the apparatus as in the diagram.

-Gently heat water in vessel using a Bunsen flame to its boiling point.

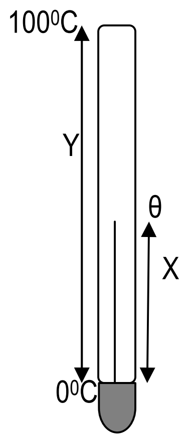
-Adjust the thermometer so that mercury thread is seen clearly when water is boiling.

-Make the end of mercury thread as the **upper fixed point.**

-With the upper and lower fixed marked points on the thermometer the distance between them is divided into 100 equal degrees so that the thermometer gets the scale. In the way it is said to be calibrated.

Using un calibrated thermometer to measure temperature:

The interval between the upper fixed point and the lower fixed point is called the fundamental interval. This is divided into a hundred equal parts and each is called a degree.



Example:

1. The top of a mercury thread of a given thermometer is 3cm from the ice point, if the fundamental interval is 5cm, determine the unknown temperature θ.

X = 3cm

Y = 5cm

$\theta = \frac{X}{Y} \times 100$

$= \frac{3}{5} \times 100$

$= 60^0C$

2. The length of a mercury thread at a low fixed point and upper fixed point are 2cm and 8cm respectively for a certain liquid X. Given that the length of mercury thread at un known temperature θ is 6cm determine the value of θ.

X = 6 – 2 = 4

Y = 8-2 = 6

θ = $\frac{X}{Y}$ x 100

= $\frac{4}{6}$ x 100

= 66.7^{0}C

3. Find the temperature in ^{o}C if the length of mercury thread is 7cm from the point and fundamental interval is 20cm.

θ = $\frac{X}{Y}$

= $\frac{7}{20}$ x 100

= 35^{0}C

4. Find the unknown temperature 0 given the following length of mercury.

-Length of steam = 25cm

-Length of ice point = 1cm

-Length of known temperature θ= 19cm

Y = 25 – 1 = 24 x 100

X = 19 – 1 = 18

= 3 x 25

= 75^{0}C

Thermometric liquids.

These include – mercury

- Alcohol
- Water

Water is not commonly used because of the following reasons:

-It is transparent i.e.
Its meniscus is difficult to see and read.

-It does not expand regularly

-It sticks on glass

-It has relatively low boiling point.

-It is poor conductor of heat.

QUALITIES OF A GOOD THERMOMETRIC LIQUID:

-Must easily be seen (opaque)

-Must expand regularly with temperature.

-Must have a high boiling temperature to measure high temperature.

-Must have low freezing point to measure low temperature.

-Must not stick on glass

-Must be a good conduct of heat.

-Must not be very expensive

-Must not be poisonous and it should be available.

Advantages of mercury over alcohol when used as thermometric liquid.

Mercury	**Alcohol**
It is opaque	It is colourless
Good conduct of heat	Poor conduct of heat as compared to mercury
Expand regularly	Does not expand regularly as mercury
Has a high boiling point (357^{0}C)	Has low boiling point 78^{0}C
and can be used to measure temperature.	
Mercury does not stick on glass.	Sticks on glass
It does not distill easily	Distills easily.

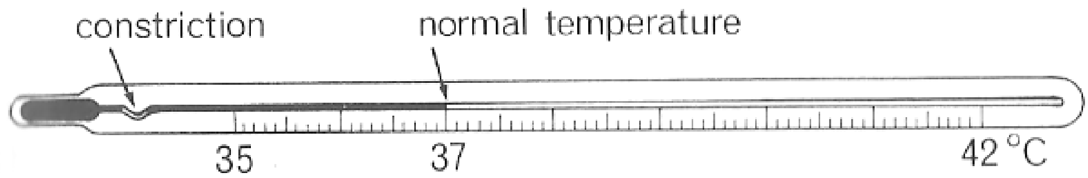
Advantages of alcohol over mercury

Alcohol	Mercury

Has a low freezing point (115^{0}c)	Has a high freezing point of -39^{0}c hence unsuitable to measure very low temperatures.
Has a high a linear expansively(expands so much for small temperature range)	Has a low linear expansivity (expands little for the same temperature range)

CLINICAL THERMOMETER:

This thermometer is used to measure the human body temperature.



-The thermometer has a very fine bore which makes it sensitive.

-Expansion of mercury makes it shoot along the tube.

-The glass from which the tube is made very thin which body heat can reach the mercury quickly to read body temperature.

-When thermometer bulb is placed into the mouth or armpit, the mercury expands and it is forced past the constriction along the tube.

-When removed, the bulb cools and the mercury in it contracts quickly.

-The mercury column breaks at the constriction leaving mercury in the tube. The constriction prevents flow back of mercury to the bulb when the thermometer is temporary removed from the patients mouth or armpits.

The thermometer is reset by shaking the mercury back in the bulb.

Effect of heat on matter:

-When a solid is heated, the cohesive forces between its molecules are weakened and the molecules begin to vibrate vigorously causing the solid to change into a liquid state.

-The temperature at which a solid changes into liquid is called the melting point. At melting point the temperature remains constant until the solid has melted.

-When the entire solid has melted and more heat is applied, the temperature rises. The heat gained weakens the cohesive forces between the liquid molecules considerably causing the molecules to move faster until the liquid changes into gaseous state.

-The temperature at which a liquid changes into gaseous state is called the boiling point. At boiling point temperature of the liquid remains constant since heat supplied weakens the cohesive forces of attraction in liquid molecules.

-If the heated substance is water its temperature rises with time as shown below.

Properties/qualities of a thermometer.

i) Quick action
ii) Sensitivity.

- Quick action

This refers to the ability of a thermometer to measure temperature in the shortest time possible. This is attained by using a thin walled bulb using a liquid which is a good conductor of heat e.g. mercury.

- Sensitivity

This is the ability of a thermometer to detect a very small temperature change. It is attained by:

i) Using a thermometer with a big bulb
ii) Use of a liquid which has a high linear expansivity.
iii) Using a narrow bore or reducing the diameter of the bore hole

HEAT CAPACITY

This is the heat required to rise the temperature of a substance by 1^0c or 1k S.I units is ŋ1^oc or ŋ1^ok

Heat capacity = $\frac{heat}{temperature\ change}$

Specific heat energy

This is the heat required to raise the temperature of the substance by 10c S.I units is ŋ$kg^{-1}\,{}^oc^{-1}$

Specific capacity has a symbol C = $\frac{joules}{kgoc}$ = $\frac{heat}{mass\ xtemperature\ rise}$

Heat = mass x c x temperature

Example

1. 6000J of heat is used to heat a liquid of mass 3kg ^{0}C from 25^oC to 45^0C. Find the specific heat capacity of the liquid.

$$H = M\ C\ \theta$$
$$6000 = 3 \times c \times 20$$
$$C = 100Jkg^{-1}\,{}^oC^{-1}$$

2. 10,000J of heat is used to heat the metal block of mass 400m 20^0c -100^0c.find the (C) of the metal block.

θ = (100 -20) = 80^0C

H =M C θ

10,000 = 0.4 x c x 80

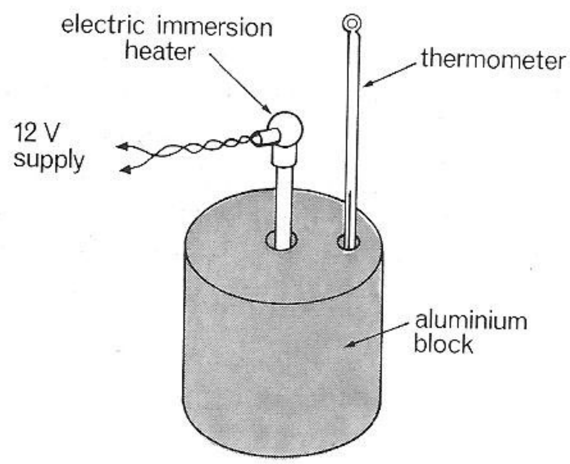
C = 312.5$Jkg^{-1}\,{}^oC^{-1}$

3. Find the heat required to raise the temperature of a block of mass 200g from25^0C to 65^0C (specific heat capacity of the block is 130$Jkg^{-1}{}^oC^{-1}$)

H = M C θ

H = 0.2 X 130 X 40 =1040J

DETERMINATION OF SPECIFIC HEAT CAPACITY OF A METALIC BLOCK



The mass (m) of the metallic block is first measured and recorded using a beam balance.

The heater of known power (P) and thermometer are placed in the block. The initial temperature of the block is recorded. The heater is switched on and left to heat for some time (t).

The purpose of cotton wool is to ensure that no heat is lost to the surrounding.

Assume no heat is lost to the surrounding

Heat supplied = heat absorbed or gained by the metal

$$Pt = m\, c_m \times \theta$$

$$C_m = \frac{Pt}{m\theta}$$

Where c_m is the specific heat capacity of the metal

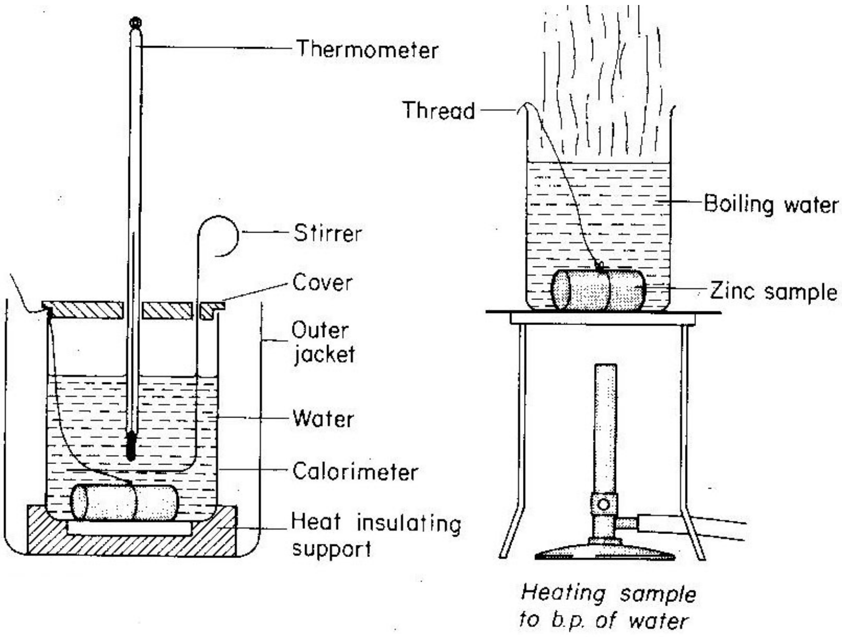
Θ- Is the temperature change i.e. ($\theta = \theta_2 - \theta_1$)

Question

A heater rated 2kw Find the heat in

i) 5 seconds
ii) 10 minutes
iii) 2 hour

DETERMINATION OF SPECIFIC HEAT TEMEPRATURE OF A SOLID BY METHOD OF MIXTURES.



