STATIC ELECTRICITY

STATIC ELECTRICITY

Definition

This is the type of electricity due to charges in electrons which do not move.

Or

This is the type of electricity due to stationary charges.

Electrostatics

This is the study of stationary electric charges.

TYPES OF CHARGES

There are two types of charges;

1. Positive charge
2. Negative charge

Positive charge

-This is the type of charge with deficiency number of electrons.

Negative charge

-This is the type of charge with excessive number of electrons.

FUNDAMENTAL LAW OF ELECTROSTATICS

-It is called **'first coulombs**' law that states "like charges repel while unlike charges attract each other".

CHARGING OF THE BODY (ELECTRIFICATION)

-This is the process of either adding or removing charged electrons from a body.

METHODS OF CHARGING A BODY

There are three methods of charging the body and these are;

1. By friction or rubbing
2. By contact

3. By induction

1. BY FRICTION/ RUBBING

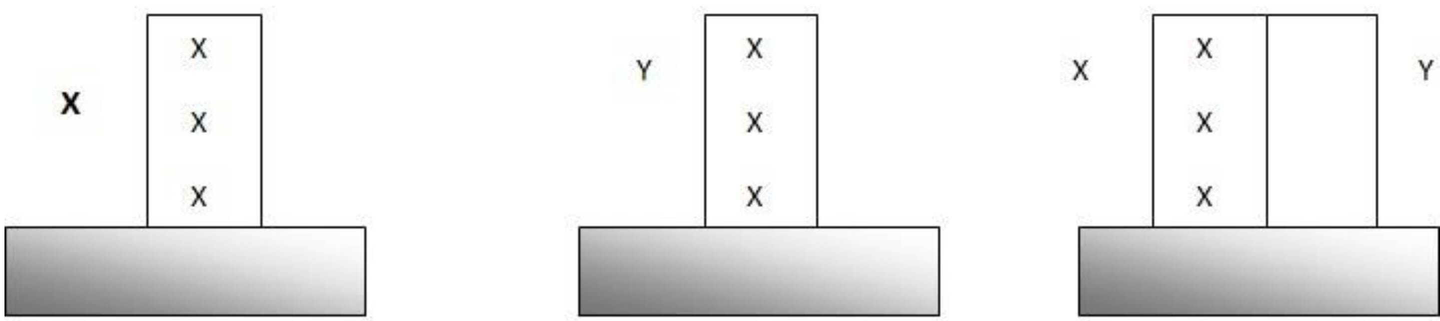
This is the method of charging a body by rubbing one body on the other.

When an ebonite rod is rubbed on fur some of the electrons are transferred from the fur to the ebonite. Therefore the ebonite becomes **negatively charged** while fur transferred from the fur to the ebonite. Therefore the ebonite becomes **negatively charged** while fur becomes **positively charged**.

While when the glass rod is rubbed in silk electron will be transferred from glass rod to silk, the glass rod will be **positively charged** while silk will be **negatively charged**.

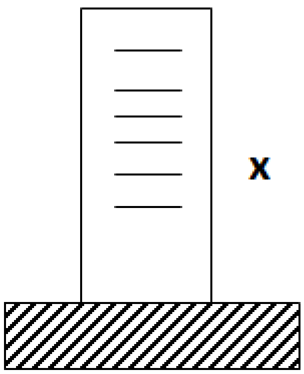
2. BY CONTACT

This is the method of charging the body by touching each other. Let's say x is positively charged and y is negatively charged.

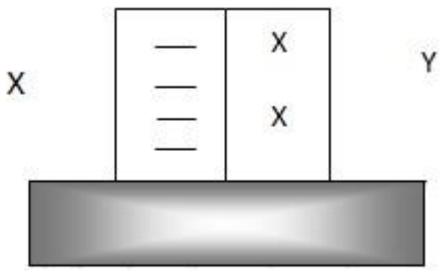


Then the positive charge will be transferred to body y, and then after sometime they will repel each other since they will have equal charge.

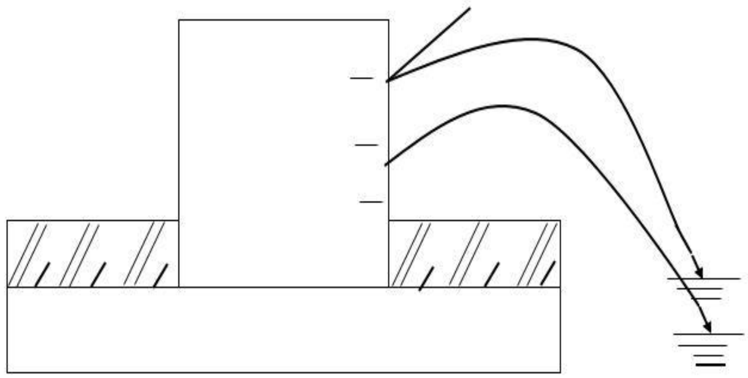
3. BY INDUCTION
This is the method of charging the body without touching. Let body x be negatively charged while body y lies both positive and negative.

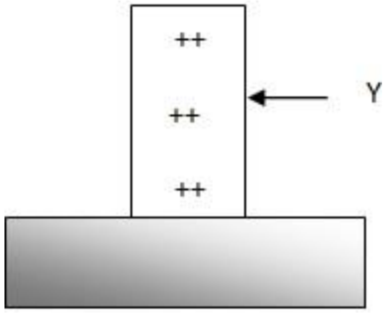


When x and y are brought together.



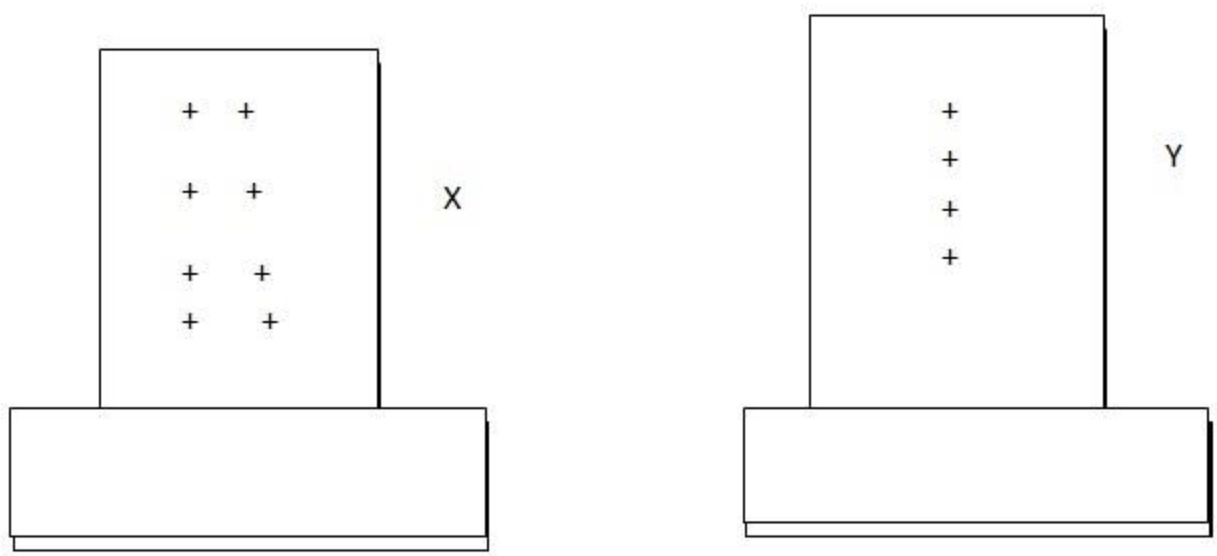
Charges from x will be separated as shown due to the law of electrostatics. Upon earthing of y negative charges will be migrating the earth and body y will remain positive charged.



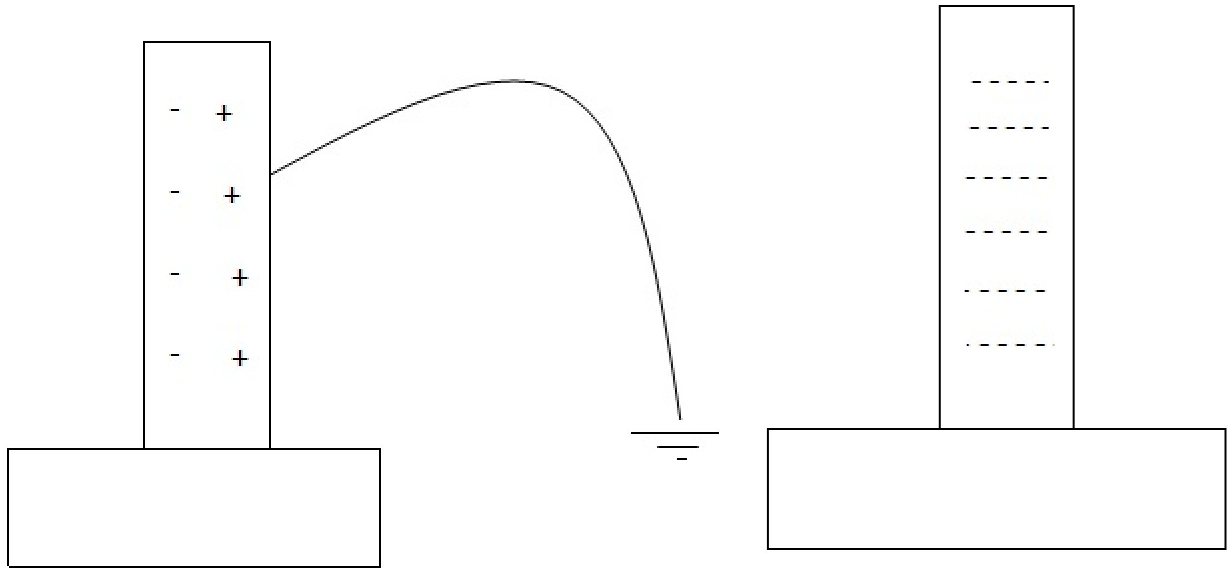


Let body x be positive while body y with both positive and negatively charged.

When they are brought near to each other

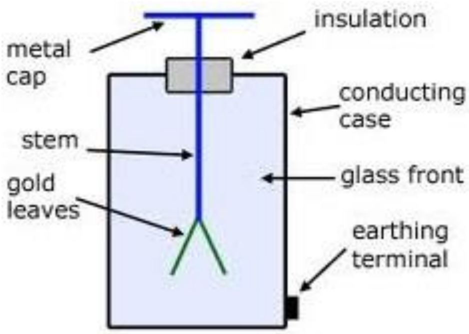


If body y is touched



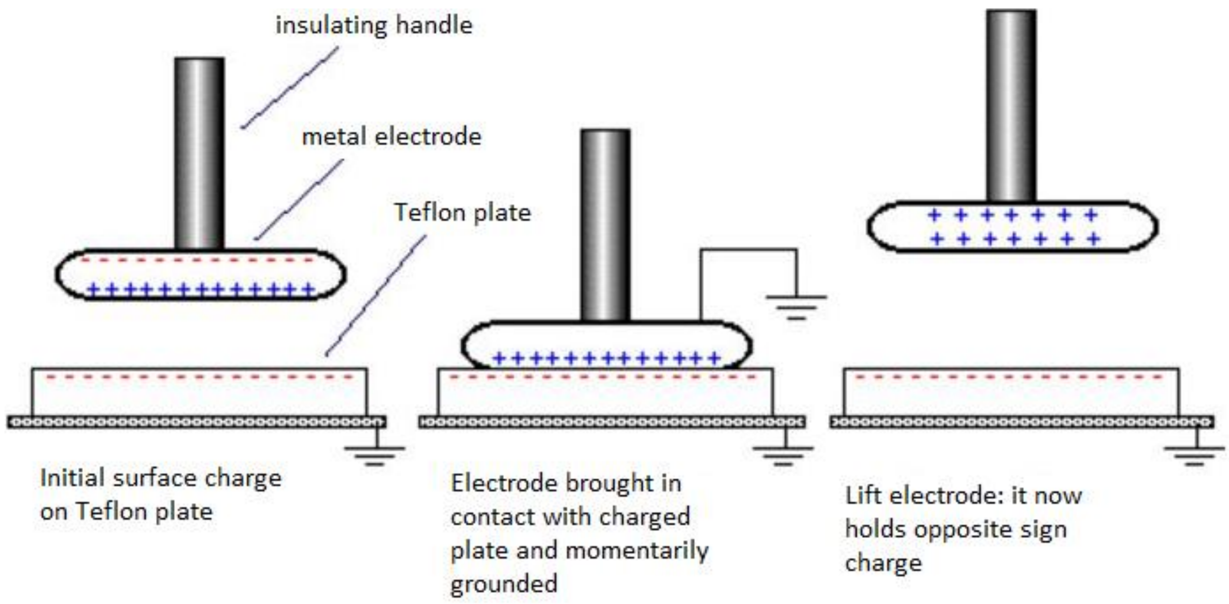
THE GOLD LEAF ELECTROSCOPE

Is an instrument or device for identifying the presence of electrons i.e. charge on an object.

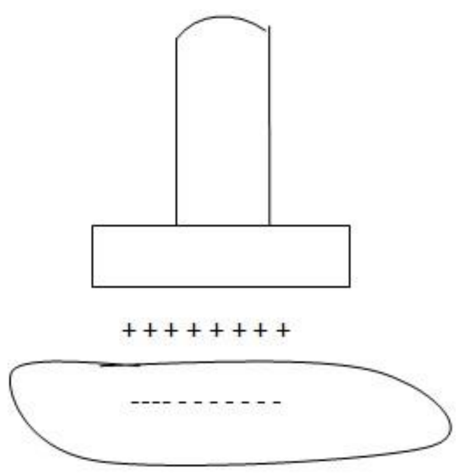


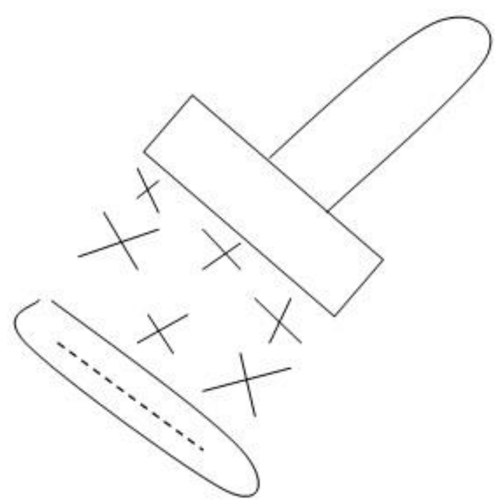
An electrophorus

This is an instrument that is used to determine the presence of charge.



An electrophorus works by induction and hence can be used to generate positive charge from a single negative charge. The charge produced on the insulating bulb is negative the top are then placed on it since the surface are only in contact at relatively few points a positive charged induced on the lower surface and a corresponding negative charge is produced on its top surface . The top of the upper disc is then touched with a finger there by carrying in away the negative charge to the earth. This is known as **earthing**.

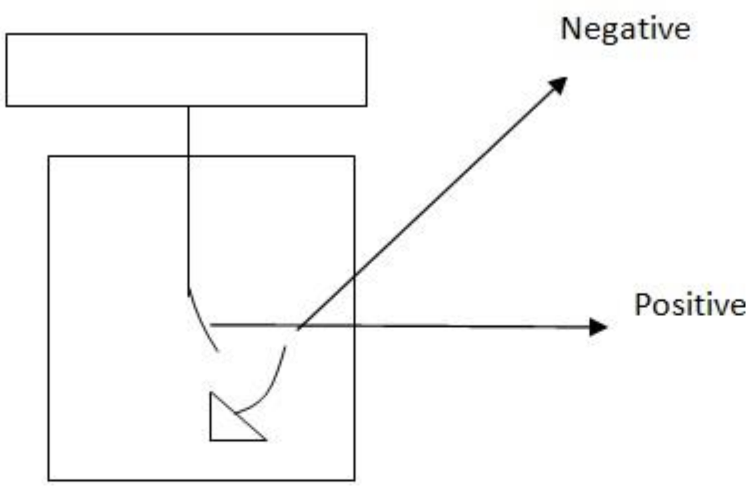




Uses of the electrophorus

An electrophorus is used in the laboratory to produce electric esparto.

Testing the sign of the charge



Identifying the insulating properties of a material, the electroscope is positively charged can be used to test per insulation property of the material. If a material is placed near a cap of the machine the metal leaf wings converge and diverge slowly on that of the material is an insulator.

A conductor - is a material which conducts heat and electricity easily.

Insulator - is a material which does not conduct heat and electricity.