Procedure

- Put water of mass m_1 in a container of heat capacity c_1
- Put calorimeter and its contents in a calorimeter jacket and record the initial temperature θ_1
- Mean while, put the solid of mass m in boiling water in a beaker as shown in figure(i) above for 5 minutes
- Record the boiling point θ_2
- Quickly transfer the solid from boiling water to the calorimeter using a string.
- Begin to stirrer until the final steady temperature θ_3 is obtained the heat shield is to prevent the heating from boiling water to reach the calorimeter.
- Assume eligible heat to the surrounding.

Heat lost by solid = heat gain θ d by the calorimeter + heat gained by H20.

$MC_S (\theta_3 - \theta_2) = M_1C_1 (\theta_3 - \theta_1) + M_2 C_2 (\theta_3 - \theta_1)$

$C_s = \frac{(M1C1 + M2C2)\ (\theta 3 - \theta 1)}{M\ (\theta 2 - \theta 3)}$

Knowing values of C_1,M_1, M_2, C_2,M and temperature changes, specific heat capacity of a solid C_s can be obtained from the above expression.

Examples:

1. 252,000J of heat are supplied to 4kg of H20 at 400c.Find the final temperature of water (specific capacity of H_20 is 4200JKg^{-1o}C^{-1})

$H = MC\ (\theta_2 - \theta_1)$

$252{,}000 = 4 \times 4200\ (\theta_2 - 40)$

Final temperature = 55^0C

2. In an experiment to determine the specific heat capacity of a solid. was put in boiling H_20 for 5min.It was then quickly transferred in 5kg liquid at 46^0C in plastic beaker. The final temperature of the mixture was found to be 500C.Find the specific capacity of the solid (specific capacity of solid is 2000JKg^{-10}C^{-1}.

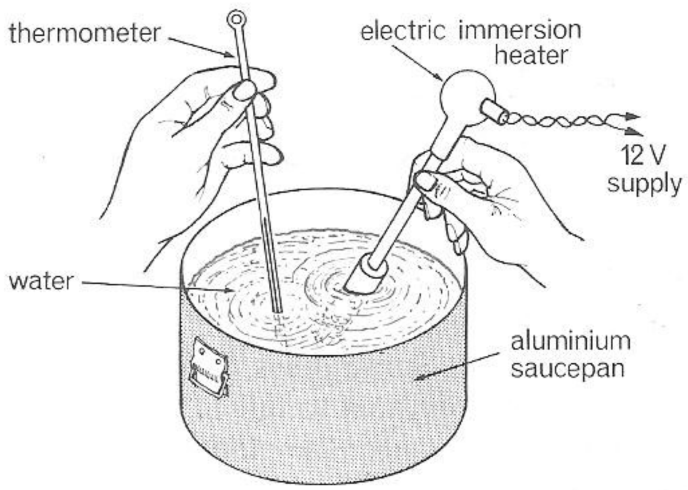
1. Heat lost by = Heat gained by liquid.
Solid

$MC\ (\theta_1\text{-}\theta_2) \quad = M_1C_1\ (\theta_3\text{-}\theta_2)$

$2 \times C\ (100\text{-}50) \quad = 5 \times 2000\ (50 - 46$

$C = 400$JKg^{-1o}C^{-1}

Determination of specific heat capacity of a liquid by electrical method



Procedure;

- Pour the liquid of known mass (m) in a plastic beaker or insulated aluminium pan
- Put the heater of known power (P) and the thermometer in the plastic beaker containing a liquid.
- Measure and record the initial temperature θ_1 of the liquid.
- Switch on the heater to warm the liquid for time (t).
- Read and record the final stable temperature θ_2 of the liquid.

Calculate the specific capacity.

Heat gained by liquid = Heat supplied by the heater.

$$MC(\theta_2 - \theta_1) = Pt$$

Specific heat capacity of the liquid $C = \frac{Pt}{M(\theta 2 - \theta 1)}$

Assumptions the;

- The amount of heat absorbed by the plastic beaker is negligible.
- No heat is absorbed by H_20 (liquid) from the surroundings.

Example;

1. An immersion heater of 60W was used to heat a liquid of 1Kg for $\frac{1}{2}$ a minute. Find the specific capacity of the liquid if the initial temperature was 27^0C and 87^0CHeat absorbed by water = Heat supplied by the heater

$MC(\theta_2 - \theta_1) = Pt$

$1 \text{x} C(87 - 27) = 60 \text{ x } 30$

$C = 30JKg^{-1o}C^{-1}$

2. Atifa was to have a warm bath. She mixes 5Kg of hot H20 at 850C with 15Kg of cold water at 250C taking C to be $4200JKg^OC^{-1}$. Find the final temperature of the mixture.

Heat lost by hot water = Heat gained by cold water

$M_hC(\theta 2 - \theta_3) = M_cC(\theta_3 - \theta_1)$

$5 \text{ x } 4200(85 - \theta_3) = 15 \text{ x } 14200(\theta_3 - 25)$

$\theta_3 = 40^oC$

Importance of high specific capacity of H_20 $C = 4200JKg^{-1o}C^{-1}$

4400J of heat required to increase the temperature by 1^0C is extremely high, because of this high value of (C) of H_20, it is commonly used as a cooling agent in many cooling systems e.g. car radiators

LATENT HEAT

Latent heat is the heat lost or absorbed by the body during change of state at constant temperature.

There 2 types of latent heat

(i) latent heat of vaporization (L_v)
(ii) Latent heat of fusion (L_f)

Latent heat of vaporization;

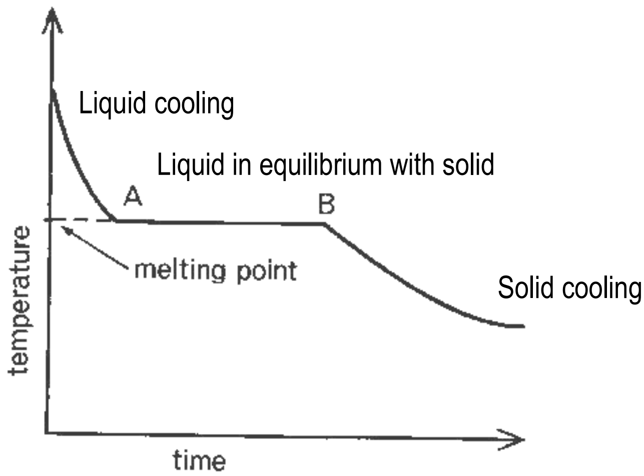
This is the amount of heat absorbed by a body to change its state 4rm liquid to vapour at constant temperature.

NB: The constant temperature is the boiling point of the liquid.

Latent heat of fusion;

This is the amount of heat absorbed by a body to change its state from solid to liquid at constant temperature. The constant temperature is the melting or freezing point.

Cooling curve of a substance



Specific latent heat of vaporization L_v

This is the amount of heat required to change 1Kg M of a substance from liquid to vapour at constant temperature.

$H = ML_v$ where H is amount of heat supplied or lost by a body.

M = mass of the body. L_v = Specific latent heat of vaporization of the body.

Examples

1. Find the amount of heat required to convert 5kg of water at boiling point to steam (Take l_v of steam as 2.3×10^6 Jkg^{-1})

Quantity of heat H = MLV

= 5 X 2.3 X 10J

= 11.5×10^6J

= 1.15×10^5J

2. How much heat is needed to change 4kg of water at 10^0c to steam at 100^0c

H = mlv

H = 4 X2 .3 X10^6J

H = 9.2 X 10^6J

3. A three (kilowatt electrical kettle is left on for 2 minutes after the water starts boiling. What mass of water is boiled off in this time ?

Latent heat absorbed by H_20 = Heat supplied by heater

M x 2.3 x 10^6 = 3 x1000 x 2 x 60

M = 0.1565kg = 156.5g

4. Find the heat given out when 10g of steam at 100^0C condenses and cool to water at 50^0C

Heat given = heat required to cool steam to water + heat required to cool water from 100^0C to 50^oC.

H = mlv + mc (θ_2 –θ_1)

$$= \frac{10\ x2300000}{1000} + \frac{10\ \ x\ 4200(100-50)}{1000}$$

= 25100J

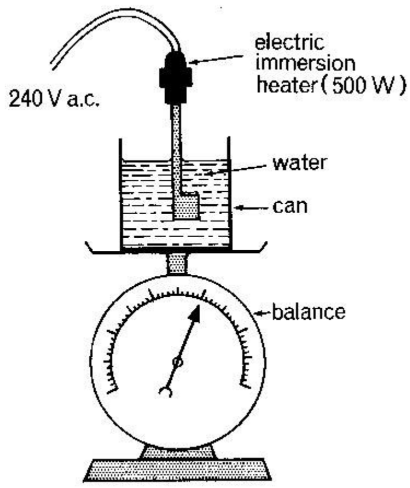
Since the amount of heat in steam is 5 times of heat in boiling water, therefore steam is more fatal than boiling water.

Importance of high value of specific latent heat of vapourization

1. Because of high value, steam is used as a heating agent e.g. cooking .

2. Can be used for sterilizing medical tools e.g. blades, forceps.

Determination of specific latent heat of vaporization of steam.



Procedure

- Assume the apparatus as in the diagram above.
- When the weight mass of in the beaker and record it as m_1.
- Switch on the heater to heat water in the beaker.
- While water is boiling, read the position of the pointer of the stop clock.
- After time (t) weigh the mass of water (m_2)
- Calculate the mass of steam from

  $M = m_1 - m_2$

  Obtain specific latent heat of vapourization from:

  Latent heat absorbed by boiling water = heat supplied by heater

$$Mlv = pt$$

$$Lv = \frac{pt}{m}$$

Where lv is the specific latent heat of vaporization.

SPECIFIC LATENT HEAT OF FUSION (L_F)

Specific latent heat of fusion is a mount of heat required to change the state of 1 kg mass of a substance from solid to liquid at constant temperature S.I unit J/kg

Example

1(a) how much heat will change 10g of ice at 0°C to water 0°C (take specific latent heat of fusion of ice to be 340,000J/kg)

$$H = mlv$$

$$H = \frac{10\ x340{,}000}{1000} = 3400J$$

2. What quantity of heat must be removed from 20g of water at 0°C to change it to ice at 0°C.

$H = ml_f$

$= \frac{20 \, x 340{,}000}{1000}$ = 6800J.

3. How much heat is needed to change 5 g of ice at -5°C .

$H = mc\theta + mlf + mcw\theta$

$= \frac{5 \, x \, 2100(0--5)}{1000} + \frac{5 \, x3 \, x000}{1000} + \frac{5 \, x \, 200}{1000}$

= 2,802.5J

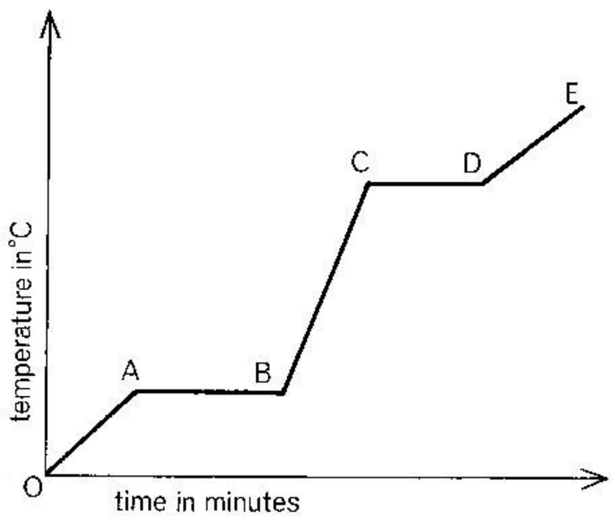
Question

1. (a)What is meant by specific heat capacity?

b) 2 kg of ice initially at -10 °C is heated until it changes to steam at 100°C.

i) Sketch a graph to show how the temperature changes with time.
Ii) Calculate the thermo energy required at each section of the graph sketched in b(i) above .
Specific latent heat of fusion of ice is = 3.36 $x10^5Jkg^{-1}$
Specific latent heat of vapourization of water is = 2.26 x 10^6Jkg^{-1}.
Specific heat capacity of water = 42 $X10^3$ J/kgk
Specific heat capacity of ice is = 2.1 $x10^3$J/kgk.

GRAPH TO SHOW HOW TEMPERATURE CHANGES WITH TIME



(iii) Thermal energy along AB,

= $MC_{ice} \, \theta$

= $2 \times 2.1 \times 10^3 (0 - ^-5)$ = 4.2×10^4J

Thermal energy along BC

$H = ML_f$

$= 2 \times 3.36 \times 10^5 = 6.72 \times 10^5 J$

Thermal energy along CD,

$= MCw\theta$

$= 2 \times 4.2 \times 10^3 \times (100-0) = 8.4 \times 10^5 J$

Thermal energy along DE,

$= Mlv$

$= 2 \times 2.26 \times 10^6 = 4.52 \times 10^6 J$

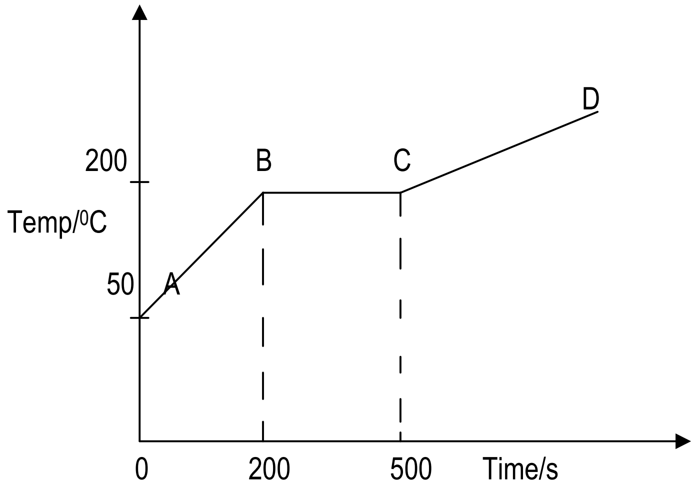
Exercise;

1. (i)State and define the 3 major methods of heat transfer.

2.(a) Distinguish between specific heat capacity and specific latent heat of a substance.

(b)Describe an experiment to determine the specific latent heat of fusion of ice.

3. The Graph showing a heating curve of a metal



(i) Explain what happens to the metal.

.

(ii)If the metal absorbs heat at the rate of 3000J/S and specific heat capacity is $400JKg^{-1\,o}C^{-1}$, calculate mass of the metal.

(ii) Find the specific latent heat of the metal,

3. (a) Find the ways you would modify a liquid in glass thermometer so that it can register temperature more quickly.

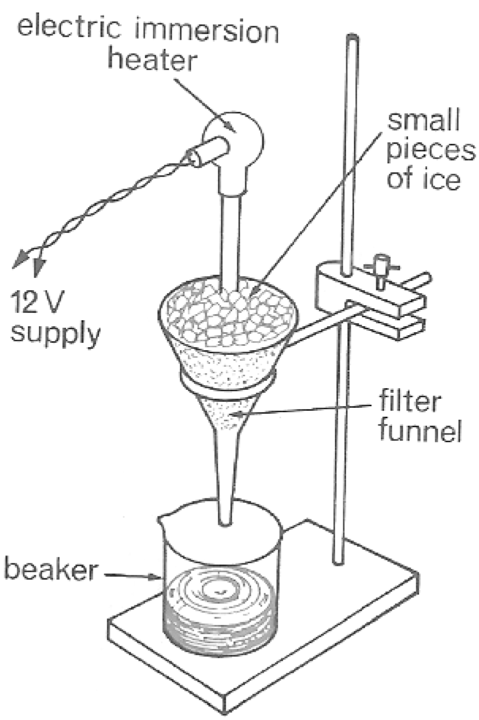
(b) Why is it usually not a good idea to have a thermometer with high heat capacity?

4. (a) Explain why the freezing compartment of a refrigerator is at the top.

(b)A glass of orange squash contains 0.2 kg of water at temperature of 24^0C.What is the minimum amount of ice you would need to add in order that the temperature of the drink is 0^0C?

Experiment to determine the specific latent heat of fusion of ice

Set up.



Procedure;

Support the plastic funnel using the retort stand.

Arrange the apparatus as in the diagram without the beaker.

When the water in the funnel starts dripping at a uniform rate, switch on the immersion heater and place the beaker under the funnel at the same time.

After sometime (t) of warming ice using the heater (of known power (p),

Remove the beaker and the mass (m) of the water collected in the beaker is weighed.

Calculate the specific latent heat of fusion of ice from:

Heat absorbed by ice = Heat supplied by heater

$$ML_f = Pt$$

$$L_f = \frac{Pt}{M}$$

Assumption;

-No heat is absorbed from the surrounding.

- All heat supplied by the heater has been absorbed by the ice only.

Significance of high value of specific latent heat of fusion

Ice is often used as a cooling agent e.g. ice cubes are added to juice to keep it cold.

Example:

An aluminum tray of mass 400g containing 300g of water is placed in a refrigerator, after 80 minutes, of tray is removed and it is found that 60g of water remain un frozen at 0^0C. If the initial temperature of tray and its content was 200c, determine the average amount of heat removed per minute by the refrigerator.

Specific capacity of aluminum = $1J/g^0C^{-1}$

Specific capacity of water = $4Jg^{-1o}C^{-1}$

Specific latent heat of fusion of ice = 340J/g

Heat removed by the fridge = Heat loss by water from 20^0C to 0^0C + Heat loss by water to ice + heat loss by tray.

$= M_wC_w (\theta_2 – \theta_1) + M_{ice} L_f + M_tC_1 (\theta_2 – \theta_1)$

$= 0.3 \times 4000 (20 – 0) + 0.24 \times 340,000 + 0.4 \times 1000 (20 – 0)$

= 113600J

Heat removed per minute = $\frac{113600}{60}$

= 1420J/min

question1:

In an experiment to determine specific latent heat of fusion of ice, the following results were obtained.

Mass of water obtained in the beaker = 20g

Power of the heater = 50W.

Time heater is switched on = 2min 6seconds

Determine specific latent heat of fusion of ice.

Latent heat and kinetic theory

(a) Latent heat of fusion.

During change of state from solid to liquid (melting at constant temperature, the heat supplied weakens the intermolecular forces of attraction, the molecular spacing increase, changing from static molecules of solid to fast moving molecules in liquid state.

The average K.E of molecules remaining constant because melting takes place at constant temperature.

(b) Latent heat of vaporization;

During change of state from liquid to vapour, the molecules must overcome of intermolecular forces of attraction so that they gain freedom to move about independently. As a result, the supplied is used to overcome these forces resulting in gain molecular potential energy but not their kinetic energy and also the work to expand against atmospheric pressure.

Why specific latent heat of vaporization of a substance is always greater than specific latent heat of fusion for the same substance.

Specific latent heat of vaporization is always greater than Lf because for molecules of a liquid to escape. $they\ require\ a\ lot\ of\ heat\ which\ increase\ K.E\ in\ order\ to\ overcome\ the\ intermolecular\ forces\ of\ attraction.$

While for latent heat of fusion very low amount of heat is required to weaken the intermolecular forces of attraction.

CHANGE OF STATE

1. Melting

It is a process by which a solid substance changes into a liquid e.g ice (solid) changes to water (liquid) when heated. Temperature at which solid substance changes to liquid is called melting point.

NB: There is no change in temperature of substance at its melting point. This is because the heat supplied is used to

weaken cohesive forces of attraction between molecules.

2. Boiling

This is the process by which a liquid when heated changes to the gaseous state at a fixed temperature e.g pure

water at 100^0c changes to vapour by the process of boiling.

There is no change in temperature at boiling point because the heat supplied is used to weaken cohesive attraction

of molecules and the rest is converted to kinetic form of energy.

3. Evaporation;

It is the process by which a liquid changes to gaseous state at any temperature. The rate of evaporation is affected

by the following factors;

Factors;

1. Temperature
2. Amount of humidity in the atmosphere
3. Pressure
4. Surface area
5. Nature of the liquid
6. Wind and dryness of air

Temperature;

The higher the temperature, the higher the average speed at which molecules move and therefore there will be more molecules moving to the liquid surface.

Pressure;

Increase in pressure lowers the rate of evaporation.

Surface area:

When the surface area of a liquid is increased, more molecules are brought to the surface and more rate of evaporation is increased.

Nature of the liquid

Different liquids have different cohesive forces ,those which have greater cohesive forces tend to evaporate less than liquids with less cohesive forces.

Wind and dryness of air

Dryness of air around the liquid surface causes rapid evaporation. Wind blows away water vapor along the body and this causes rapid evaporation to take place.

Differences between boiling and evaporation

Boiling	Evaporation
Takes place at a fixed temperature called boiling .	Occurs at any temperature

Boiling takes place throughout the liquid.	Takes place only on the surface of the liquid
Boiling is a vigorous process	Evaporation is a gentle process
Bubbles are formed with in the liquid	No bubble is formed on the surface of the liquid.
Boiling doesn't result into cooling	Evaporation result into cooling.