Examples;

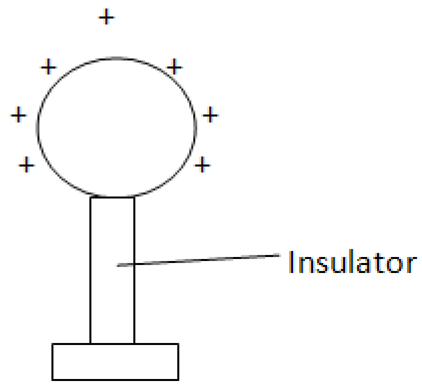
- Wood
- Plastic
- Rubber

•Detecting the presence of a charge in the body or on a body.

Charge distribution in a conductor

a)Spherical Conductor

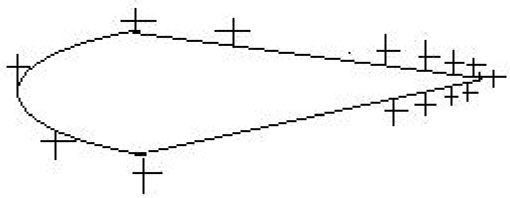
In a spherical conductor charge is distributed equaly throughout the conductor.



Spherical Conductor

b)<u>Pearl Shaped Conductor</u>

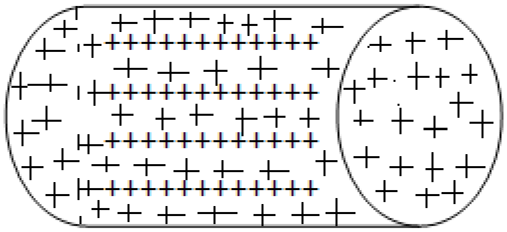
In a pearl shaped conductor more changes accumulate on the sharp corners of a conductor than the other parts.



Pearl Shaped Conductor

c) <u>Hollow Conductors</u>

Charge distribution in a hollow conductors, such as a hollow cylinder in the figure below Is only on the outside of the cylinder. The inside of the cylinder has no charge



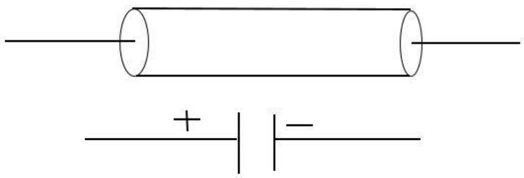
Hollow Conductor

Capacitor

This is a device which is used for storing the amount of charge.

Capacitor is used in:

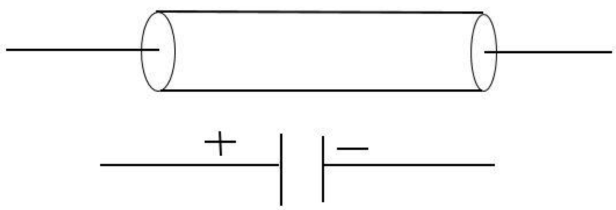
- Television
- Radios
- Computer



•A capacitor **stores charges** by keeping them in its plates.

Dielectric material

This is a medium placed between the plates of a capacitor. It is supposed to be an insulator.



Examples of dielectric material are;

- Paper
- Mica
- Electrolyte
- Vacuum

Capacitance (c)

This is the ability of a capacitor to store electric charges.

Always the amount of charge stored is directly proportional to the potential difference.

$Q \propto v$………….. (1)

α is directly proportional

Q = cv

Where by c- capacitance

The SI unit of capacitance is **Faraday**

Other units are;

- Mil- mF = $1x10^{-3}$ F
- Micro –µF = $1x\ 10^{-6}$ F
- Nano –F = $1\ x10^{-9}$ F
- Pico – F = $1x\ 10^{-12}$ F

Example

1. A capacitor of capacitance 200mF is allowed to charge. The P.d between the plates is 10Volts. How much charge will accumulate on the plate during the period of changing data?

   DATA

C=200mf=$200\ x\ 10^{-6}$ F

v=10v

Q=?

Q= CV

SOLUTION

Q =$200\ x100^{-6}x10$

Q =$2\ x10^{2}\ x10^{-6}\ x10$

Q =$2\ x\ 10^{-3}$ C

The SI unit of the charge is **coulombs**

2. A 3mf capacitor has a potential difference of 12V. Determine the total charge.

DATA

C=mf=$3\ x10^{-3}$F

V=12V

Q =?

Q =CV

SOLUTION

Q =3 x10^{-3} x12

Q =36 x10^{-3} C

The total charge is 36 x10^{-3} C

TYPES OF CAPACITOR

Capacitors are categorized in:

1. **Paper or plastic capacitor**

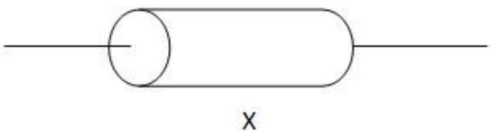
This is a type of capacitor which uses paper or plastic as dielectric material.

2. Mica capacitor

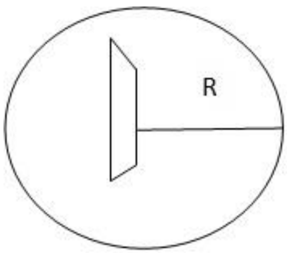
This is the type of a capacitor which uses the electrolyte as a dielectric materials i.e. water

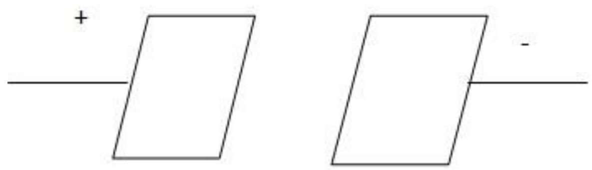
All capacitor can be categorized due to theories;

- **Cylindrical capacitor**



- **Spherical capacitor**

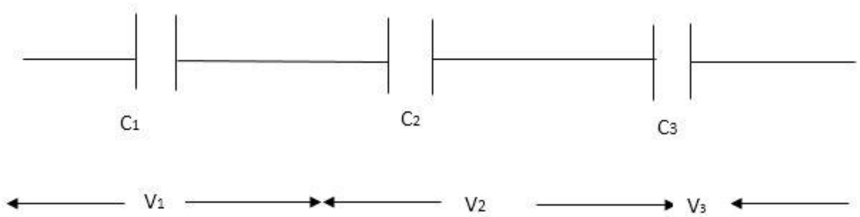




COMBINATION OF CAPACITORS

Capacitors can be combined in **series** or **parallel.**

SERIES COMBINATION



When capacitors are arranged in series each capacitor will have the same charge but with different potential difference.

But $\frac{Q}{C} = \frac{CV}{C}$

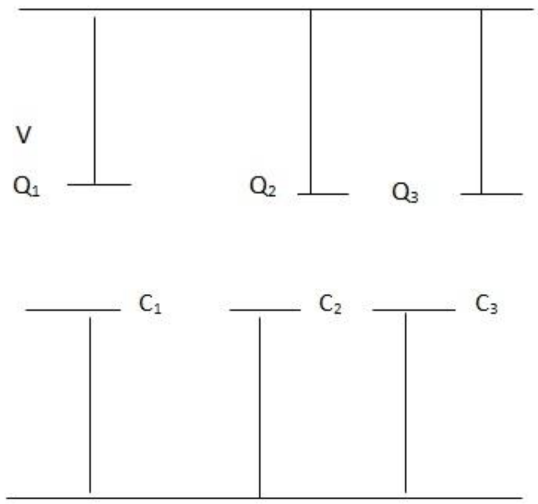
$$\frac{Q}{C_T} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$Q\left(\frac{1}{C_T}\right) = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

Therefore capacitors arranged in series the total or equivalent capacitance given by;

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Parallel combination



When capacitors are arranged in parallel they will have the same potential difference but their charge will differ;

Total charge (Q_T)

$Q_T = Q_1+Q_2+Q_3$

But Q = CV

$Q_1V = C_1V+C_2V+C_3V$

$C_T = c_1+c_2+c_3$

For the parallel combination of the capacitor their equivalent or total capacitance is given by;

$C_T = C_1+C_2+C_3$

Example

1.Three capacitors A, B and C are arranged in series. Their capacitance were given 10µc, 20µc, and 30µc. Calculate the value of a single capacitor that would replace them.

DATA

Capacitor series

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

C_1=10µc

C_2=20μc

C_3=30μc

SOLUTION

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{C_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30}$$

$$= \frac{6+2+3}{60}$$

$$\frac{1}{C_T} = \frac{11}{60}$$

C_T=5.45μc

2. A 1000μf capacitor has been charged to a Potential difference of 25V. What is the charge on the plate of a capacitor?

DATA

Capacitance= 1000μf = 1000 x 10^{-6}

P.d = 25V

Charge (Q)

Q = CV

SOLUTION

Q = 1000 x 10^{-6} x 25

Q = 1 x 10^{-3} x 25

Q = 25 x 10^{-3}

Q = 0.025c

The charge on the capacitor is 0.025 coulombs.

3.A capacitor of capacitance 250μf is allowed to change until the potential difference between the charges is 10V how much a charge accumulates on the plates during the charging process.

Data

Capacitance (C) = 250μf = 250 $x10^{-6}$

P.d (V) =10V

Q=CV

SOLUTION

Q=250 $x10^{-6}$ x10V

Q=250 x 10^{-5}C

Q=0.0025C

4.What value of the capacitor could be used to replace a set of 5μf, 10μf and 15μf capacitors connected in series

Solution

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{5} + \frac{1}{10} + \frac{1}{15}$$

$$\frac{1}{C_T} = \frac{6+3+2}{30}$$

$$\frac{1}{C_T} = \frac{11}{30}$$

Take the reciprocal of the value

$$C_T = \frac{30}{11}$$

C_T= 2.727μf.

5.Three capacitors of values 2µf, 3µf and 6µf are connected in series and in parallel. What is the equivalent capacitance in each case?

Solution

When connected in series

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_T} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$

$$\frac{1}{C_T} = \frac{3+2+1}{6}$$

=1µf

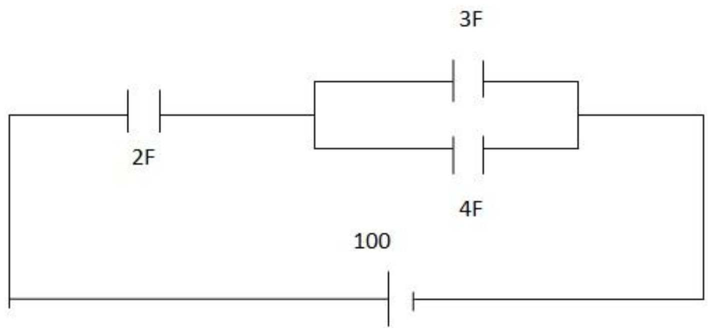
Case 2 parallel

$C_T = C_1 + C_2 + C_3$

$C_T = 2+3+6$

$C_T = 11$µf

6.Find the equivalent capacitance of the diagram shown and the total quantity of charge stored given that the total potential difference of the circuit is 10V



Solution

C_1= 2f

C_2= 3f

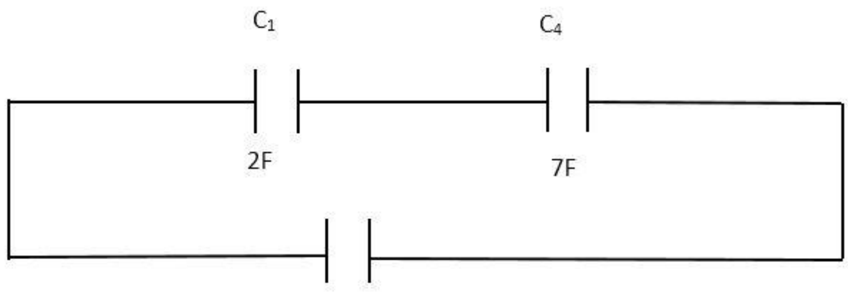
C_3 = 4f

Since C_2, C3 are in parallel

$C_4 = C_2+C_3$

= 3+4

= 7f



Since C_1 and C_4 are in series then

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_4}$$

$$\frac{1}{C_T} = \frac{1}{2} + \frac{1}{7}$$

$$\frac{1}{C_T} = \frac{9}{14}$$

Take the reciprocal

The value of the capacitor is $\frac{14}{9}$F

Total charge

$Q= C_1V_1$

$Q=\frac{14}{9}F \times 10$

Q=15.56C

7. A capacitor of two parallel plates capacitated by air has a capacitance of 15pF. A potential difference of 18 volts is applied across the plates. Determine the charge on the capacitor

Solution

Capacitor = 15pf = 15 $x10^{-12}$

V = 18V

Q = CV

= 15 x 10^{-12} X 18V

Q = 270 $x10^{-12}$C

(b) If the space between is filled with mica the capacitor ratio increase to 240pF

How much more charge can be put on the capacitor if there is 1.8V supply?

Solution

Capacitance =240pf = 240 x 10^{-12}f

Volts = 1.8v

Q=CV

Q=240 $x10^{-12}$ x 18

Charge will be 4.32 $x10^{-9}$C

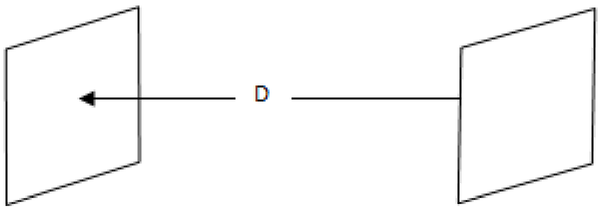
FACTORS AFFECTING CAPACITANCE OF A CAPACITOR

1. **Cross section area (A) of the plates.**

   As the cross section area increases, the capacitance also increases.

   $C \alpha A$ …..(i)

2. **Distance of the separation of the plates.**



$$C \alpha \frac{1}{d} \ldots \ldots \ldots (ii)$$

As the distance increases the capacitance decreases.

3. **Di electric material**

The capacitance varies with the variation of the dielectric material.

Combining equation i and ii

$$C \alpha \frac{A}{d}$$

$$C = G \frac{A}{d}$$

G =permittivity of free space.

Examples

1.A capacitor of $2mm^2$ cross section area and distance of separation of the plate of 2mm is connected to a Potential difference of 20V.

1. Find the capacitance of a capacitor
2. Amount of the charge stored

Solution

$A=2mm^2$

d=2mm

V=20volts

C=?

$C = G \frac{A}{d}$

Q=?

$G = 1.8 \times 10^{-12}$

$$C = \frac{1.8 \times 10^{-12} \times 2 \times 10^{-6}}{2 \times 10^{-3}}$$

$C = 1.8 \times 10^{-15}$

Q = CV

$Q = 1.8 \times 10^{-15} \times 20$

Charge = 3.6×10^{-14}C

Lighting Conductor

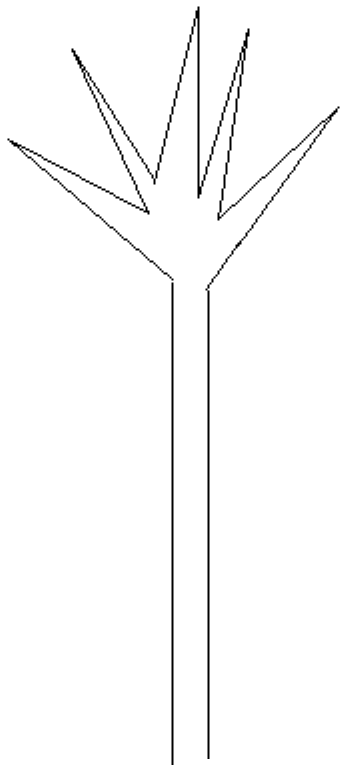
Lightning is huge discharge of static electric charges between clouds or cloud and the ground.

A lightning conductor is a metal rod attached to a building and connected to a think copper strip that leads into the ground. Its tio has sharp spikes.

Lightning conductors can help to protect building and other structures from lightning strikes.

The lightning conductor is placed above the highest point on the building because lightning tends to hit the highest object within its region or path.

When lightning strikes the conductor ,electric flow along the wire and dissipated to the ground there by protecting the building.



Lightning Conductor

CURRENT ELECTRICITY

CURRENT ELECTRICITY

Current electricity is the rate at which an electricity source will make charges to flow or pass a certain point in a conductor or in an electric circuit.

This means that, when electrical devices are joined in an electric circuit, electrons flow in a continuous path. It is the flow rate of which is referred to as **current electricity** or **electric current**.

The sources of electricity are of different nature which include;

i. Generators

ii. Charged capacitors

iii. Dry cells

iv. Dynamo

v. Solar panels

The device in which energy transformation occurs and is maintained is called **electrical source.**

Load - is the device used for transforming the electrical energy into any of the sensible forms of energy. for example; heat, light, mechanical or sound energy etc.

The quantity of electricity is measured in **coulombs** denoted by **'C'.**

It follows that, if the quantity of charge of 6 coulombs is passed at a certain point of a conductor in 3 seconds, then;

$$\text{Electric current} = \frac{\text{quantity of charge}}{\text{time}}$$

$$\text{Electric current} = \frac{6 \text{ coulombs}}{3 \text{ seconds}}$$

Electric current = 2 coulombs/second or 2C/s

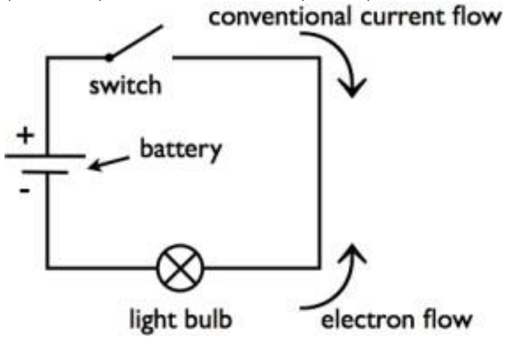
SIMPLE ELECTRIC CIRCUITS

Electric circuit - is a continuous path formed by connecting electrical devices. Such as Battery, switch, socket etc along which electrons can flow.

A simple electric circuit may consist of;

1. Cell or any source of current electricity.
2. Switch or control to allow or restrict the flow of current electricity.
3. Conductor to transmit the current electricity.
4. Load to consume the supplied power delivered by the current electricity.

The figure below shows the simple electric circuit containing a sound (cell), a control (switch) and the load (bulb);



The electric devices used in a circuit are called **circuit**, **components** or **elements**.

USES OF COMPONENTS OF ELECTRIC CIRCUIT

1. **Cell or battery** – Is a source of electric current.
2. **Switch** – Is a device used to switch on an electric current in order to allow the flow of an electric current or off an electric current thus to stop the flow of the electric current respectively.
3. **Resistor** – Is a component included in an electric circuit because of its resistance to current electricity flow. There are **variable value resistors** and **fixed value resistors,** all are made of resistance wire or carbon.
4. **Ammeter** – Is an instrument with low internal resistance used for measuring electric current.
5. **Connecting wire** – Is a material used to provide a direct path which allows the flow of current between two points in a circuit and are used to connect circuit components.
6. **Capacitor** – Is an electric conductor or a system of electrical conductors which can store electric charge.
7. **Voltmeter** – Is an instrument with high internal resistance used for measuring potential difference of any two points in an electric circuit.
8. **Socket and plugs** – Are devices that connect electrical appliances to the power supply so that electric power can flow through them.

CONCEPT OF CURRENT, VOLTAGE AND RESISTANCE IN AN ELECTRIC CIRCUIT

The electric current flows from a point with low potential to the point with high potential.

The S.I unit of electric current is **Ampere** denoted by **'A'**. The electric current **(I)** encounters resistance **(R)** along its path, which will result in voltage drop **(V)** in a circuit.

The S.I unit of resistance is **Ohms** denoted as **Ω.**

The **potential difference (P.d)** which causes electric current to flow is defined as "the energy per coulomb consumed when electricity moves from one point to another".

The S.I unit of potential difference is **volt (V)**. This **voltage** is given as the product of current flowing between two points and resistance offered between the two points

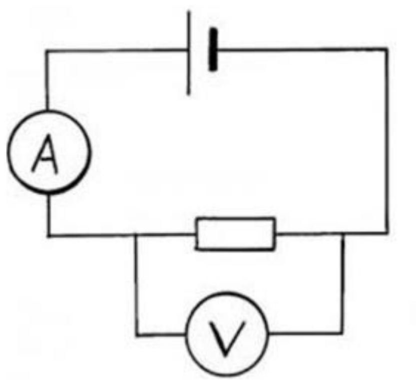
I.e. Voltage = Current In amperes X Resistance in Ohms

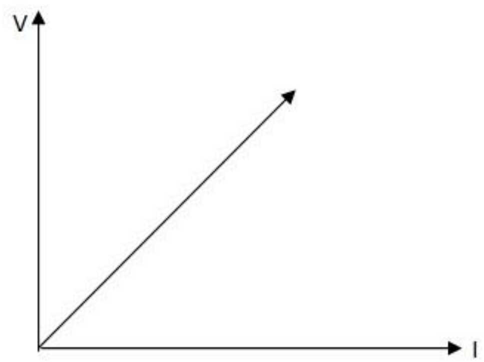
$V = I \times R$

V = IR

OHM'S LAW

-It states that "the voltage across the conductor is directly proportional to the electric current flowing if temperature is constant"





The resultants shows that the resistance of a wire (P.d) is proportional to the current flowing through the conductor

I.e. $V \alpha I$

Introducing proportionality constant **'K'**

V = KI

The constant of proportionality is called the **resistance 'R'** thus,

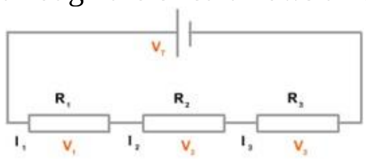
V = IR

COMBINATION OF RESISTORS

Resistors can be connected either in **series** or **parallel** depending on the magnitude of effective resistance required. Series connection gives a bigger value of effective resistance and the parallel connection gives small value of effective resistance.

RESISTORS IN SERIES

By connecting resistors in series, when the switch **'S'** is closed, the current **'I'** which flows through the circuit flows through each resistor.



Total resistance between points A and B which is commonly referred to as **equivalent resistance (R_{eq})** will produce a potential difference in the circuit given by ohm's law as;

$V = IR_{eq}$

The voltage across each resistor in the circuit is given by $V_1 = IR_1$ and $V_2 = IR_2$

The sum of the voltage drops equal to the potential difference in the circuit (i.e. potential difference between (A and B)

Total voltage = $V_1 + V_2$

$\therefore V_T = V_1 + V_2$

Total voltage = $V_1 + V_2$

Since V = IR, $V_1 = IR_1$ and $V_2 = IR_2$

$IR_T = IR_1 + IR_2$

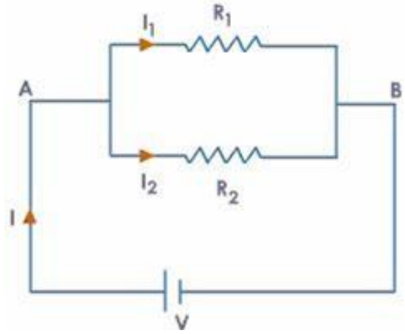
$IR_T = I(R_1 + R_2)$

$R_T = R_1 + R_2$

RESISTORS IN PARALLEL

In the figure below I is the current in the main circuit. On the other hand I_1 and I_2 are current through individual resistors R_1 and R_2.

The sum of all currents through the resistors which are connected in parallel gives the value of current equal to the main circuit.



.

Therefore, $I_T = I_1 + I_2$

If R_T is the equivalent resistance of the main circuit between A and B, then by Ohm's law the current is given by;

$$I = \frac{V}{R_T} \text{ for branch 1 and 2}$$

$$I_1 = \frac{V}{R_1} \text{ and } I_2 = \frac{V}{R_2}$$

From $I_T = I_1 + I_2$

$$\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2}$$

On diving both sides by V

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{R_2 + R_1}{R_1 R_2}$$

Cross multiplication

$1(R_1R_2) = R_T (R_1 + R_2)$

$$R_T = \frac{R_1 R_2}{R_2 + R_1}$$

For two resistors connected in parallel.

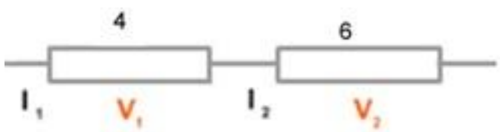
EXAMPLES

1.Given that R_1= 4Ω and R_2= 6Ω, find the equivalent resistance when the resistors are connected.

1. In parallel
2. In series

Solution

1.Series

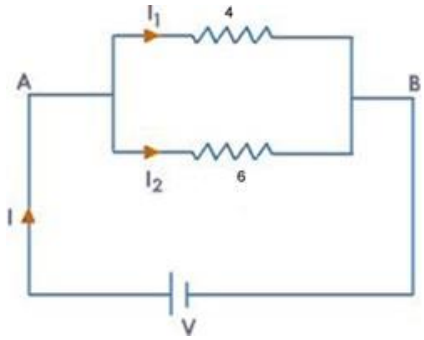


$R_T = R_1+R_2$

R_T = 4Ω + 6Ω

R_T = 10Ω

2.Parallel



$$R_T = \frac{R_1\ R_2}{R_2+R_1}$$

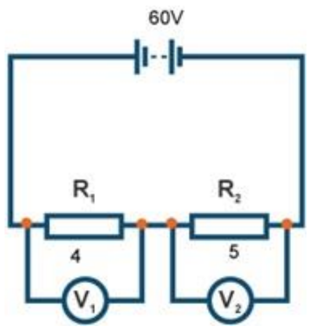
$$R_T = \frac{4 \text{ x } 6}{4+6}$$

= 2.4Ω

2.Two conductors of resistance 4Ω and 5Ω are connected in series across a 60V supply. Find;

a. The total resistance
b. The current in the circuit

c. The potential difference across each resistor



$R_T = R_1 + R_2$

$= 4\Omega + 5\Omega$

$= 9\Omega$

the total resistance = 9Ω

$I = \frac{60}{9}$

I = 6.7A

Potential difference across R_1

$V_1 = IR_1$

$V_1 = 6.7 \times 4 = 26.8v$

Potential difference across R_2

$V_2 = IR_2$

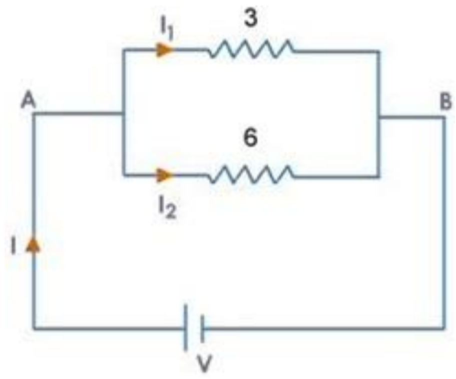
$V_2 = 6.7 \times 5 = 33.5v$

Total current = 26.8 + 33.5 = 60A

3.Consider the circuit shown below. What will be the reading on the Ammeter?

Solution

V = 12V



$$R_T = \frac{R_1 R_2}{R_2 + R_1}$$

$$R_T = \frac{3 \times 6}{3+6}$$

R_T =2Ω

$$I = \frac{V}{R_T}$$

$$I = \frac{12}{2}$$

I = 6A

EXERCISE

1. In a circuit, the amount of charges passing through a point is 9 coulombs in 4.5 seconds. What is the electric current passing at that point?

Solution

Quantity of charges = 9 coulombs

Time = 4.5 sec

Electric current =?

$$\text{electric current} = \frac{\text{Quantity of charges}}{\text{time}}$$

$$= \frac{9}{4.5}$$

Electric current = 2coulombs/sec

2. The two resistances 15Ω and 5Ω are connected in series across 20v supply, find;

a. Total resistance
b. The total current in the circuit
c. The current through each resistor

Solution

Data given

$R_1 = 15\Omega$

$R_2 = 5\Omega$

Voltage = 20v

The total resistance

$R_T = R_1 + R_2$

$= 15\Omega + 5\Omega$

$= 20\Omega$

The total current in a circuit (I)

From V = IR

$$I = \frac{V}{R}$$

But v = 20v, R = 20Ω

$$I = \frac{20V}{20\Omega}$$

I = 1A

The current through each resistor

$$I_1 = \frac{V_1}{R_1}$$

But V = 20V, R_1 =15Ω

$I_1 = \frac{20\ V}{15\ \Omega}$

= 1.3A

$I_2 = \frac{V_2}{R_2}$

but V = 20 V, R = 5Ω

$I_2 = \frac{20\ V}{5\ \Omega}$

$I_2 = 4A$

MAGNETISM

MAGNETISM

A magnet is a substance which attracts metals or magnetic materials.

Magnetism is the behavior shown by magnet, the behavior of attracting metals/magnetic materials.

PROPERTIES OF MAGNET

1. Magnets attract magnetic materials like iron, steel, cobalt and nickel.

2. Magnet posses two poles northern pole (N) and southern pole(S).

3. Like magnetic poles repel but unlike magnetic poles attract.

4. If a magnet is suspended freely always point in the northern – south direction.

The end pointing north is called **North Pole (N)** of magnetic and the end pointing south is called the **South Pole (S)** of the magnetic.

TYPES OF MAGNETS

Magnets can be divided into three types namely;

1.Permanent magnet

These are natural magnets. The force of magnetism exist for a long time after being magnetized.

2. Temporary magnets

These are magnets where by the force of magnetism exist just for a short time after being magnetized.

3. Electric magnets

These are artificial or man-made magnets where by force of magnetism exist only if there is the flow of electricity.

MAGNETIC AND NON-MAGNETIC MATERIALS
1. MAGNETIC MATERIAL

Materials which are attracted by magnet are called **magnetic materials**. Magnetic materials are not self magnetic since they do not attract each other. **Example** of magnetic materials are iron, steel, cobalt, and nickel. Magnetic materials can be made magnetic by artificial methods of **magnetization**.

2. NON-MAGNETIC MATERIAL

Material which cannot be attracted by magnets are called **non-magnetic material** and these materials cannot be made magnetic. **Examples** of non-magnetic materials are brass, zinc, copper and carbon.

APPLICATION OF MAGNETS

Magnets are used in;

-Loud speakers

-Telephone receiver

-Microphones

-Computers

-Electric generators

-Tapes etc.

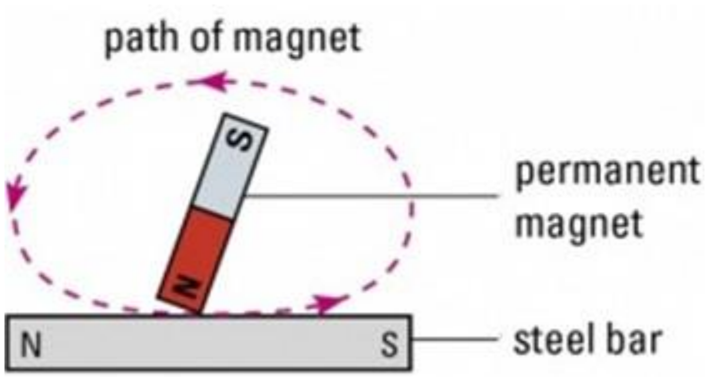
MAGNETIZATION /MAKING MAGNETS

There are three methods by which magnetic materials can be turned into a magnet namely. **Stroking**, **induction** and **electrical magnetization**

1. **STROKING METHOD**

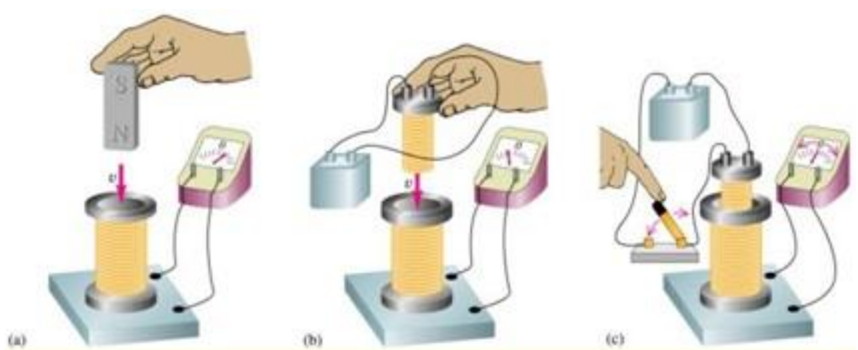
In this method the steel bar and any other material to be magnetized is placed on the bench.

The pole of bar magnet is dragged along the bar from one end and the other. At the end it is lifted up well away from this steel bar and brought back to the same end where drugging started. This is repeated several times.



2. **INDUCTION METHOD**

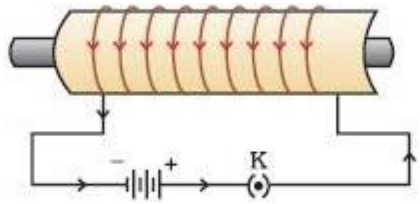
This is the process by which a magnetic material is induced to become magnet**.**



3. ELECTRICAL METHOD

In this method a wire wound several times around the object which has to be magnetized and then the end of the wires is then connected to the terminal of a battery.

This method is commonly used for magnetization purpose because it produces strong magnets.