Cooling by evaporation

The molecules which escape from the surface of liquids are those with greater kinetic energy, the molecules which remain in the liquid are those with very low kinetic energy. The energy, the molecules use, as their kinetic energy is the latent heat which they absorb. The absorption of this latent heat from the liquids brings about a fall in temperature, thus a body cools.

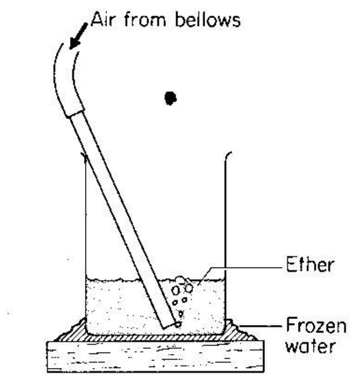
Application of cooling by evaporation

-cooling of a body by evaporation of sweat from the body

-cooling water using a porous pot or refrigerator

-cooling of the dog by the saliva on its tongue evaporation

Demonstration of cooling by evaporation



A beaker about one third full of ether is stood in a small pour of water on a flat piece of wood

Air is then bubbled through the ether. The ether evaporates into bubbles and the vapour is carried quickly away as the bubbles rise to the surface and burst thus increasing the rate of evaporation.

After sometime, the water on the wooden block cools to 0^0c and freezes to form ice. This demonstrates that evaporation causes cooling.

Explanation

As the ether evaporates, it absorbs latent heat from its liquid state with the result that it cools below 0^0c. At the same time heat becomes conducted through the walls the beaker from the pool of water below it and eventually the water cools to 0^0c. After this, it begins to loose latent heat and freezes.

The refrigerator

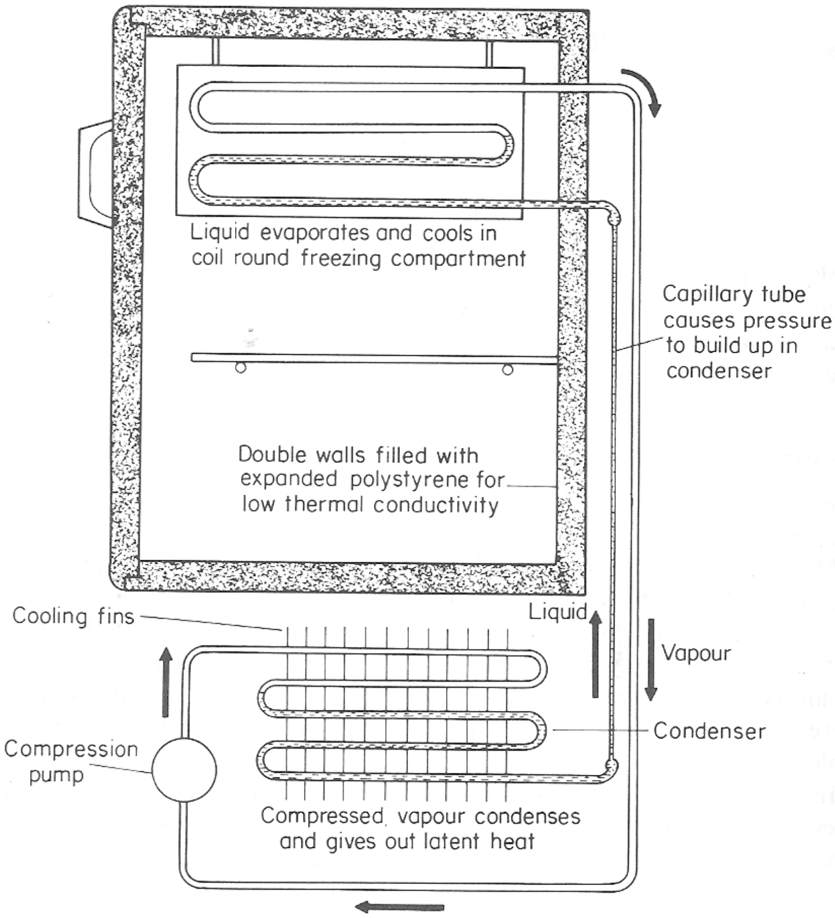


Fig. 19.5. Domestic electric refrigerator

It operates on the evaporation by cooling principle.

The liquid used in a refrigerator is Freon which is volatile (Freon is collective term for suitable refrigerants e.g. dichlorodifluoromethane boiling point about -30^{0}c or 243k).

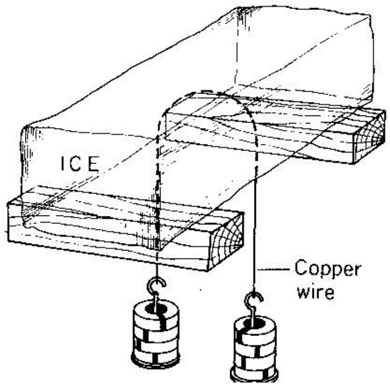
Freon evaporates inside the coiled tubes surrounding the freezing compartment assisted by a pump which reduces the pressure.

When Freon evaporates, it absorbs heat from the surrounding air and this causes the refrigerator and its content to cool. The vapour produced is pumped away and compressed in the condenser where it condenses to liquid again.

The heat released during condensation is quickly removed by cooling fins at the back of the refrigerator.

The process of evaporating and condensing Freon is repeated on and on, thus causing the refrigerator to cool further.

Demonstration of effect of pressure on melting point (regelation)



A weighted copper wire is allowed to pass through a block of ice. It sinks through, without cutting the ice block into two pieces

Explanation

When a copper wire is pulled, a very high pressure is exerted on the ice block, lowering its melting point and the ice melts.

The wire sinks through the water which is no longer under pressure and freezes above the wire because melting point returns to 0^0c

In freezing, the water gives out its latent heat of fusion and thus conducted down through the wire to enable the ice below it to melt. This effect is called regelation (freezing).

Note: If an iron wire is used in demonstration, it passes through the ice more slowly. No effect is obtained if string is used.

VAPOUR PRESSURE.

It refers to the pressure exerted on the wall of the container by the vapour.

Consider a liquid in a closed vessel when molecules escape from the liquid they form vapour the surface of the liquid

the vapour molecules move in directions and exerts a pressure called vapour pressure.

When the bounce off, the vessel strikes the liquids on surface and enter it. The dynamic equilibrium is eventually

reached ,in which the rate at which molecules live the liquid is equal to which others returns to it.

When this happens, the space above the liquid is said to be saturated with vapour.

The vapour pressure used in this state is called saturated vapour pressure but before the equilibrium the vapour

is said to be unsaturated.

Saturated vapour pressure

It is the pressure exerted on the walls of a contain by the vapour when the rate at which molecules are entering

the liquid is equal to the rate at which molecules are entering the liquid.

OR : **Saturated vapour pressure**

Is pressure exerted the vapour in a dynamic equilibrium in its own liquid.

Boiling point

Is the temperature at which at which the saturated vapour pressure is equal to the external atmospheric pressure.

At this temperature liquid molecules have enough energy to form bubbles of vapour inside the liquid. The bubbles

formed at the bottom contain saturated vapour when the reach the surface they burst.

FACTORS WHICH AFFECT THE BOILLING POINT AND FREZING/MELTING POINT OF WATER

Addition of impurities

Increase or decrease in pressure

Effects of impurities on boiling and melting points

a) Melting point
The impurities lower the melting point of a surface e.g when impurity is added to ice it melts at a lower temperature. This is because impurities weaken the cohesive forces in ice molecules making it easy for them to move freely hence the change of state from solid to liquid.

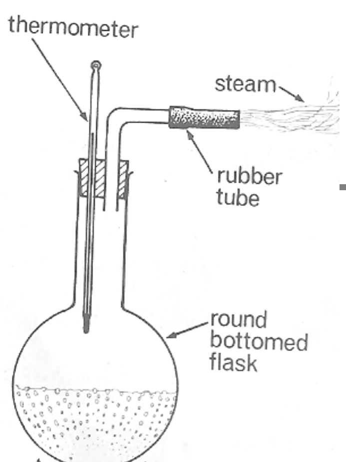
b) Boiling point

Impurities raise the boiling point of a substance e.g when salti added to water the mixture must be heated at a higher temperature before it boils. This is because impurities strengthen the cohesive forces between water molecules so more heat must be supplied to weaken them. The increase in the heat supply makes the boiling point to rise.

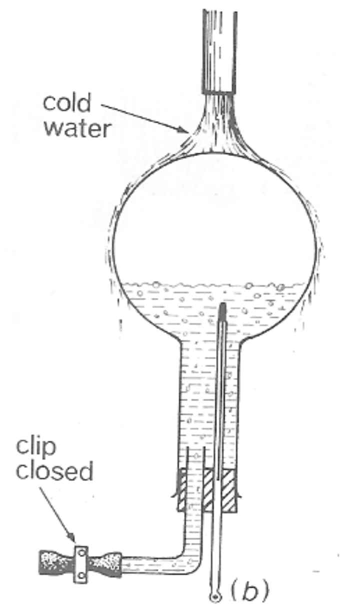
Effect of pressure on boiling and melting points

Boiling points

Increase in pressure raises the boiling point of liquid. This can be showed below resulting in decrease in gas pressure.



- Water in the flask shown above has to be heated to about 100^0c before it boils. If the pressure above the flask is high, the liquid starts to boil at a much lower temperature than usual.
- This can be shown by boiling water in the flask for a few minutes so that the steam sweeps out most air .Heating is stopped and the clip is closed
- Cold water is poured on the inverted flask, so condensing the steamed water this reduces pressure above water.
- The water starts to boil and if cooling in this way it continued boiling goes on until above 40^0c

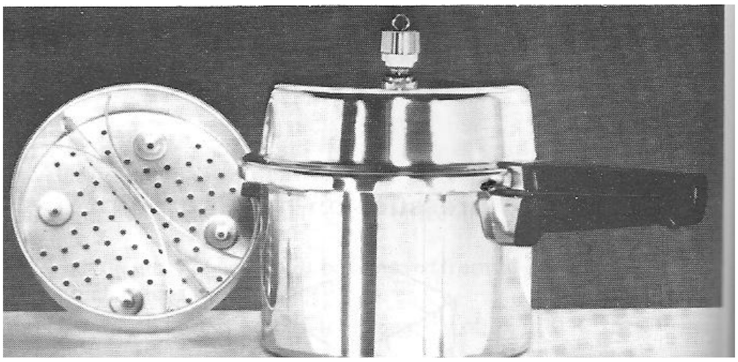


Melting point

Increase in pressure lowers the melting point of a solid e.g ice. This effect makes skating /skiing possible, the pressure of ice skate melts the ice under it, so that there is a thin layer of water between the skate and ice. The layer of water acts as a lubricant and almost completely removes friction between skate and ice.