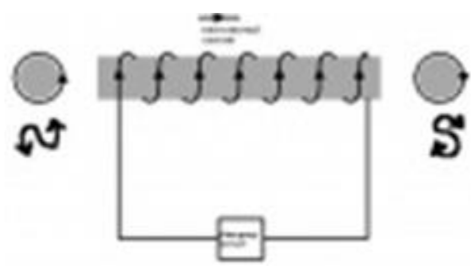
DEMAGNETIZATION

The process of removing magnetism from a given substance or material is known as **demagnetization.**

METHODS OF DEMAGNETIZATION

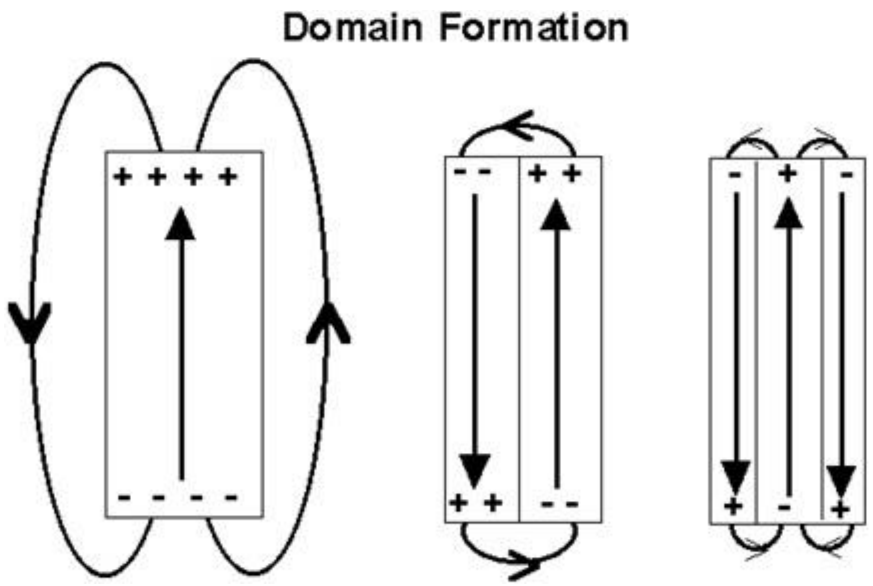
Hammering and **heating** are the method used to demagnetization magnets with their poles facing east-west directions.It is advisable to place the magnet in the east-west direction because the earth has magnetism which will also aid demagnetization.

Using solenoid carrying cans alternating current;

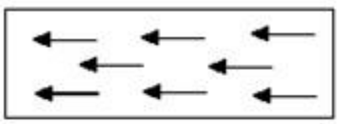


THE DOMAIN THEORY OF MAGNETISM

Each magnetic material is made up of extremely small molecules called **Domains.** In magnetic materials which are not yet a magnetic poles in different direction.



A material becomes magnetized after its domain has so aligned in such a way that their N- Poles face one common direction and S- poles face another common direction.



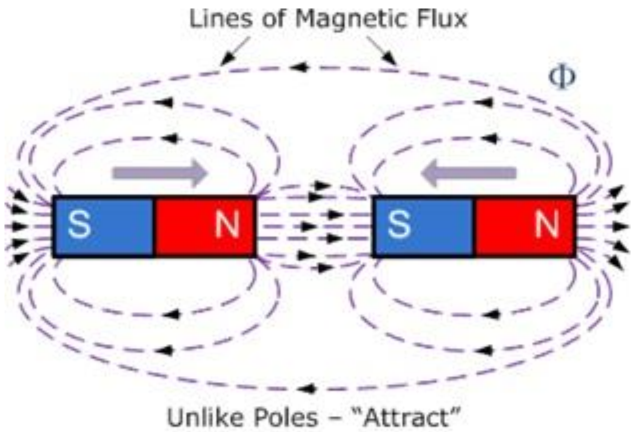
Magnetised
(domains lined up)

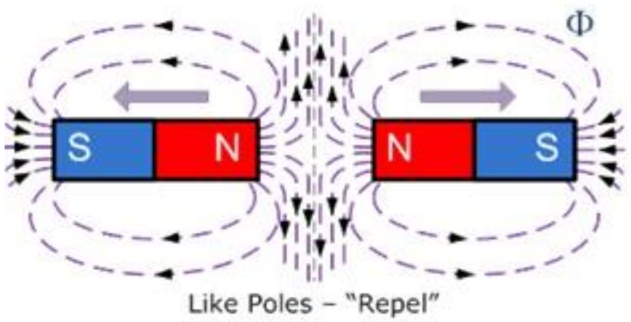
The main difference between magnet and magnetic materials lies in the way domains inside those bodies are aligned.

MAGNETIC FIELD

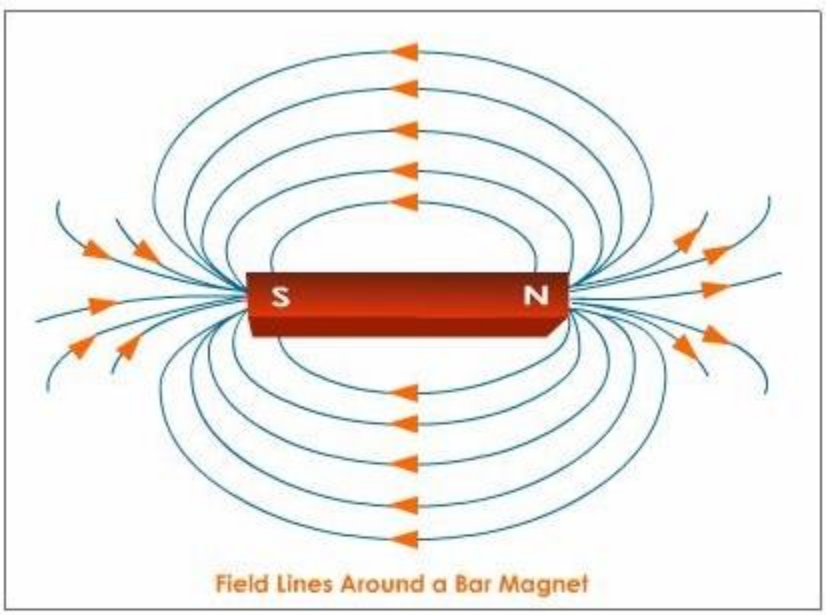
A magnetic field is space around a magnet where a magnetic force is felt.

In any magnet there are several invisible lines that extend from north pole to the south pole through outside to the magnet forming closed loop. These lines are called **a magnetic field**

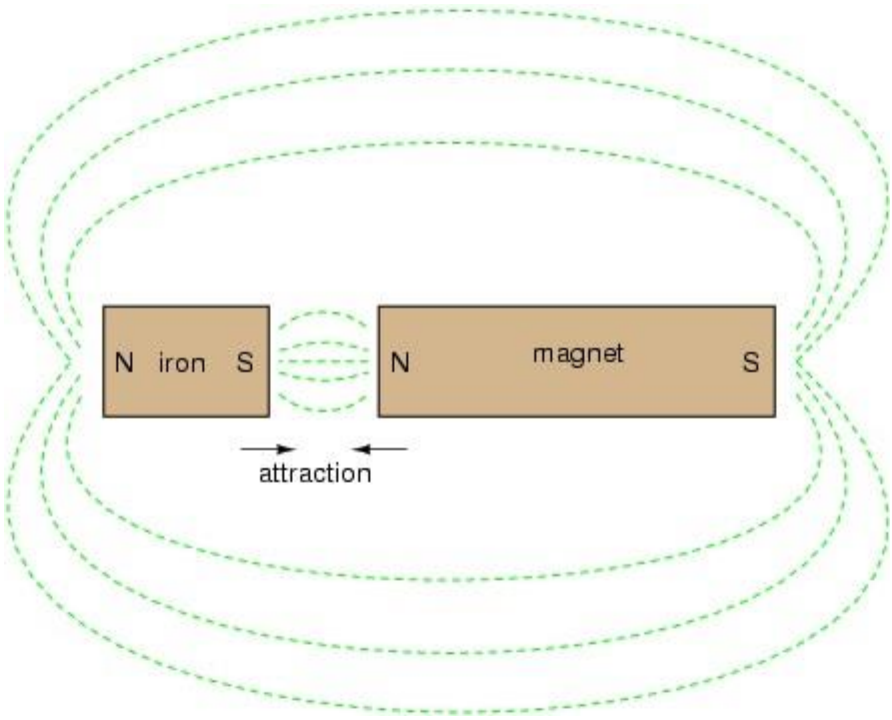




PROPERTIES OF THE MAGNETIC LINES OF A FORCE



Field Lines Around a Bar Magnet



Whenever two similar poles are placed to each other, there is a point between them of which the magnetic field lines do not pass, such as a point is called **natural point x**.

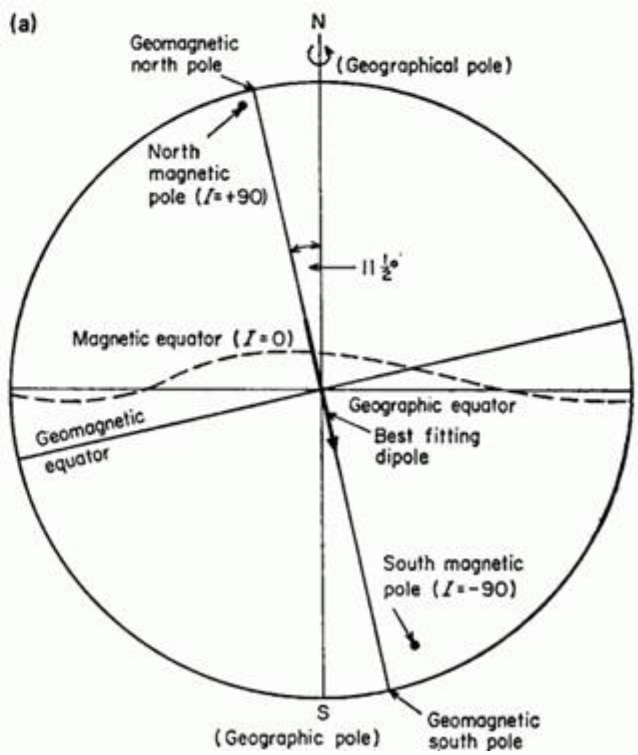
In (E) the piece of soft iron becomes magnetic when placed inside the field and cause the force to come closer to one another. Thus, it consulates the field. The concentration of lines of force in soft iron can be used to shield objects from unwanted magnet field.The iron tin material (f) produces the neutral central, The space enclosed by soft iron or steel would be for magnetic field effect.

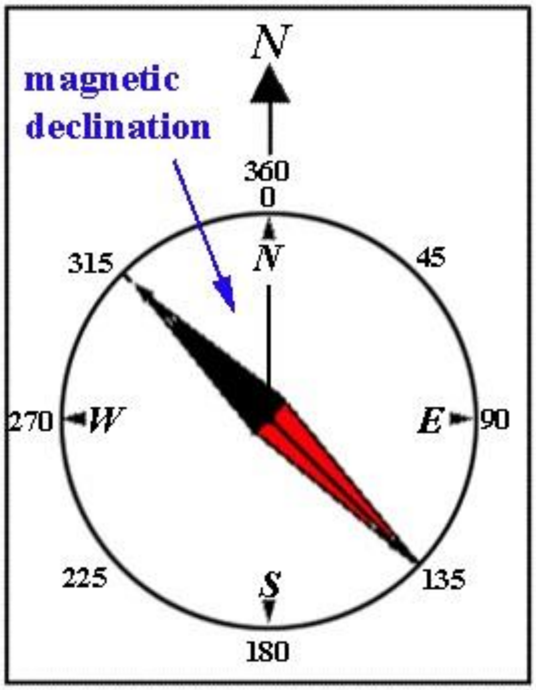
THE EARTH′S MAGNETISM

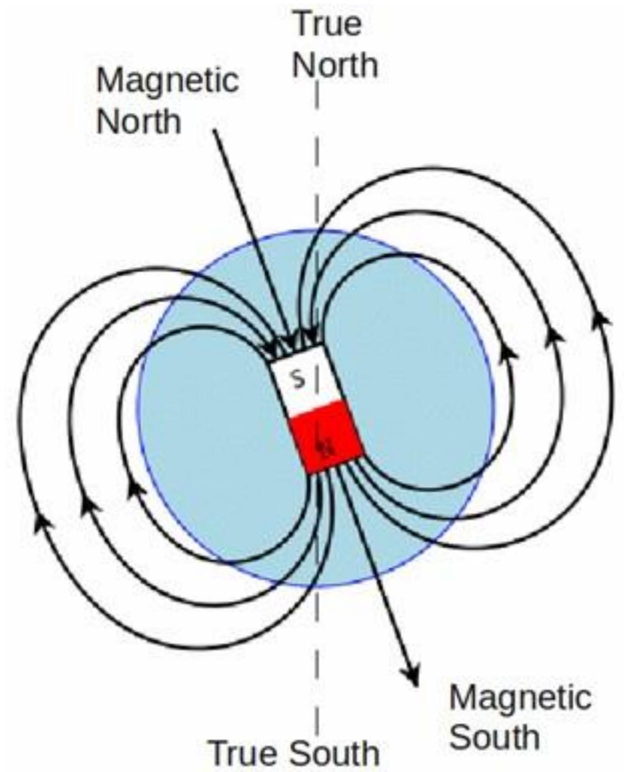
A freely suspended magnet or compass needle always points in the north south direction. This is due to the magnetic field of the earth. The earth magnetic field extends from deeply below the surface to the south land kilometer up in the sky.

The direction pointed by the compass needle is slightly different on the time or geographical north. Angle of declination is formed between magnetic north and geographical north.

The angle which the magnet is suspended makes a horizontal is called the **angle of dip**,The angle of dip is zero at equator and 90â• ° at equator.


(a)
Geomagnetic north pole
N
(Geographical pole)
North magnetic pole (I=+90)
11½°
Magnetic equator (I=0)
Geographic equator
Geomagnetic equator
Best fitting dipole
South magnetic pole (I=-90)
S
(Geographic pole)
Geomagnetic south pole


N
magnetic declination
360
0
N
315
45
270
W
E
90
225
S
135
180



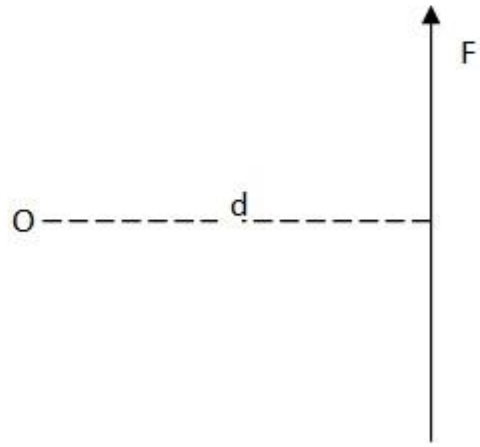
Declination and the earth magnetism

EQULIBRIUM

EQUILIBRIUM

Moment of a force

The moment of a force about a point is given by the product of the **force's magnitude** and the **perpendicular distance** between the line of action of the force and the point.



The perpendicular distance between the line of action of the force '**F**' and the point '**O**' is '**d**'.

The moment of the force is therefore = force x Distance.

Moment of force = Force x Distance (N X m)

The SI unit of moment of a force is **Nm**

Example

1. The line of action of a force 48N is at perpendicular distance of 1.5m from the point. Find the moment of the force about the point.

Data given

Magnitude of the force = 48N

Perpendicular distance = 1.5m.

Find moment of a force =?

:Moment of a force = force x Distance

= 48 N x 1.5 M

Moment of the force = 72Nm

2. The moment of a force about a point is 1120Nm. If the magnitude of a force is 5600N, find the perpendicular distance between the point and the line of action of the force.

Data given

Moment of a force = 1120Nm

Magnitude of a force = 5600N

Perpendicular distance =?

From:

$$\text{Perpendicular Distance} = \frac{\text{moment of a force}}{\text{magnitude of a force}}$$

$$= \frac{1120}{5600}$$

Perpendicular distance = 0.2m

3. The moment of a force is 1000 Nm. If the line of the force is at perpendicular distance of 100m, find the magnitude of a force.

Data given

Moment of a force =1000Nm

Perpendicular distance =100m

Magnitude of a force =?

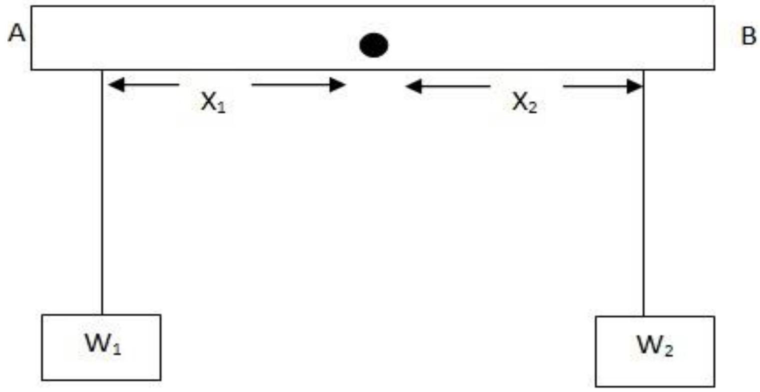
$$\text{From: magnitude of a force} = \frac{\text{moment of a force}}{\text{Perpendicular Distance}}$$

$$\text{magnitude of a force} = \frac{1000}{100}$$

Magnitude of a force is 10N.

The principal of Moments

The principle of moments states that " If a body is in equilibrium under the action of forces which lie in one plane, the sum of the clockwise moments is equal to the sum of the anti clockwise moments about any point in that plane".



M is the point of fulcrums.

Clockwise moment = $\mathbf{W_2 \times X_2}$

Anti clockwise moment = $\mathbf{W_1 \times X_1}$

Sum of clockwise Moment = Sum of anticlockwise Moment

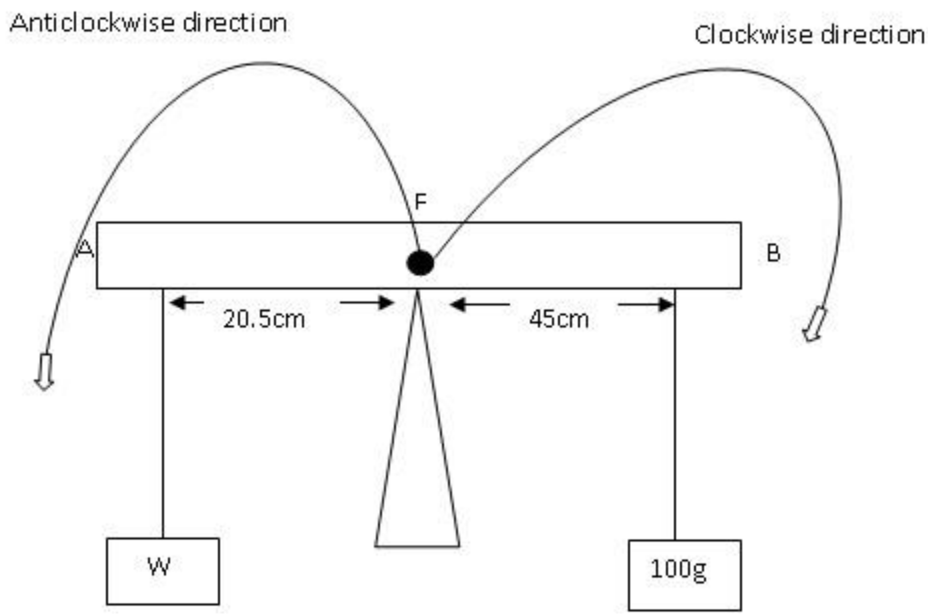
$\mathbf{W_2 \times X_2 = W_1 \times X_1}$

$$W_2 = \frac{W_1 \times X_1}{X_2}$$

$$W_1 = \frac{W_2 \times X_2}{X_1}$$

Examples:

1. 100g weight is suspended 45 cm from the pivot A of a light rot. If a weight is suspended 20.5cm from the point balance the 100g weight, determine the W_1 if a 300g weight is used to balance the 100g weight, determine the distance of the 300g weight from the point.



Clock wise moment = 100g x 45cm

Anticlockwise moment = w x 20.5cm

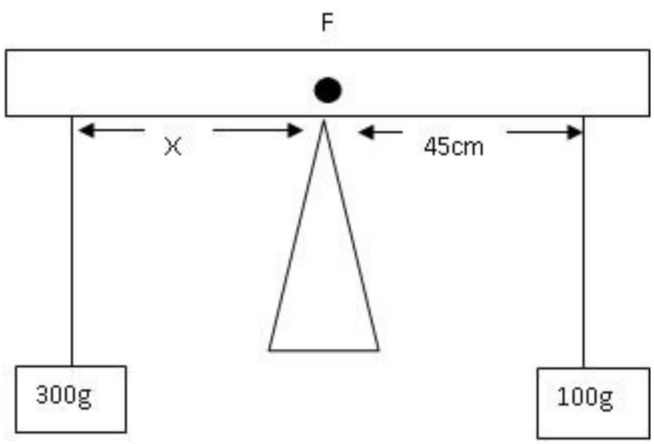
Sum of clockwise Moment = anticlockwise moment

100s x 45cm = 20.5Wcm

$$W = \frac{100 \times 45}{20.5}$$

W = 220g

2. If a 100g weight is used to balance the weight determine the distance of the 300g weight from the point.



Clock wise moment = anticlockwise moment

100g x 45cm = 300g x X

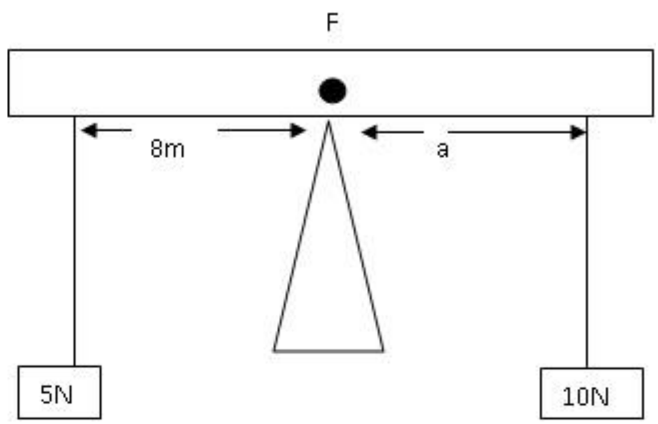
$$X = \frac{100 \times 45}{300}$$

The distance from the pivot is 15cm

EXAMPLE

Anticlockwise = 15cm and 300g

Clockwise = 100g and 45cm



Solution:

Clockwise moment = ant clockwise moment

a x 10N = 8M x 5N

$$a = \frac{40}{10}$$

a = 4m

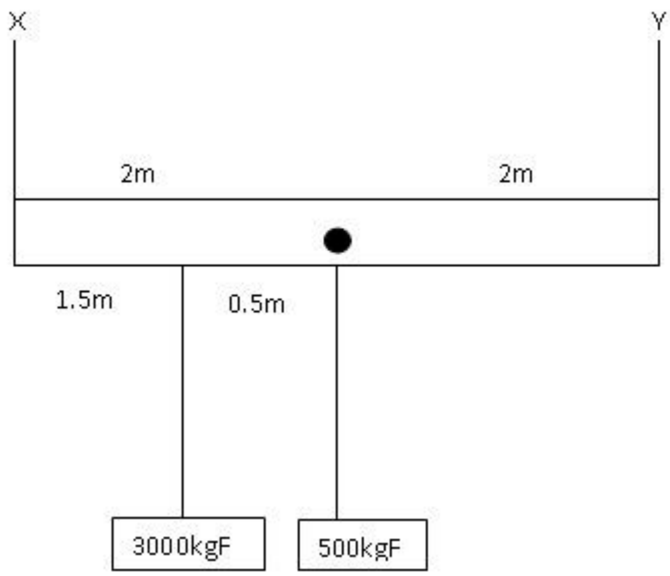
The distance required was 4m

UNIFORM BEAM

Example

1. A heavy uniform metal beam AB weighting 500kg if is supported at it ends. The beam carries a weight of 3000kg at distance of 1.5m from the end of A. If the beam is 4m long, determine the thrust on the supports A and B.Since the beam is uniform its weight acts vertically down ward at the middle.

-let the thrust at point A be 2 and the point B be Y



Taking moment about point A

Clock wise moment 3000kg x 1.5m + 500kg x 2m

Anti clock wise = Y x 4M

Clock wise moment = Anti clock wise moment

3000kgF x 1.5m + 500kgF x 2 = Y x 4m

4500 + 1000=Y4m

5500kgm = Y4m

$$Y = \frac{5500kgFm}{4m} = 1375\ kgF$$

Down force = upward force

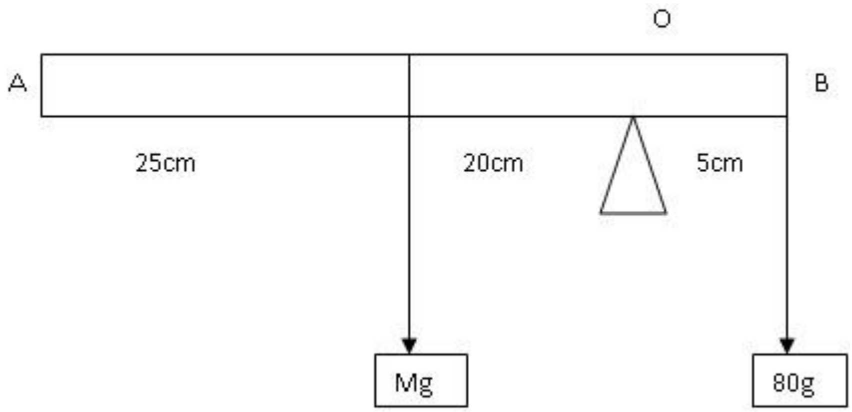
(3000 + 500) =X + 1375

3500 = X + 1375

X = 3500 -1375

Then the force required is = 2125kgF

2. A uniform half – meter, rule AB is balanced horizontally on a knife edge placed 5cm from B with a mass of 80g at B.find the mass of the ruler.



Clockwise moment = Anticlockwise moment

80g x 5cm = m x 20

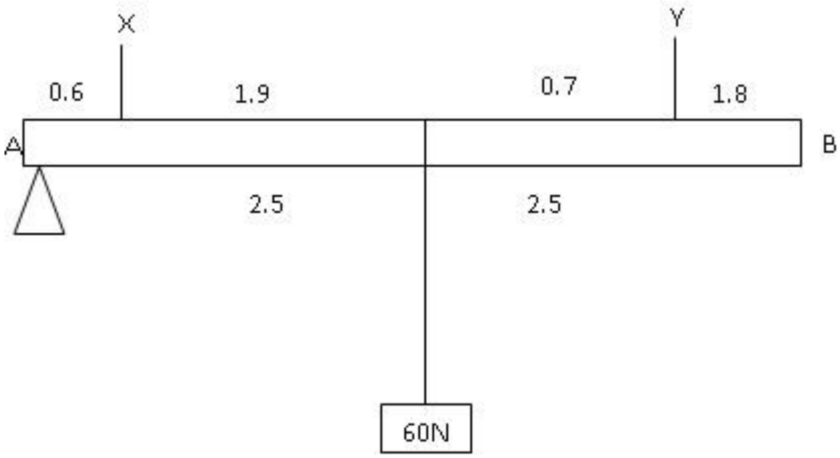
400cm = 20 x M

$$M = \frac{400}{20}$$

M = 20g

Exercise

1. A uniform bar AB of height 5m weights 60N. The bar is supported at a horizontal position by two vertical strings X and Y. If string X is 0.6m from A and string Y is 1.8m from B. Find the tension in the string.



Moment about A

Clock wise Moment = 60 x 2.5

Anti clockwise Moment = 0.6 x X + 3.2Y

Clockwise moment = anticlockwise moment

60 x 2.5 = 0.6 x X + 3.2y………(1)

X + Y =60…………(2)

X = 60 – Y

150 =0.6X + 3.2Y   substitute the value of X to the equation 2

150 = 0.6(0.6 – Y) +3. 2Y

150 =36 – 0.6Y +3.2Y

150 =36 + 2.6Y

114 = 2.6Y

Y = 43.84 then

= 60 -48.84

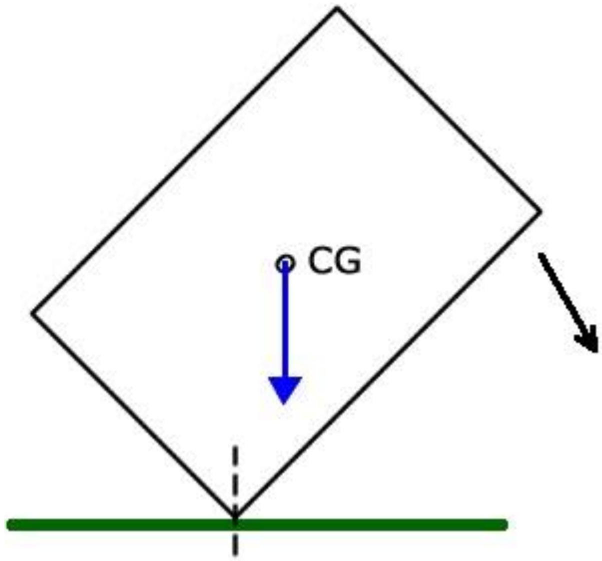
= 16.15

Tensions is the string = 16.5N

CENTER OF GRAVITY

The weight of body is due to the attraction of the earth for its particles. In other words each particles of which given body are made is attracted towards the center of the earth.

This attracting force is the weight of each individual particle. Since the body consists of many particles then the weight is the resultant of all the parallel forces acting on the individual particles as shown below.

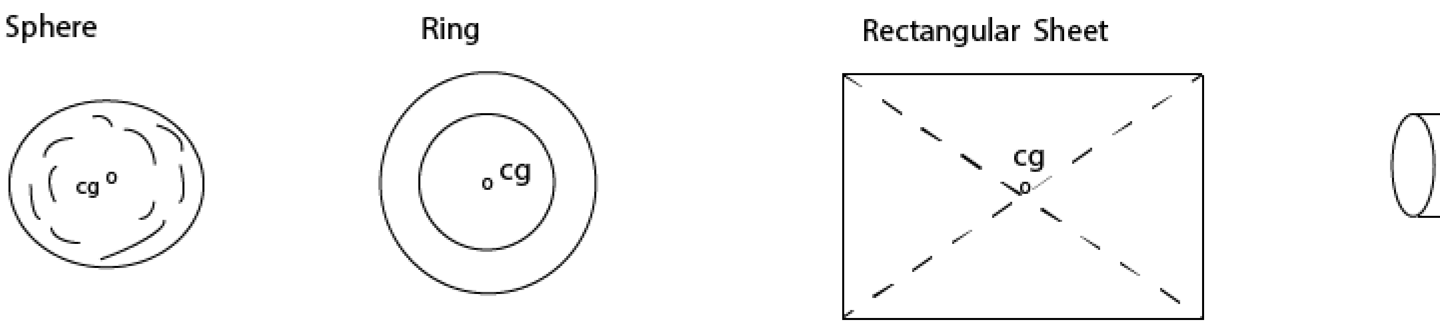


For a rigid body, there is one point at which the resultant force appears to act, this point is known as the center of gravity G of the body.

The center of gravity is therefore defined as the point through which the resultant of the weight of all the particles of the body acts

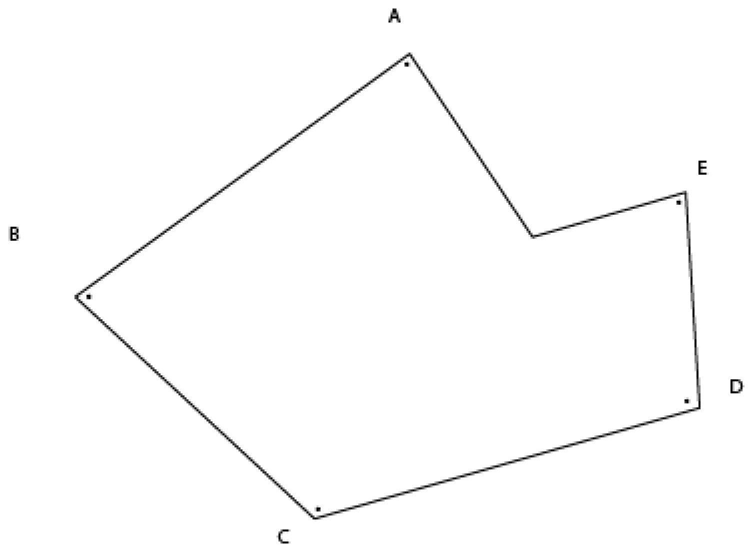
COUPLES

A couple consists of two equal and opposite parallel forces and it has turning effect.



Centre of gravity of regular objects.

Irregular shaped bodies.
Locating centre of gravity of a cardboard.



.
Steps
1. Punch holes on the corner points ABCDE.
2. Run a pencil through the first hole (A) and let the cardboard hang freely.
3. Attach a small mass to one end of a string and suspend it by tying the other end on that pencil.
4. Using a felt pen draw a line on the cardboard along the string.
5. Repeat the procedure 2 - 4 above using the holes B, C, D and E.

The point where the lines will meet is the centre of gravity of a cardboard.

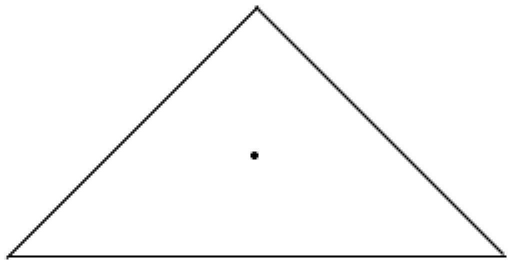
Conditions for equilibrium

First Condition
The sum of forces acting the object is zero.