The pressure cooker

This is a strong aluminium pan, whose lid is sealed with a rubber sealing ring to prevent steam from escaping from inside the pan.
As the substance e.g water is heated to boil,the steam pressure inside builds up causing the boiling point to rise to about 120^{0}c
The high temperature makes the substance get cooked quickly.



GAS LAWS

Gases when heated will show a significant change in pressure volume and temperature. Unlike solids and liquids which show on insignificant change in volume. There are 3 gas laws -:

1. Boyle's law
2. Charles's law
3. Pressure law

BOYLE'S LAW.

It states that the pressure of a fixed mass of gas is inversely proportional to its volume provided temperature remains constant.

Mathematically

$P \propto \frac{1}{v}$ at constant temperature.

PV = k (constant)

So, in calculation we use ;

$P_1V_1 = P_2V_2$

Example 1

The pressure of a fixed mass of gas is 5artmospheres when its volume is 200cm^3. Find its pressure when the volume

(i) Is halved
(ii) Is doubled

(iii) Is increased by $1\frac{1}{2}$ times provided temperature remains constant.

Solution

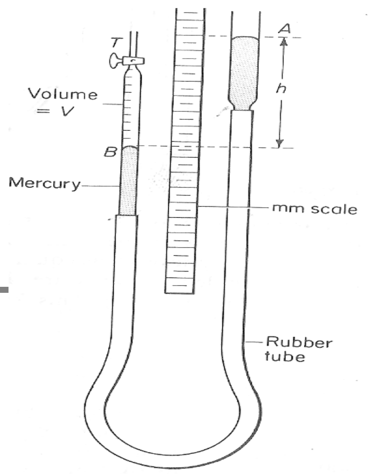
(i) $P_1 V_1 = P_2V_2$
$5 \times 200 = P_2 \times 100$
$P_2 = 10$ atmospheres.

(ii) $P_1V_1 = P_2 V_2$
$5 \times 200 = P_2 \times 400$
$P_2 = 2.5$ atmospheres

(iii) $P_1 V_1 = P_2 V_2$
$5 \times 200 = p_2 \times 300$
$= 3^1/_3$ atmospheres.

When pressure is doubled the volume is halved or vice versa

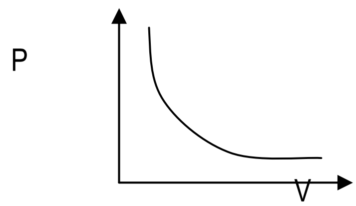
EXPERIMENT TO VERIFY BOYLE'S LAW

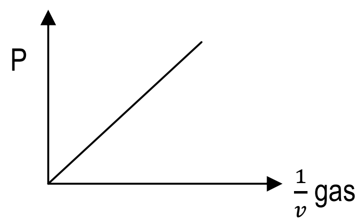


- Trap dry air in a bulb by pouring mercury through the reservoir
- For each volume (v) of trapped air , determine the height differences (h) between mercury levels y and x
- Find the pressure (p) = H + h where H is the atmospheric pressure.
- Record results including $\frac{1}{v}$ as in the table below.

V(cm^3)	h(cmHg)	P =(H + h)/cmHg	$\frac{1}{V}$(cm^{-3})

Graphs of Boyle's law.





CHARLES'S LAW.

It states that volume of affixed mass of gas at constant pressure is directly proportional to its absolute temperature**.**

Mathematically.

Volume v ∝ T where T is absolute temperature

V = kT = $\frac{v}{T} = k(constant)$

In calculation we use

$\frac{v1}{T1} = \frac{v2}{T2}$

Example 1

i) Affixed mass of gas occupies 500cm^3 at 27°C. At what temperature will the volume of the gas double if pressure remains constant?

ii) Find the volume of gas at -123°C if pressure remains constant.

$T_1 = 27°C + 273 = 300K$ $T_2 = ?$

i) $\frac{V1}{T1} = \frac{V2}{T2} = \frac{500}{3o0} = \frac{1000}{T2}$

$T_2 = 600K$

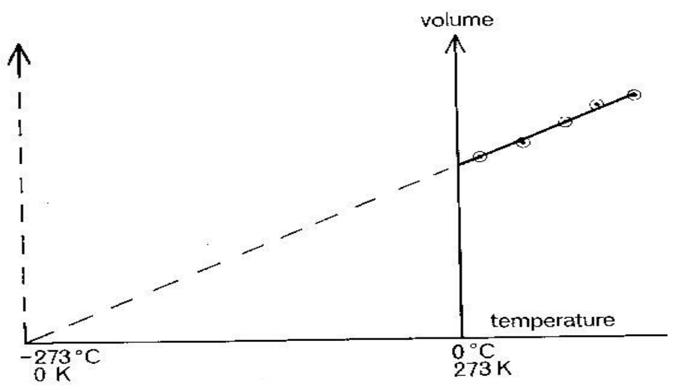
ii) $T_1 = 27 + 273$ $T_2 = -123 + 273$

$= 300K$ $= 150K$

$\frac{V1}{T1} = \frac{V2}{T2}\frac{500}{300} = \frac{V2}{150}$

$V_2 = 250cm^3$.

Graphs of Charles's law.



The graph is a straight line; it crosses the temperature axis at -273°C

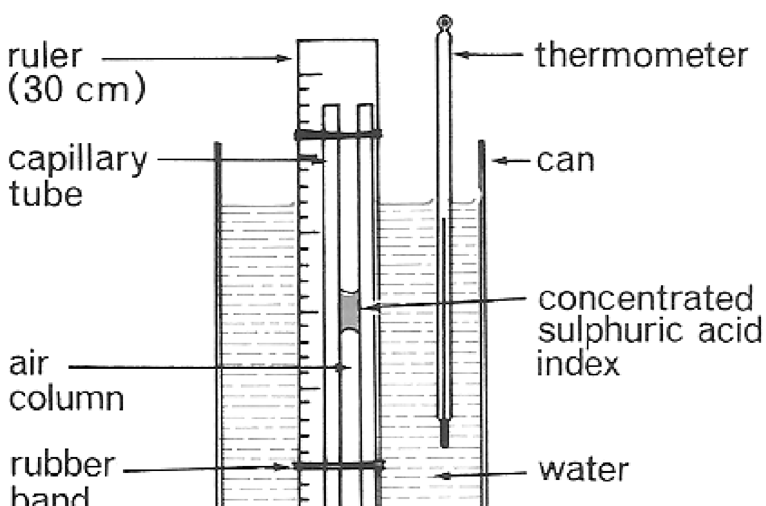
Absolute zero temperature (ok)

This is the lowest temperature possible where all molecules of gases have zero kinetic energy.

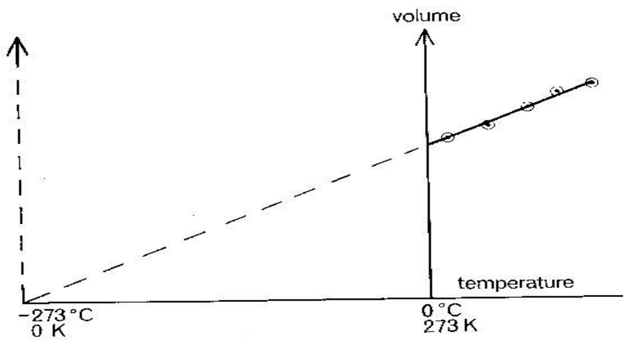
All gases liquefy before this temperature and don't obey gas laws at this temperature because they have turned into liquid.

Experiment to verify Charles's law.

- Trap air in a capillary tube using a sulphuric acid index
- Set the apparatus as in the diagram above.
- Vary the volume of trapped air by gently warming water in the beaker.



- For every temperature θ of water in the beaker record corresponding volume of trapped air using the scaleon the meter ruler.
- Record the results as in a suitable table
- Then a graph of volume against temperature is plotted as shown.



- The graph is very straight line and crosses temperature Axis at -273^{0}c. This verifies Charles' law.

NOTE
- Trapped air acts as gas
- Constant pressure will equal to the atmospheric pressure of the trapped air.
- Pressure due to the weight of the index is equal to zero.
- Concentrated sulphuric acid is used for trapping air in capillary tube
- Drying the trapped air.

PRESSURE LAW.

The pressure of a fixed mass of gas at constant volume is directly proportional to its absolute temperature.

Mathematically

$P \propto T$

$P = KT = \frac{P}{T} = K$ (Constant)

In calculation we use

$= \frac{p1}{t1} = \frac{p2}{t2}$

Example

The pressure of gas in a cylinder is 15atm at 27°C what will It be at 177°C at what temperature will the pressure be 10 atmospheres.

$T_1 = 27 + 273 = 300K$ $\qquad$ $T_2 = (177 + 273)K = 450K$

$\frac{P1}{T1} = \frac{P2}{T2} = \frac{15}{300} = \frac{P2}{450}$

$P_2 = 22.5$atm.

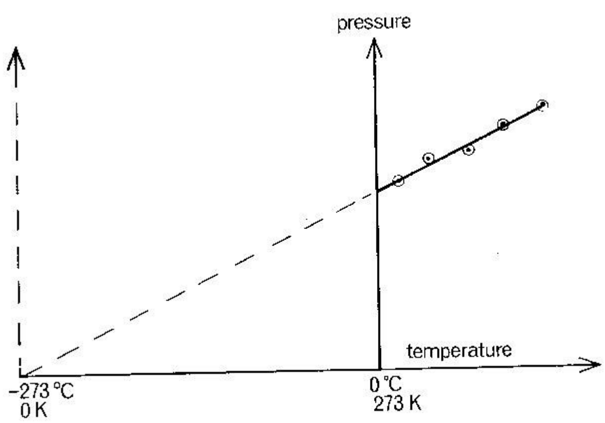
(i) $P_1 = 15$atm $\qquad$ $P_2 = 10$atm

$T_1 = 300K \qquad T_2 = ?$

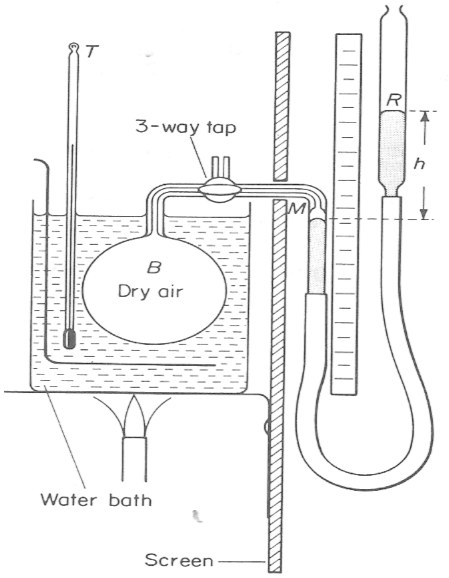
$\frac{P1}{T1} = \frac{P2}{T2} = \frac{15}{300} = \frac{10}{T2}$

$T_2 = 200K.$

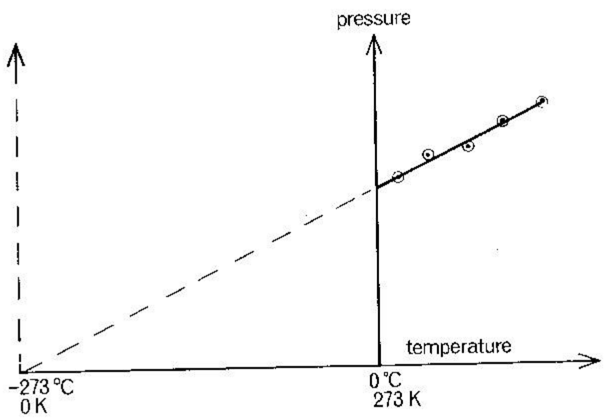
Graphical form of pressure law.



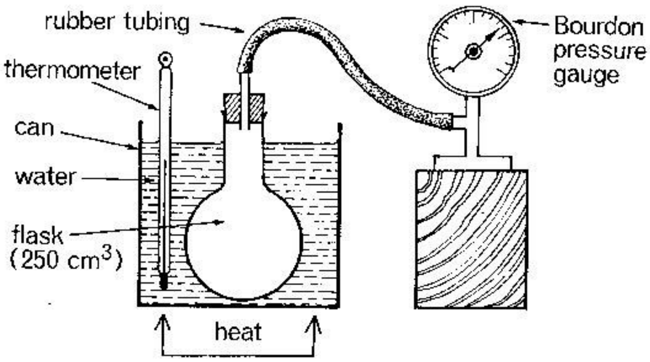
Experiment to verify pressure law.



- Set the apparatus as
- Gently heat the water in the beaker to vary temperature.
- For every temperature θ set adjust the mercury level in the manometer until it touches the I mark.
- Record the height difference p of trapped air given by p = H + h, where H is atmosphere pressure.
- Plot a graph of p against θ as shown.



Method 2



- *The apparatus is set up as shown above*
- *The rubber tubing from the flask to the pressure gauge should be as short as possible*
  The flask must be in water almost to the top of its neck.
- *The can is heated from the bottom; the pressure is then recorded over a wide range of temperature. The heating is stopped to allow steady gauge reading for each reading taken.*
- *The results are tabulated and a graph of pressure against temperature plotted. A straight line graph touching the temperature axis at -273^oC verifies pressure law*

Equation of state (ideal gas equation)

This is an equation which relates pressure, volume and absolute temperature of a fixed mass of a gas in different states. It is written as $\frac{pv}{T}$ = constant where T is the absolute temperature.

But in calculation we use

$\frac{p1v1}{T1} = \frac{P2V2}{T2}$

EXAMPLE
The pressure and volume of a fixed mass of gas at 27^{0}C is 5atm and 300^{o}C respectively. Find the temperature of a gas in ^{o}C, occupying the volume of 4500^{o}C at pressure of 4 atmospheres.

$T_1 = 27 + 273 = 300$ T_2=?

$\frac{p1v1}{T1} = \frac{P2V2}{T2}$

$\frac{T2\ X\ 5\ X\ 3000}{300} = \frac{4\ X\ 4500\ X\ 300}{T2}$

$T_2 = 360K$

In Celsius scale $T_2 = 360 – 273 = 87^0C$

Question

1. A cycle pump contains 50cm^3 of air at 17°C at 1 atmosphere. Find

i) The pressure when the air is compressed to 10cm3 and its temperature rises to 27°C
ii) Volume of air at pressure of 4 atmospheres and temperature of 77°C.

Standard temperature and pressure (S.T.P)

This is the physical condition of temperature equal to 0°C and pressure is equal to 76cmhg at S.T.P,1 mole of any gas occupies 22.4l

GAS LAW AND KINETIC THEORY.

Kinetic theory can be used to explain

i) Cause of gas pressure
ii) Boyle's law
iii) Charles's law
iv) Pressure law.

CAUSES OF PRESSUERE.

1. Gas molecules are in constant random motion colliding with each other and bombarding the walls of the container. As they bombard the walls of the container, they exert a force on the walls. These forces cause gas pressure.

2. **BOYLE'S LAW**

At constant temperature, the average speed of gas molecules is constant. When the volume of the container decreases, the rate of collision and bombardment increases resulting in increase of force exerted on the walls and increase in pressure. Likewise increase in volume at constant temperature result in decrease in pressure.

3. **CHARLES 'S LAW.**

When temperature of gas molecules increases, they move faster. To maintain the pressure constant, the volume of gas must increase simply because when temperature decreases, the volume has to in decrease to maintain the pressure constant.

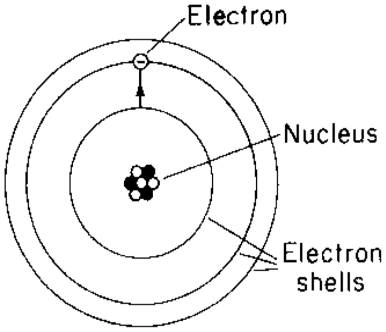
4. **PRESSURE LAW.**

When the temperature of gas increases, molecules move faster. When the volume is less, this decreases the rate of bombardment resulting in decrease in gas pressure.

ELECTROSTATICS

This refers to the study of charge at rest. To understand the nature of charge, it is necessary to know the structure of an atom.

Structure of an atom



The electrons are negatively charged while protons are positively charged. The two types of charges however are of the same magnitude in a neutral atom.

In a neutral atom, the number of negative charges is equal to the number of positive charges and the atom is said to be electrically neutral. Therefore, electrostatics is the study of static electricity because the charges which constitute it are stationary.

ELECTRIFICATION

This is the process of producing electric charges which are either positive or negative.

Methods of producing Electric charges

- By friction or rubbing (good for insulators and non conductors).
- By conduction/contact (good for conductors).
- By induction (conductors).

Electrification by friction

Two uncharged bodies (insulators) are rubbed together. Electrons are transferred from the body to the other. The body which looses electrons becomes positively charged and that which gains electrons becomes negatively charged.

Acquire positive charge	**Acquire negative charge**
Glass	silk
Fur	Ebonite (hard rubber)
Cellulose Ace tale	Polythene

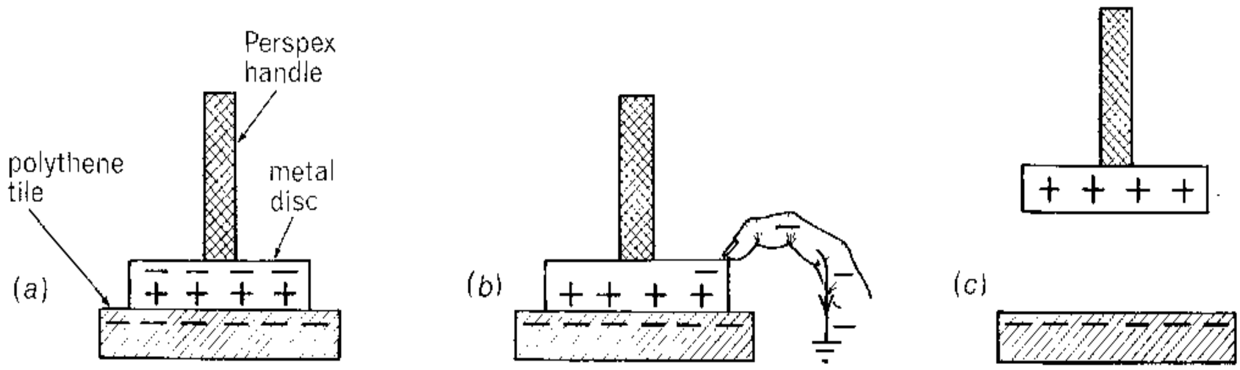
Explanation of charging by friction

When two bodies are rubbed together, work is done, transferred electrons from one body to another. This results into two bodies acquiring opposite charges.

Law of Electro statics

- Like charges repel each other.
- Unlike charges attract each other.

Electrification by conduction

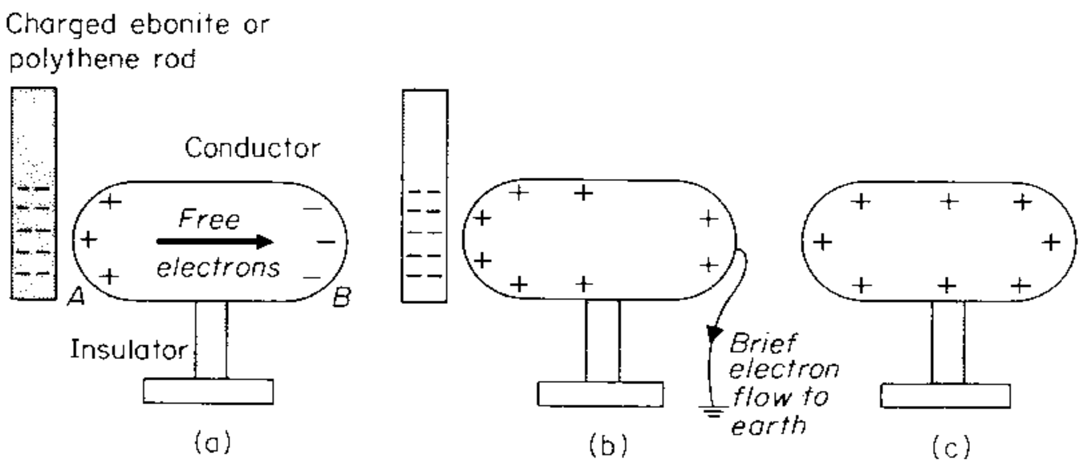


- Support the uncharged conductor on an insulated stand.
- Put a positively charged rod in contact with the conductor.
- Because of mutual repulsion between the positive charges in the rod, some of them are converted or transferred to the conductor.
- When the conductor is removed from the rod, it is found to be positively charged.

NB: The insulated stand prevents flow of charge away from the conductor. To charge the conductor negatively, a negative rod is produced.