Second Condition
The sum of the moment acting on an object is zero.

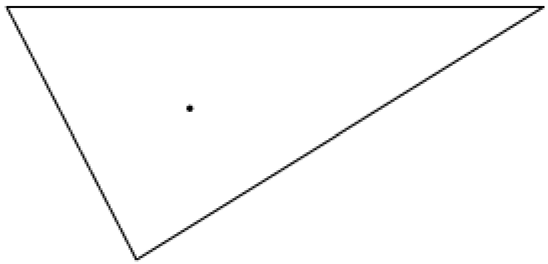
Stable, Unstable and Neutral equilibrium
Stable equilibrium.

An object is in a stable equilibrium if after a small displacement it return to its initial position.



Stable Equilibrium

Unstable Equilibrium
An object is in an Unstable equilibrium if after a small displacement it moves further from its initial position.



Unstable equilibrium.

Neutral equilibrium

An object is in a neutral equilibrium if when displaced it does not return to its initial position neither does it move further from its initial position.Sphere at rest on a horizontal table is in a neutral equilibrium.

SIMPLE MACHINE

SIMPLE MACHINE

MACHINES

A machine is any device which is used to simplify work.

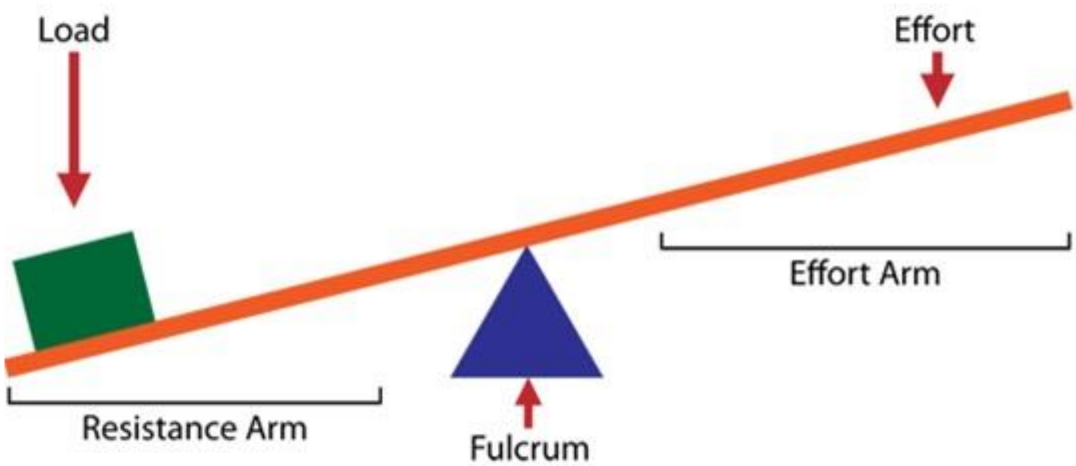
- In a machine, a force is applied at one convenient point to overcome force acting at another point.

Simple Machine and complex Machine
A simple Machine is the one which involve one movement example; inclined plane

A Complex Machine is a combination of more than one simple machine. Example Bicycle

Six types of Simple Machine are;

1. Levers
2. Pulley
3. Inclined Plane
4. The Screw Jeck
5. Wheel and axle
6. Hydraulic Press



The figure above shows a load being lifted by using a crowbar. A downward force is applied at one and point of the crowbar in order to extend an upward force on the stone. The upward force shifts the stone by one crowing its weight. The down ward force applied on the crowbar is called the effort and the weight of the stone is the load.

Effort - is defined as the force used to operate a machine.

Load - is the resistance which a machine overcomes.

Mechanical Advantage

In general a machine is designed in such a way that the applied force effort is less than the load. The action of the load to the applied effort is a measure of usefulness of mechanical advantage (M.A) of a machine.

$$\text{Mechanical Advantage} = \frac{\text{load}}{\text{effort}}$$

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

Since mechanical Advantage is a ratio of two forces it has **no unit**.

Example

1. A certain machine is designed in such a way that a force of 150N is used to lift load of 600N. What is the mechanical advantage.

Solution

Effort = 150N

Load = 600N

$$\text{Mechanical Advantage} = \frac{\text{load}}{\text{effort}}$$

$$\text{M.A} = \frac{600}{150}$$

Mechanical advantage = 4

Velocity Ratio:

In any machine, the movement of the effort causes the corresponding movement of the Load. The distance moved by each of these forces are measured with the ratio of the distance moved by effort to the distance moved by the load,it is called the **velocity ratio** (V.R of the machine)

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\text{V .R} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

V.R is the ratio of two lengths (**it has not unit**)

Example:

1. In a certain machine a force of 10N moves down a distance of 2cm in order to raise a load of 10N through a height of 0.5cm. Calculate the velocity ratio of the machine.

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\text{Velocity ratio} = \frac{2\text{cm}}{0.5\text{cm}}$$

Velocity ratio = 4

EFFICIENCY OF A MACHINE

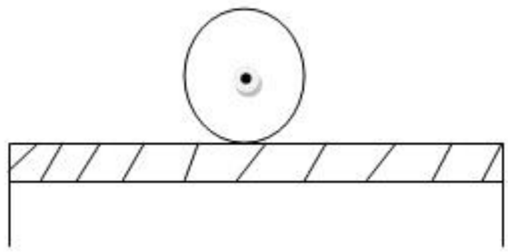
<u>Work input</u>
Work input is the total workdone by effort
Work input = Effort x Effort distance

<u>Work output</u>
Work output is the total workdone on load
Work output = load x load distance

<u>Efficiency</u>
is the ratio of work output to work input usually expressed in percentage.

efficiency is always less than 100%

This is due to energy loses due to friction.



Neutral equilibrium

Application of equilibrium

1. Vehicles used in a car race have tyres wide apart to increase stability
2. Buses have luggage compartments on their lower parts so as to lower the centre of gravity

All practical machines have losses due to friction. Therefore in such case the work output will be less than the work in put.

$$\text{Thus efficiency (E)} = \frac{\text{work output}}{\text{work input}} \times 100\%$$

But work = force x Distance moved

$$\text{Efficiency E} = \frac{\text{Load x Distance moved by the load}}{\text{Effort x Distance moved by the effort}} \times 100\%$$

$$= \text{mechanical advantage} \times \frac{1}{\text{velocty ratio}} \times 100\%$$

$$= \text{M.A} \times \frac{1}{\text{V.R}} \times 100\%$$

$$E = \frac{\text{M.A}}{\text{V.R}} \times 100\%$$

Example

1. A simple machine was used to raise a load of weight 3920N through a height of 3.5m by applying an effort of 980N, if the distance moved by the effort was found to be 20m, find.

i. The mechanical advantages
ii. The velocity ratio
iii. The efficiency of the machine

Solution

Load = 3920N

Effort = 980N

Distance moved by the effort = 20m

Distance moved by the load = 3.5m

$$\text{Mechanical Advantage} = \frac{\text{load}}{\text{effort}}$$

$$\text{Mechanical Advantage} = \frac{3920}{980}$$

Mechanical Advantage = 4

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$= \frac{20}{3.5}$$

velocity ratio = 5.71

$$\text{Efficiency} = \frac{\text{M.A}}{\text{V.R}} \times 100\%$$

$$= \frac{4}{5.7} \times 100\%$$

Efficiency = 70 %

LEVERS

Levers is a rigid body which when in use turns about a fixed point called a **fulcrum** or **pivot**.

It is used to shift heavy loads. A lever is designed such that a small force applied at one point overcomes a large force at another point. A lever is therefore a simple machine.

Classes of lever

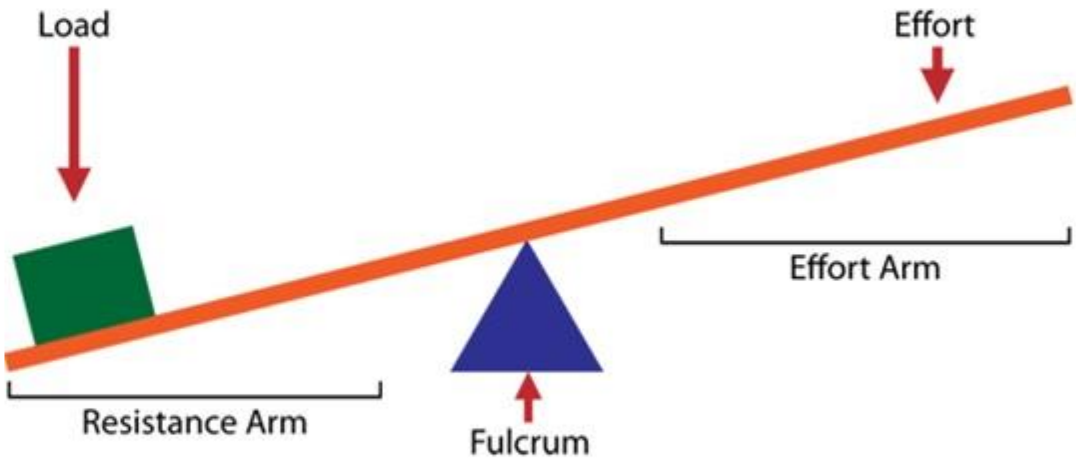
Levers are divided in to three classes or orders namely, **first class lever**, **second class lever** and **third class levers**.

Classification of levers depends on the position of the **fulcrum**, **load** and **effort**.

1. First class lever

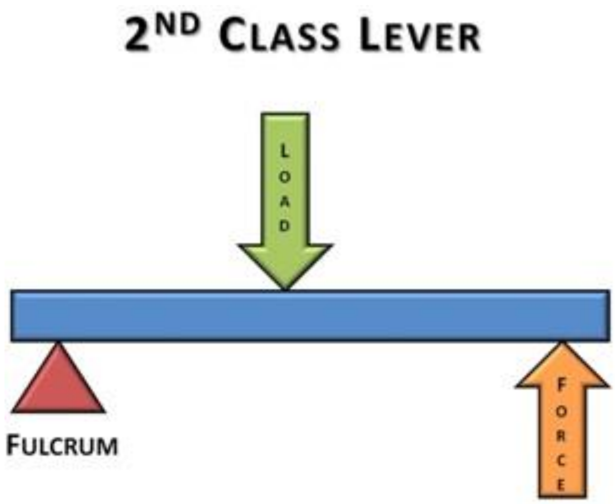
This is a class of lever whereas fulcrum between the load and effort.

Examples: claw hammer, crow bar and pair of scissors.



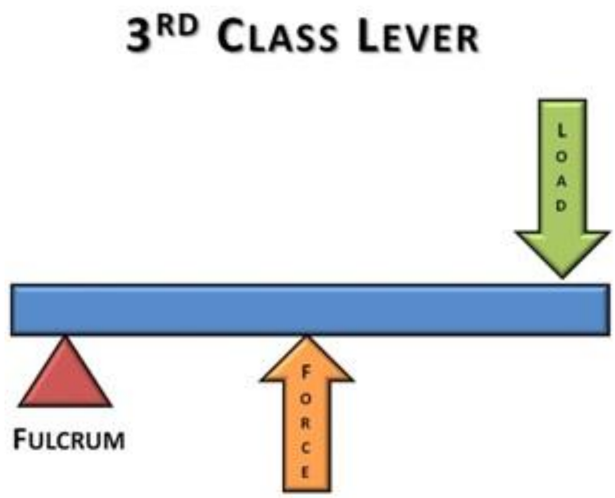
2. Second class lever
This is a class of lever whereas load is between the fulcrum and the effort.

Examples: wheel barrow, a bottle opener, nutcracker etc



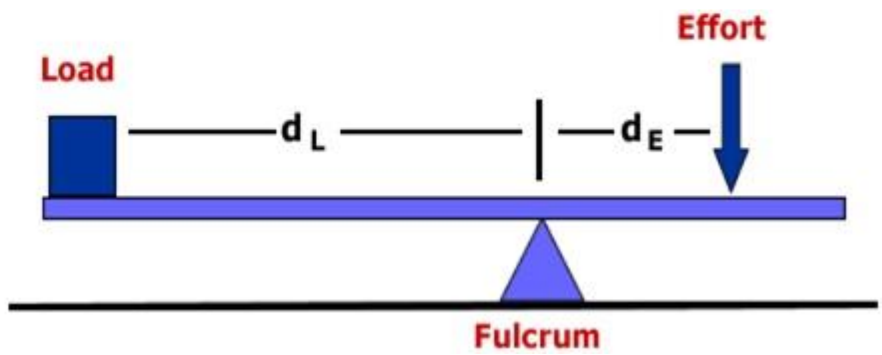
3. **Third class levers**
This is a class of lever whereas effort between the fulcrum and the load.

Examples: tongs, fishing rod and a spade.



Mechanical advantages of a lever

By considering the moments of the applied effort and load which is overcomed by the effort about the fulcrum.



From the figure above, the effort is first overcoming the load. From the principles of moments, it follows that;

The sum of clockwise moment = the sum of anti clockwise moment

Effort x Distance from Fulcrum to effort = load x Distance from fulcrum to load

$$\frac{\text{Distance from fulcrum to effort}}{\text{Distance from fulcrum to load}} = \frac{\text{load}}{\text{effort}}$$

But

$$\frac{\text{load}}{\text{effort}} = \text{Mechanical advantage}$$

$$\text{Mechanical advantage} = \frac{\text{Effort arm.}}{\text{load arm}}$$

Pulleys

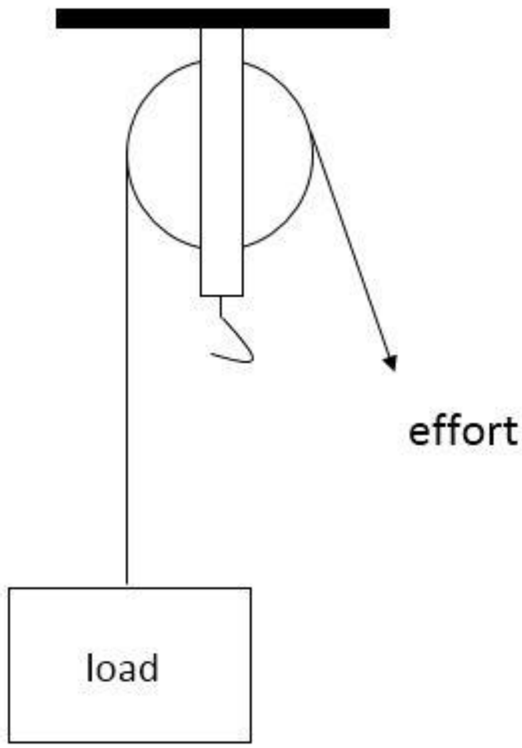
A pulley's block consists of two or more pulleys in a wooden or metal frame.

A pulley is a grooved wheel which is free to turn about an axle fixed in a frame. There are about four types of pulleys which are;

1. The single fixed pulley
2. Single movable pulley
3. Movable pulley
4. Block and tackle system.

1. The single fixed pulley

A single pulley is a fixed wheel with a rope passing round a groove in the wheels. Circumference, it is used to raise flag to the top of a flag – pole and builders use this type of pulley to lift cement bricks.



Neglecting the weight of the rope and friction of the pulley, the tension in the rope is equal to the effort and the load is equal to the effort applied on it.

Effort = tension (T) = load

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

But load = effort = tension (T)

$$\text{M.A} = \frac{\text{Effort}}{\text{effort}}$$

M.A = 1

From this type of pulley the load and effort all move the same distance.

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

V.R = 1

2. The movable pulley

The pulley is free to move and can be in two arrangements show in figures (a) and (b) shown below. The first arrangement consists of single movable pulley the second arrangement consists of two pulleys in which one is fixed.

FIGURE (A)

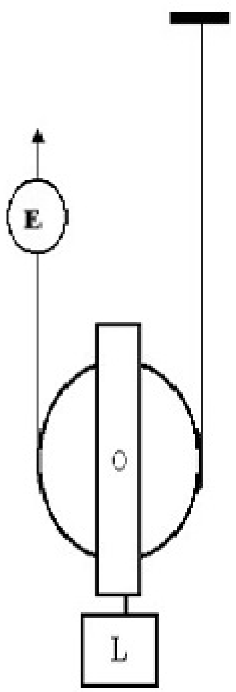
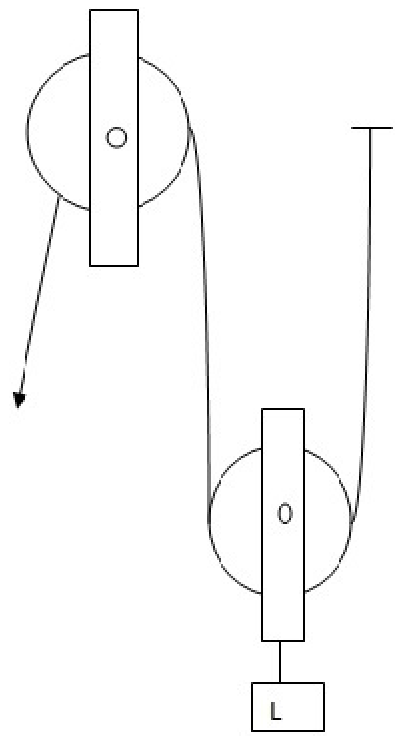


FIGURE (B)



The tension (T) in the string is equal to the effort applied, so the total upward pull on the pulley is twice the effort 2E (E = T). The load L = 2T, T is the tension in the string so load 2 = 2E (neglecting the friction losses and weight of the pulley and string the mechanical advantage is given by;

$$M.A = \frac{\text{load}}{\text{effort}} = \frac{L}{E} = \frac{2E}{E} = 2$$

M.A = 2

When the effort moves a distance x, the two sections of the string each are shortened a length half x, Therefore the load moves upwards through a distance half x.