Electrification by induction

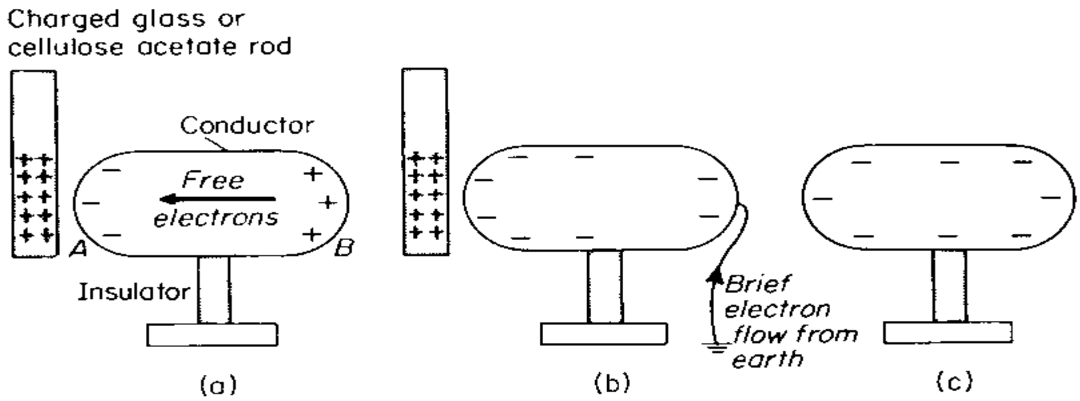
(a) Charging the body positively.



Procedure

- Put the conductor on an insulated stand as in (i)
- Bring a negatively charged rod near the conductor.
- The positive and negative charges separate as shown in (ii)
- Earth the conductor by momentarily touching it with a finger and electrons flow from it to the earth as in (iii) in presence of the charged rod.
- Remove the charged rod, the conductor is found to be positively charged.

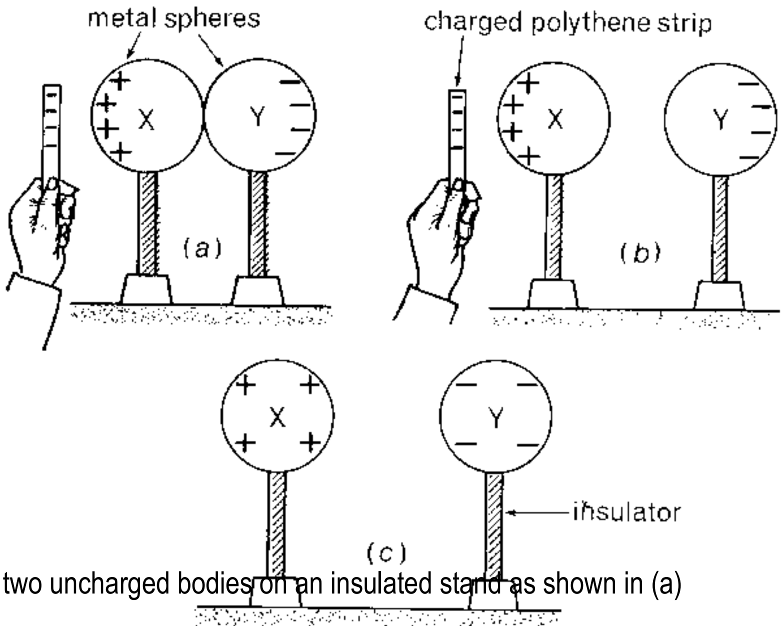
(b) Charging the body by induction negatively,



Procedure

- Put the conductor on an insulated stand as in (i)
- Bring a positively charged rod near the conductor.
- The positive and negative charges separate as shown in (ii)
- Earth the conductor by momentarily touching it with a finger and electrons flow from it to the earth as in (iii) in presence of the charged rod.
- Remove the charged rod, the conductor is found to be negatively charged.

Charging two bodies simultaneously of opposite charges



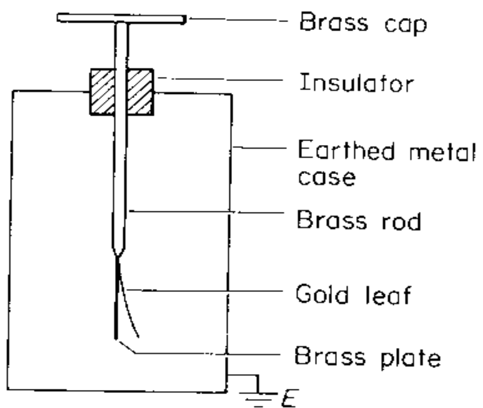
- Support two uncharged bodies on an insulated stand as shown in (a)
- Bring a positively charged rod near the two bodies, positive and negative charges separate as in (b).
- Separate (A) from (B) in presence of the inducing charge.
- Remove the inducing charge, (A) will be negatively charged and (B) will be positively charged.

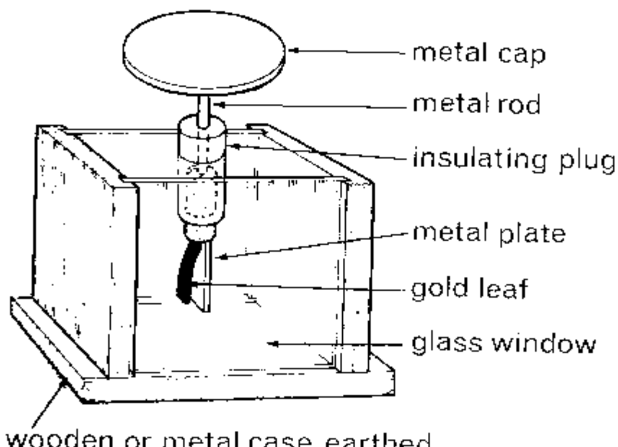
CONDUCTORS AND INSULATORS

A conductor is a material which allows charge to flow through it. It has loosely bound electrons known as conduction electrons. The flow of these electrons constitutes current flow e.g. all metals, graphite, acids, bases and salt solutions are conductors.

An insulator is a material which does not allow flow of charge through it. It has no conduction electrons because its electrons are strongly bound by the nuclear attractive forces e.g. rubber, dry wood, glass, plastic, sugar solutions etc.

The gold leaf electroscope

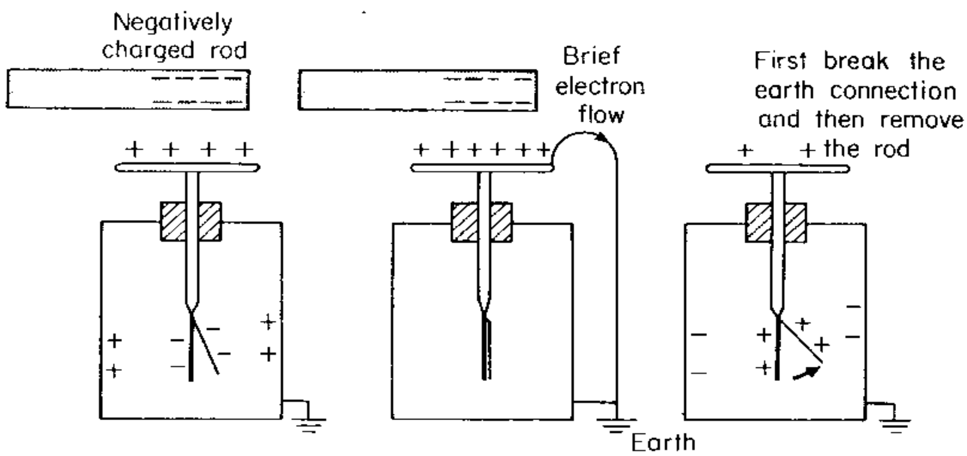




- It consists of a brass cap and brass plate connected by a brass rod.
- A gold leaf is fixed together with a brass plate with a brass.
- The brass plate, gold leaf and part of brass rod are put inside a metallic box which is enclosed with glass windows.

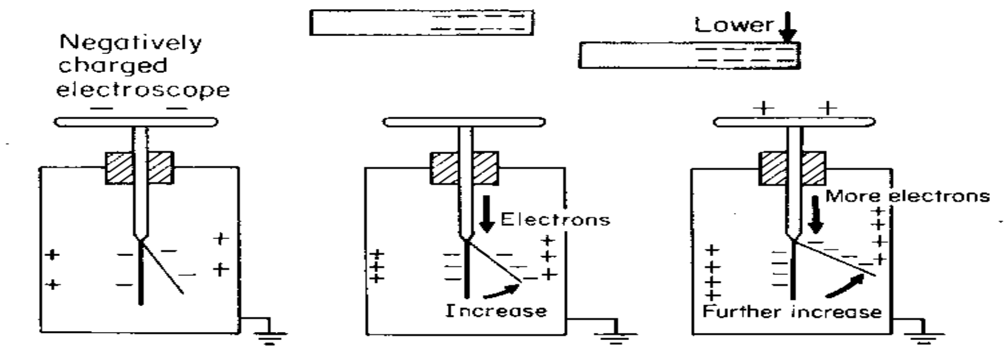
CHARGING A GOLD LEAF ELECTROSCOPE BY INDUCTION.

(i) Charging it positively



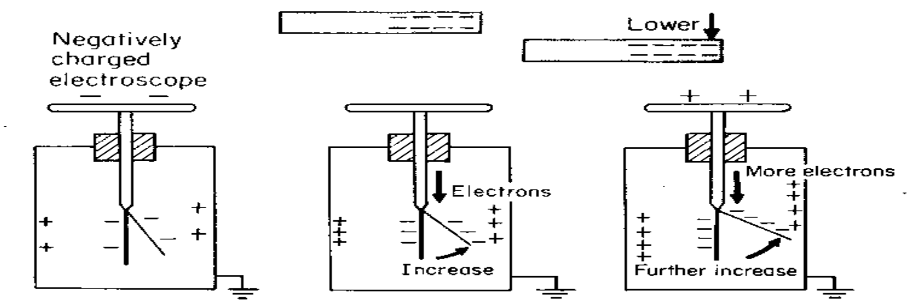
- Bring a negatively charged rod near the cap of the gold leaf electroscope.
- Positive charges are attracted to the cap and negative charges are repelled to the plate and gold leaf.
- The leaf diverges due to repulsion of the same number of charges on the plates.
- Earth the gold leaf electroscope in presence of a negatively charged rod.
- Electrons on the plate and leaf flow to the earth.
- The leaf collapses.
- Remove the negatively charged rod, positive charges on the ca spread out to the rod and leaf therefore the leaf diverges hence the gold leaf is positively charged.