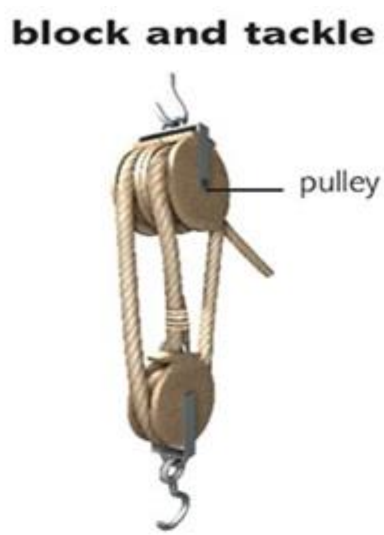
$$\textbf{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\text{Velocity ratio} = \frac{x}{\frac{1}{2}x} = 2$$

Velocity ratio = 2

3. Block and tackle

Block is made up of two of more pulleys fixed in a wooden or metal frame. The pulleys in each block are fixed on separate axles. One string is used. It is tied to the top of the block and then passes around each of the pulleys. In block and tackle system pulleys, it is only the lower block which is free to move.



Figure, the tension in each section of the rope is equal the effort applied at the free end. The total tension in the rope sections supporting the movable block is equal to the load. That is load L=4T since there are four sections.

The tension (T) in the string equals to the load applied effort (E), that is E = T, then it follows that:-

Load (L) = 4 x Effort, which means that the load is equal to the effort multiplied by a number of rope sections.

In figure (b)

Load = number of rope sections that supports the load x Effort (number of pulley)

Load = 3 x effort

$$M.A = \frac{Load}{Effort} = \frac{3 \times Effort}{Effort}$$

M.A. = 3

Efficiency of block and tackle system

The efficiency (e) of a machine is given as;

$$E = \frac{M.A}{V.R} \times 100\%$$

For block and tackle system

M.A = Number of pulleys and

V.R = Number of pulleys of the system

Example

1.A block and tackle pulley system has a velocity ratio of 4. If a load of 100N is raised by using a force of 50 N. Calculate the mechanical advantage and efficiency of the system.

Solution

Data given

Velocity ratio = 4

Load = 100N

Effort = 50N

$$\text{Mechanical Advantage} = \frac{100\ N}{50\ N} = 2$$

M.A = 2

$$\text{Efficiency} = \frac{M.A}{V.R} \times 100\%$$

$$\text{Efficiency} = \frac{2}{4} \times 100\%$$

Efficiency = 50%

Example 2

2. A simple pulley system has velocity ratio of 3. Its efficiency is 90%, what load can it raise by an effort of 100N.

Solution

Data given

V.R = 3

E = 90%

E = 100N

M.A =?

$$E = \frac{M.A}{V.R} \times 100\%$$

$$M.A = \frac{90\%}{100\%} \times 3$$

M.A = 2.7

Load = M.A x Effort

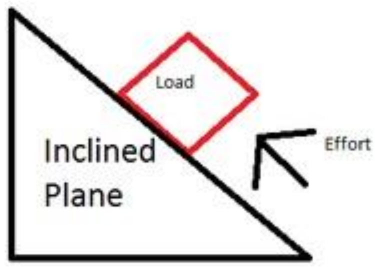
= 2.7 x 100

Load = 270N

The inclined plane

An inclined plane is the simple machine formed by a sloping plane surface, used to raise heavy loads by pulling, pushing or dragging along the surface of the plane.

Force is applied parallel to the plane, hence the effort moves a distance equal to the length of the plane.



The load rises up a distance equal to the vertical height of the plane, which is AB.

$$\textbf{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\textbf{Velocity ratio} = \frac{\text{Length of the plane}}{\text{Height of the inclined plane}}$$

$$\text{Velocity ratio} = \frac{OB}{AB}$$

Neglecting the friction, the work done by effort is equal to the work done on the load.

Then E x length of inclined plane = L x height of inclined plane

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

$$\text{M.A} = \frac{\text{Length of inclined plane}}{\text{Height of the plane}} = \frac{\text{Load}}{\text{Effort}}$$

$$\text{M.A} = \frac{OB}{AB}$$

Example

1. A loaded wheel barrow weight 800N is pushed up an inclined plane by a force of 150N parallel to the plane. If the plane rises 50cm for every 400cm length of the plane, find the velocity ratio, mechanical advantage and efficiency of the plane.

Solution

Data given

L = 800N

E = 150N

Height of inclined plane = 50cm

Height of inclined plane = 400cm

$$V.R = \frac{\text{Length of inclined plane}}{\text{Height of the plane}}$$

$$V.R = \frac{400}{50} = 8$$

$$V.R = 8$$

$$M.A = \frac{\text{Load}}{\text{Effort}}$$

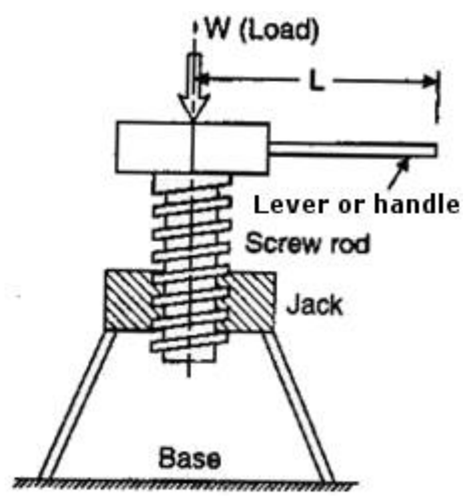
$$= \frac{800}{150} = 5.3$$

$$E = \frac{5.3}{8} \times 100\%$$

Efficiency = 66.25

The screw jack

A screw jack consists of a rod in which there is thread. The thread of the screw is regarded as continuous inclined plane mapped round a cylinder. The distance between two successive threads is called the **pitch of the screw.**



The thread of a screw jack threads into base is turned by means of handle. The load acts on top of the screw, at the same time effort is applied to the handle. When the handle makes one complete turn, the distance moved 2R. The effort raises the load through the distance equal to the pitch p of the screw, making the length of the handle then velocity ratio can be found as follows;

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\text{Velocity ratio} = \frac{\text{Circumference of circle of radius R}}{\text{Pitch of screw}}$$

$$\text{Velocity ratio} = \frac{2\pi R}{P}$$

R = Radius

P = Pitch

Example

1. The handle of a screw jack is 35cm long and the pitch of the screw is 0.5cm. What force must be applied at the end of the handle when lifting a load of 2200N? If the efficiency of jack is 40%

Solution

Data given

R = 35cm

P = 0.5cm

L = 2200N

E = 40%

$$V.R = \frac{2\pi R}{P} = \frac{2 \times 22 \times 5}{0.5}$$

V.R = 440

$$E = \frac{M.A}{V.R} \times 100\%$$

$$40 = \frac{M.A}{440} \times 100\%$$

$$M.A = \frac{40 \times 440}{100}$$

M.A = 176

$$\text{Mechanical Advantage} = \frac{\text{load}}{\text{effort}}$$

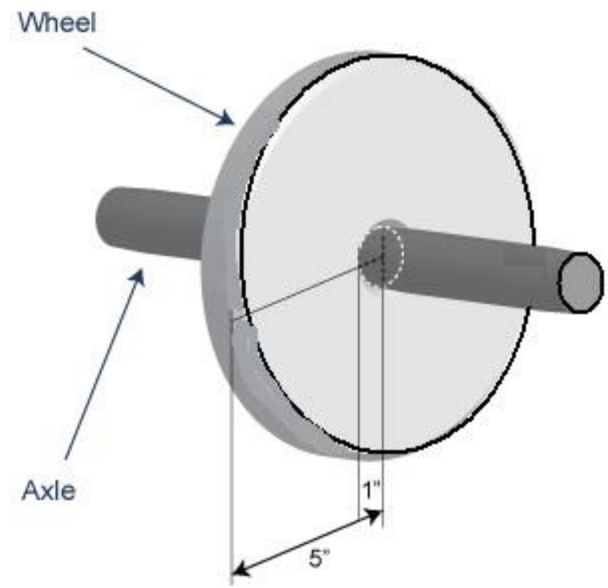
$$\text{Effort} = \frac{\text{load}}{M.A}$$

$$= \frac{2200N}{176}$$

Effort = 12.5N

WHEEL AND AXLE

A wheel and axle is a simple machine which consists of a wheel and axle mounted with the same axis of rotation the radius of the wheel is always greater than that of the axle. When in operation, the effort E is applied to a string wound round the wheel while the load is attached to a string round the axle in opposite direction to that of the string in the wheel.



R = 5 and r = 1

In figure, R is the radius of the wheel r is the radius of axle. When the wheel completes one turn the axle rotates s once. Thus the effort and the load moves the distances.

2πR and 2πr

E = 2πr wheel

C = 2πr axle

$$\text{Velocity ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}}$$

$$\text{Velocity ratio} = \frac{2\pi R}{2\pi l} = \frac{\text{Radius of the wheel}}{\text{Radius of the Axle}}$$

V.R = R/r

Example

1. A wheel and axle of efficiency of 80% is used to raise a load of 2000N. If the radius of the wheel is 50cm and that of the axle is 20m. Calculate:-

a. The velocity ratio and mechanical advantage of the machine.
b. The effort required to overcome the load

Data given

Load = 2000N

E = 80%

R = 50cm

r = 2cm

V.R =?

M.A =?

Effort =?

$$\text{Velocity ratio} = \frac{R}{r} = \frac{50}{2}$$

Velocity ratio = 25

$$\text{Efficiency} = \frac{M.A}{V.R} \times 100\%$$

$$M.A = \frac{E}{100} \times V.R$$

$$M.A = \frac{80}{100} \times 25$$

Mechanical advantage = 20

b) M.A = 20

Load = 2,000N

Effort = ?

$$M\ A = \frac{\text{Load}}{\text{Effort}}$$

$$\text{Effort} = \frac{\text{Load}}{MA}$$

$$\text{Effort} = \frac{2000}{20}$$

Effort = 100N

MECHANICAL ADVANTAGE, VELOCITY RATIO, AND EFFICIENCY OF HYDRAULIC PRESS

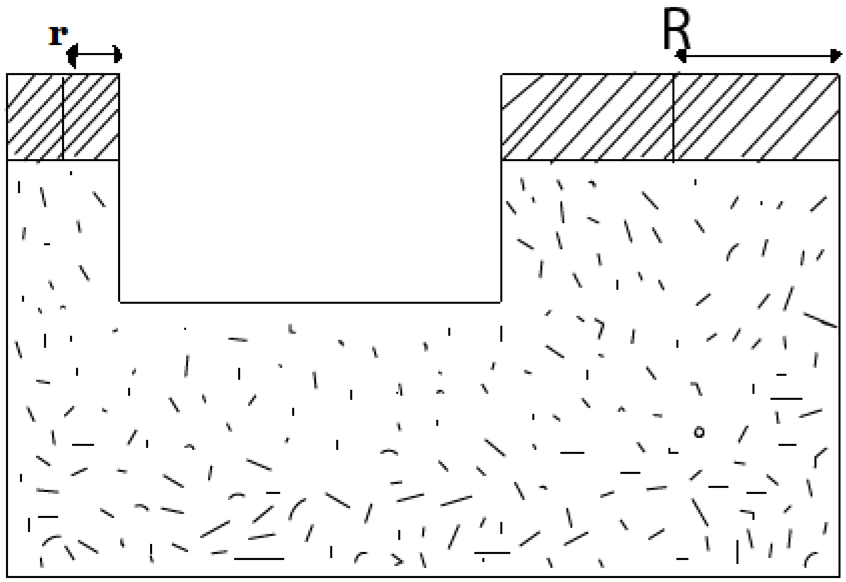
In a hydraulic press a small force (effort) applied on the small piston is used to overcome greater force (load) on the large piston. When a small effort E is applied downwards on the effort piston of radius r, the load piston of radius R lift the load L.

By principle of transmission of pressure in liquids, the pressure on effort piston equal to that on the load piston.

$$\frac{\text{Effort}}{\text{Area of effort piston}} = \frac{\text{load}}{\text{area of load piston}}$$

$$\frac{\text{load}}{\text{Effort}} = \frac{\text{area of load piston}}{\text{area of effort piston}}$$

$$\text{M.A} = \frac{\pi R^2}{\pi r^2} = \frac{R^2}{r^2}$$



MOTION IN A STRAIGHT LINE

MOTION IN STRAIGHT LINE

MOTION

This is the changing of position of an object.

Distance and displacement

- If the body moves 5m east of the fixed point A. In the first case 5m represents a physical quantity, i.e. the magnitude.This is the distance; on the other hand 5m east represents a physical quantity which specifies magnitude and direction thus that is displacement.

- **Distance** - Is the length between two points . SI unit of distance is **meter (m).**
- **Displacement -** is the distance in a given direction. SI unit of displacement is metre(m)

SPEED AND VELOCITY

If a body covers a certain distance in a given time then the speed of the body may be found by dividing the distance traveled by the time taken.

Speed - Is the distance traveled per unit time.

Thus speed = $\frac{\text{distance travelled}}{\text{time taken}}$

The SI unit of speed is **m/s (meter per second)**

T = time

S = distance

V = speed

Velocity = $\frac{\text{displacement}}{\text{time taken}}$

SI unit = m/s

Velocity - Is the speed in a given direction.

Example 1

1. A body covers a distance of 480m in 6sec. Calculate its speed.

Solution

Data given:

Distance = 480m

Time taken = 6sec

Speed =?

Speed = $\frac{\text{distance}}{\text{time}}$

Speed = $\frac{480\text{m}}{6\text{s}}$

Speed = 80m/s

ACCELERATION

Acceleration - Is the rate of change of velocity.

Thus;

Acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$

Acceleration = $\frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$

a = $\frac{v - u}{t}$

Initial velocity - is the starting velocity.

Final velocity - is the finishing velocity.

The SI unit of acceleration is **m/s^2 (meter per Second Square).**

RETARDATION

Retardation - is the negative acceleration

Example 1

1. A car with a velocity of 90km/h under uniform retardation and brought to rest after 10s. Calculate its acceleration

Solution

Data given

Initial velocity = 90km/h

Final velocity = 0m/s

Time taken = 10s

Acceleration =?

To change the initial velocity to m/s

$$\frac{90 \times 1000}{60 \times 60} = \frac{900}{36}$$

= 25m/s

Acceleration = $\frac{v-u}{t}$

= $\frac{0-25}{10}$

a = $^{-}2.5m/s^2$

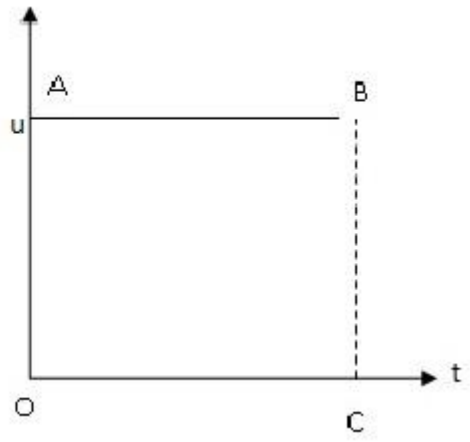
VELOCITY TIME GRAPH

If a body moves with a uniform or constant velocity then for any given time, the velocity remains the same. The graph of velocity against time is a straight line parallel to the time axis.

Suppose a body is moving with uniform velocity is for **time (t)** then from the relation.