(ii) Charging it negatively**.**



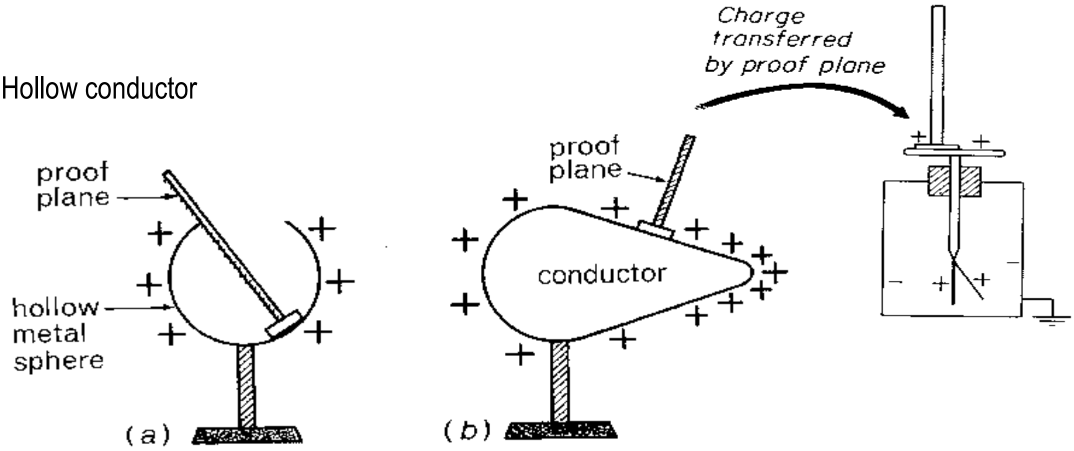
- Get an uncharged gold leaf of electroscope.
- Bring the positively charged rod near the gold leaf cap.
- Negative charges are attracted to the cap and positive charges are repelled to leaf and glass plate.
- Earth the gold leaf electroscope in presence of a positively charged rod.
- Negative charges flow from the earth to neutralize positive charges on plate and leaf.
- The leaf collapses.
- Remove the positively charged rod, negative charges on the cap spread out on the leaf plate, therefore, the leaf diverges and a gold leaf therefore becomes negatively charged.

Testing for presence of charge



Distribution of charge on a conductor.

(a) Hollow conductor



When the proof plane is placed on the outside surface of a charged hollow conductor, charge is transferred to the uncharged G.L.E, the leaf diverges as shown in (a). This proves that charge was present on the outside of the surface.

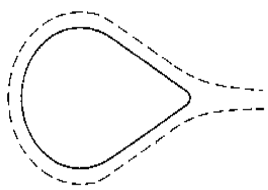
When the proof plane is placed on the inside of a charged conductor is transferred to the uncharged G.L.E, the leaf does not diverge as in (b) therefore, charge resides on the outside surface of the hollow charged conductor.

(b) Curved bodies

(c)

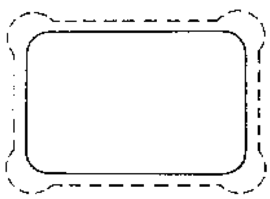
A curve with a big curvature has a small radius and a curve with small curvature has big radius therefore, curvature is inversely proportional to radius. A straight line has no curvature.

Surface charged density is directly proportional to the curvature. Therefore a small curvature has small charge density. Surface charge density is the ratio of charge to the surface area.



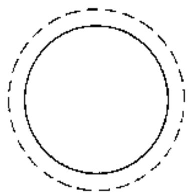
Pear shaped

(ii)Rectangular conductor



Cylindrical

(iii) Spherical conductor



Action of points

Charge concentrates at sharp points. This creates a very strong electrostatic field at charged points which ionizes the surrounding air molecules producing positive and negative ions. Ions which are of the same charge as that on the sharp points are repelled away forming an electric wind which may blow a candle flame as shown in the diagram below and ions of opposite charge are collected to the points

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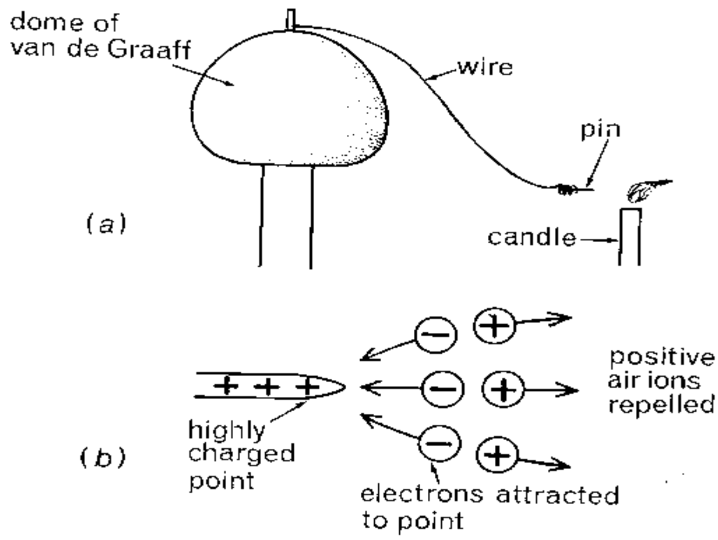


Therefore, a charged sharp point acts as;

(i) Spray off' of its own charge in form of electric wind.

(ii) Collector of unlike charges. The spray off and collecting of charges by the points is known as **corona discharge** (action of points.)

Application of action of points (corona discharge)

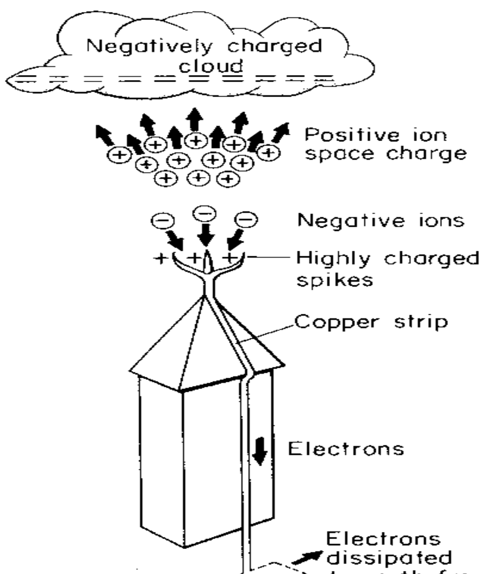
Used in a lightening conductor.

- Used in electrostatics generators.
- Electrostatic photocopying machines.
- Air crafts are discharged after landing before passengers are allowed. Air crafts get electrified but charge remains on the outer surface.

Lightening conductor

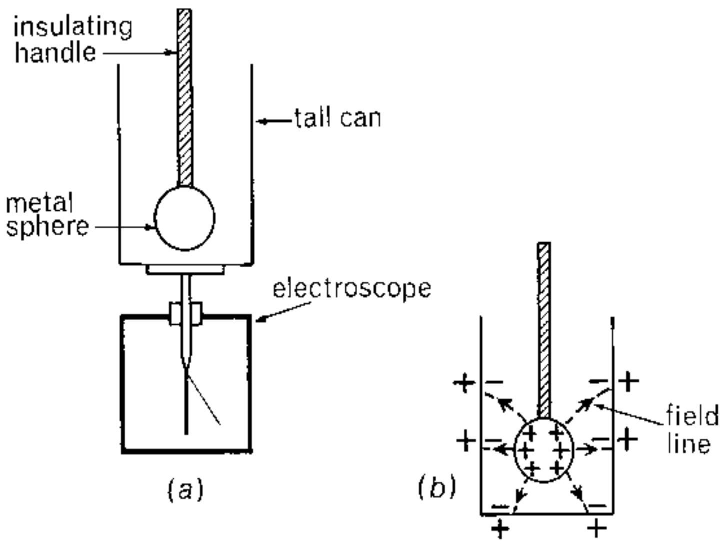
A lightening conductor is made up of a thick copper strip which is fixed to the ground and on the walls of the tall building ending with several shaped spikes. It is used to protect structures from damage once struck by highlightening.

How it works



- A moving cloud becomes negatively charged by friction.
- Once it approaches the lightening conductor, it induces opposite charge on the conductor.
- A high charge density on a conductor ionizes the air molecules and sends a stream of positively charged ions which neutralize some of the negative charges of the cloud.
- The excess negatively charged ions are safely conducted to the earth through a copper strip.

Ice pail experiment



Electric fields

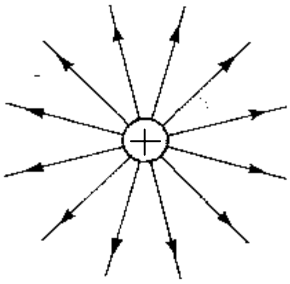
This is a region a round the charged body where electric forces are experienced. Electric fields may be represented by field lines. Field lines are lines drawn in an electric field such that their directions at any point give a direction of electric field at that point. The direction of any field at any given point is the direction of the forces on a small positive charge placed at that point.

Properties of electric field lines

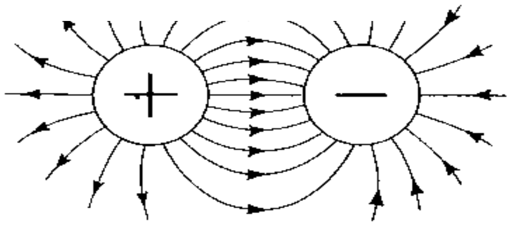
- They begin and end on equal quantities of charge.
- They are in a state of tension which causes them to shorten.
- They repel one another side ways.

Field patterns

(a) Isolated charge

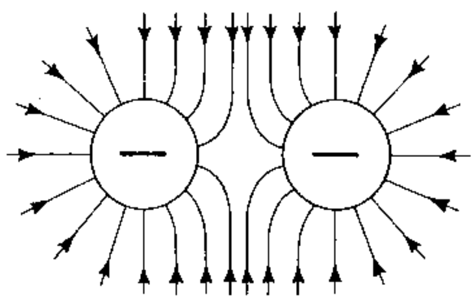


(b) Unlike



Longitudinal tension in the field lines

(c) Like charges close together

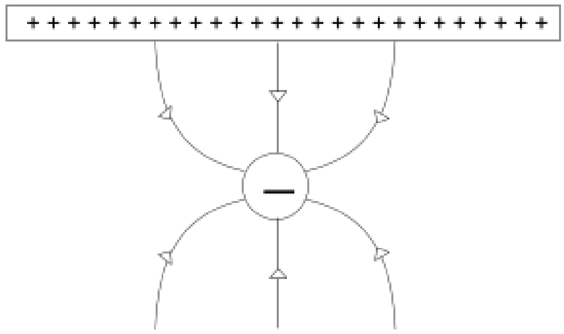


Lateral repulsion between the field lines

A neutral point is a region where the resultant electric field is zero i.e. field lines cancel each other and therefore no resultant electrostatic forces exist.

(d) Field between charged points and plates

(i) **Negative charge close to a positively charged plate**



(ii) Positive charge on a negatively charged plate