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

Distance = Velocity x Time

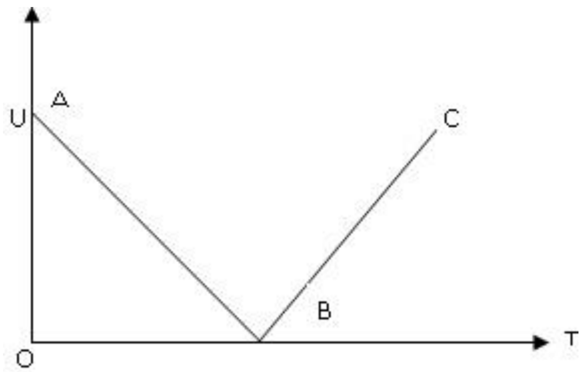


VELOCITY TIME GRAPH FOR UNIFORM MOTION

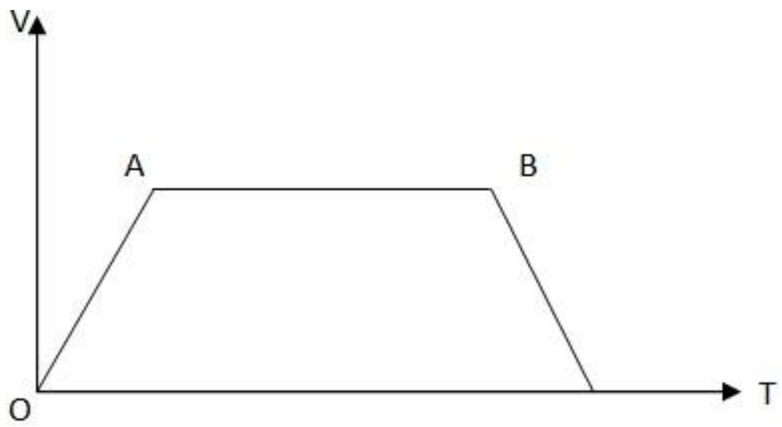
•Area under the graph AB is the area of the rectangle OABC which is also **ut**. Thus it follows that the area under the velocity time graph represents distance.

•For a body thrown vertically upwards, it retards by the force of gravity on its upward journey. If the body has the **initial velocity U**, its velocity becomes zero at the highest point of its motion. The body then accelerates downwards until it reaches the point of projection with velocity U.

•The graph of the velocity against time for a body thrown vertically upwards.



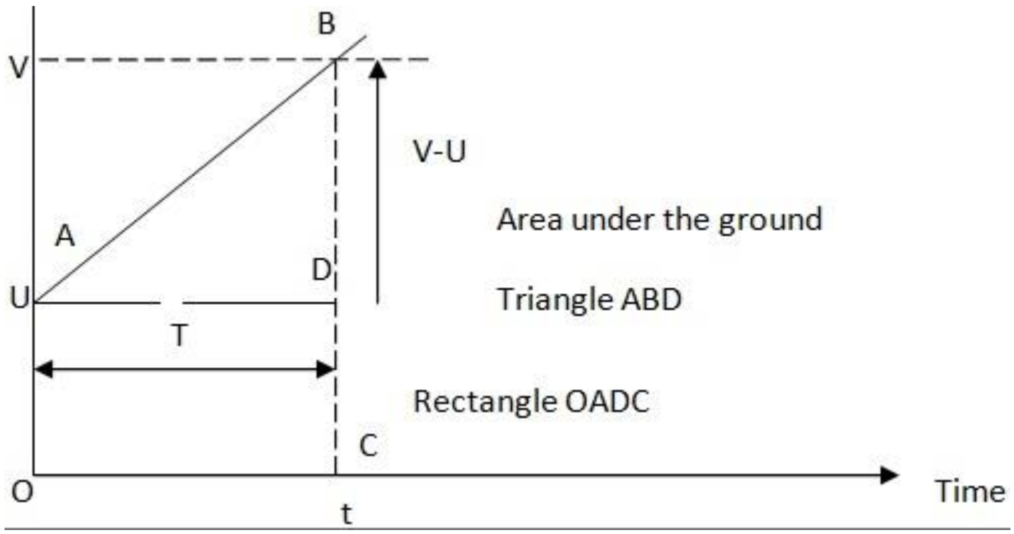
•The line AB represents upward motion and the line BC represents downward motion



•From point O to A, the body accelerates uniformly to velocity U, and it accelerates uniformly to a velocity V. The body then continues to move with this velocity up to point B.

•As the body moves from A to B its acceleration is zero. Finally decreases its velocity from V to zero, as it moves from B to C. In this case the velocity is retarded.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time taken}}$$



$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$\therefore a = \frac{v-u}{t}$$

From the figure above, the slope of the graph is given as $\frac{v-u}{t}$

EQUATIONS OF MOTION

Now it follows that;

$a = \frac{v-u}{t}$ (cross multiplication)

at = v – u

V – U = at

v = u + at ……… (i)

- • Distance traveled by a body is given by the area under the graph. The area covered by the triangle ABD and the rectangle OADC.
- Area of triangle ABD

$= \frac{1}{2}$ x base x height

$= \frac{1}{2}$ x t x (v - u)

$= \frac{1}{2}$ (v - u) t

Area of a rectangle OADC

= base x height

OADC = t x u

= ut

•Total area under the curve = area of a triangle ABD + area of rectangle OADC.

$S = \frac{1}{2}(v - u)t + ut$

$S = \frac{1}{2}(vt - ut) + ut$

$S = \frac{1}{2}vt - \frac{1}{2}ut + ut$

$S = \frac{1}{2}vt + \frac{1}{2}ut$

$S = \frac{1}{2}t(v + u)$

$S = \frac{(v+u)t}{2}$

From the first equation;

V = u + at

$S = \frac{(v+u)t}{2}$

$S = \frac{(u+at+u)t}{2}$

$S = \frac{(2u+at)t}{2}$

$S = ut + \frac{1}{2}at^2$…………….. (ii)

•The first and second equations of the motion can be combined to give the third equation of motion as follows:

V = u + at

•By squaring both sides of the equation;

$V^2 = (u + at)^2$

$V^2 = (u + at)(u + at)$

$V^2 = u^2 + 2uat + a^2t^2$

$V^2 = u^2 + 2a(ut + \frac{1}{2}at^2)$

$S = ut + \frac{1}{2}at^2$

$V^2 = u^2 + 2as$ ……………. (iii)

Therefore the three equations of motion are

1. $a = \frac{v - u}{t}$
2. $s = ut + \frac{1}{2} at^2$
3. $v^2 + 2as$

EXAMPLES

1. A body moving with a velocity of 30m/s is accelerated uniformly to a velocity of 50m/s in 5s. calculate the acceleration and the distance traveled by the body.

Data given

Initial velocity (U) = 30m/s

Final velocity (V) = 50m/s

Time (t) = 5s

Acceleration =?

Distance traveled =?

$a = \frac{v-u}{t}$

$a = \frac{50m/s - 30m/s}{5s}$

$a = \frac{20m/s}{5s}$

$a = 4m/s^2$

∴ Acceleration = $4m/s^2$

Distance traveled = ?

$S = ut + \frac{1}{2} at^2$

$S = 30m/s \times 5s + \frac{1}{2} \times 4m/s^2 \times 5 \times 5$

$= 30m \times 5 + \frac{1}{2} \times 4 \times 25$

= 150 + 50

= 200 m

∴ Distance traveled = 200m

2. Starting from rest, a car accelerates uniformly at $2.5m/s^2$ for 6s. The constant speed is maintained for one third of a minute. The brakes are then applied making the car to retard uniformly to rest in 4sec. Determine the maximum speed attained in km/h and the displacement covered In km.

Solution

Data given

Initial velocity (U) = 0m/s
Final velocity (V) = 2.5m/s
Time (t) = 6s
V = u + at

$V = 0m/s + 2.5m/s^2 \times 6s$

V = 0m/s + 15

V = 15m/s

$V = \frac{15 \times 60 \times 60}{1000}$

V = 9 X 6

V = 54km/hr

Distance (s) = ut + $\frac{1}{2}at^2$

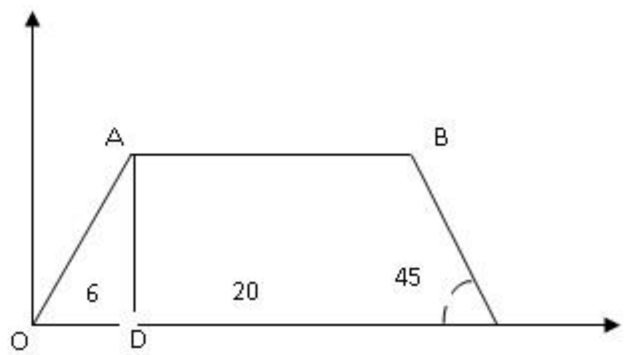
$S = 0 \times 6 + \frac{1}{2} \times 2.5 \times 36$

S = 45m

Convert into km

X = 45/1000

X = 0.045km



Distance covered from A to B

Distance = velocity x time

= 15m/s x 20s

= 300m

S_2 = 0.3 km

Distance covered from B to C

U = 15m/s

t = 4s

v = 0m/s

a =?

a = $\frac{v-u}{t}$

a = $\frac{0-15}{4}$

a = $^-3.75m/s^2$

$v^2 = u^2 + 2as$

$0^2 = 15^2 + 2 \times 3.75 \times S$

= 225 + 7.5S

$^-225 = 7.5S$

$S = \frac{225}{7.5}$

S = 30m

S_3 = 0.03km

Alternatively

Area under the graph = Distance

Area of trapezium OABC = $\frac{1}{2}$ (OC + AB) AD

= $\frac{1}{2}$ (30 + 20) x 15

= $\frac{1}{2}$ x 50 x 15

= 25 x 15

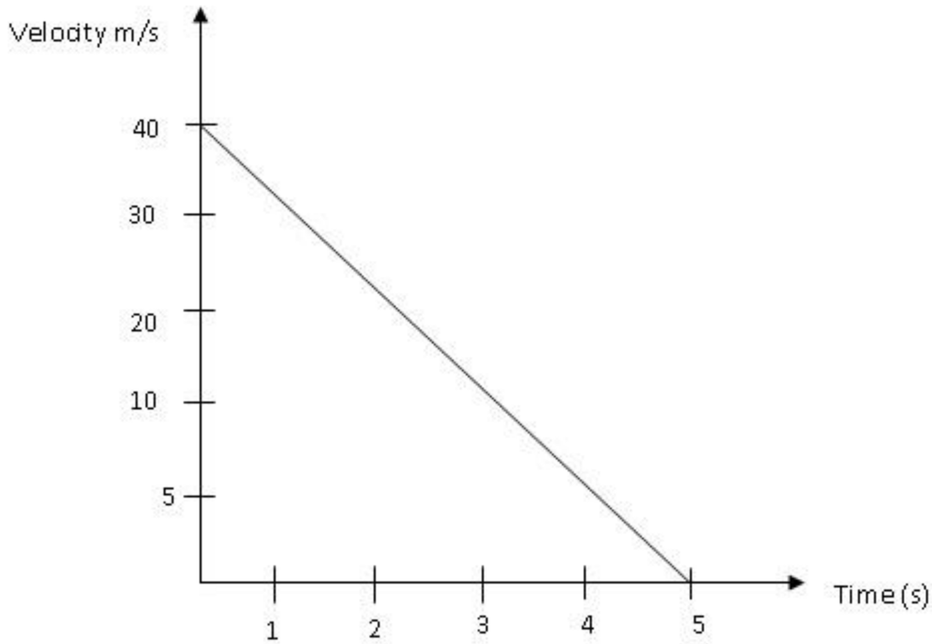
= 375m

= 0.375 km

3. A train with a velocity of 40m/s is uniformly retarded and brought to rest after 5 seconds. Determine its deceleration and draw the graph

Solution

(u) = initial velocity
(v) = final velocity
Time (t) = 5s



Deceleration = $\frac{v-u}{t}$

$= \frac{0m/s - 40m/s}{5s}$

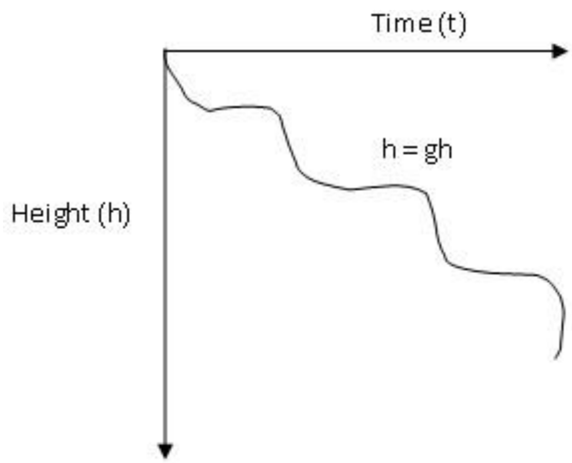
$= {}^{-}8m/s^2$

$\therefore$Deceleration = ${}^{-}8m/s^2$

MOTION UNDER GRAVITY

All bodies on the earth will always fall down towards the earth's surface when released from a point. What makes these bodies fall downwards is the acceleration due to gravity called **acceleration** of free falling body which is **9.8 or 10 N/kg.**

Acceleration of free falling body is denoted by **'g'**. Light bodies like feathers, paper etc are observed to fall down more slowly than iron balls. This is because light bodies are very much affected by air resistance.



a) **Free body falling from rest**

Acceleration a = acceleration due to gravity g i.e. that is a = g

Initial velocity (u) = 0

After time (t) velocity (v) is given as:

$V = u + at$

But $a = g$

$V = u + gt$

But $U = 0$

$V = 0 + gt$

$V = gt$

As body is falling the distance traveled downward is the height (h) is given by

$U = 0$

$S = h$

$S = ut + \frac{1}{2}at^2$

$h = 0 + \frac{1}{2}gt^2$

$h = \frac{1}{2} gt^2$

The displacement time graph will be a quadratic curve as shown in fig (a) above. Using the third equation of motion, which is $v^2 = u^2 + 2as$ with u = 0, a = g, (for a falling body)

$V^2 = u^2 + 2as$

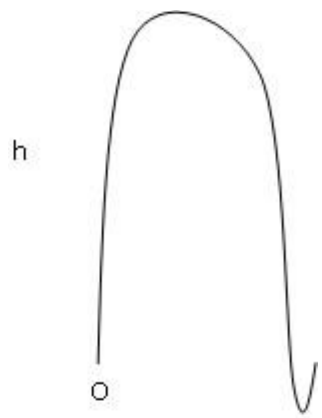
$V^2 = 0 + 2gs$

$V^2 = 2gs$

. $\sqrt{v^2} = \sqrt{2gs}$

$V = \sqrt{2gs}$

a) An object thrown vertically upward



From the figure above a ball is thrown vertically upwards, it rises to a height **'h'** on its journey upward; it has an acceleration negative due to gravity. That is $a = {}^{-}g$ (it is going against pull). If it is thrown with the initial velocity U, then velocity at time t is given by $a = {}^{-}g$

$V = u + at$

$V = u - gt$

Distance $S = ut + \frac{1}{2} at^2$

$S = h, a = {}^{-}g$

$h = ut - \frac{1}{2} gt^2$

Using the equation $v^2 = u^2 + 2as$

$a = {}^{-}g$

Examples

1. A body is released from rest at a certain height above the ground. If the body strikes the ground with a velocity of 60m/s calculate the height from which the body was released and the time taken by the body to strike the ground.

   Solution

   Data given

   Initial velocity (u) = 0m/s

   Final velocity (v) = 60m/s

   Gravity (g) = 10

   Height =?

   Time (t) =?

   $V^2 = u^2 + 2as$

   $V^2 = u^2 + 2gs$

   $V^2 – u^2 = 2gs$

   $S = \frac{V^2 - U^2}{2g}$

   $S = \frac{60^2 - 0^2}{2x10}$

   S = 180m

Tim:

$a = \frac{v - u}{t}$

t = $\frac{v-u}{a}$ = $\frac{v-u}{g}$

t = $\frac{60-0}{10}$

Time = 6sec

2. A stone is thrown vertically upwards from the ground with a velocity of 30m/s. Calculate

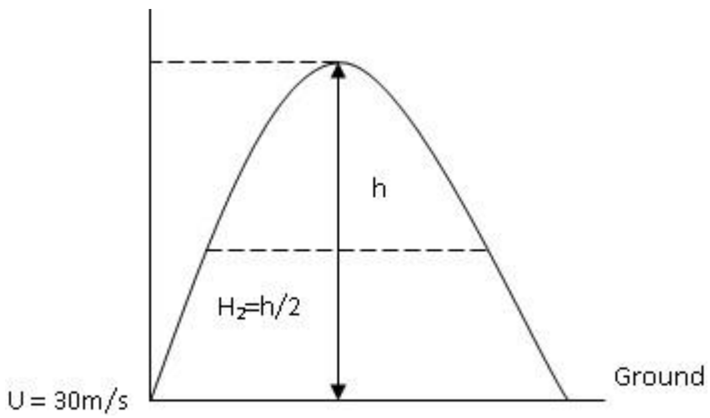
a. The max height reached

b. The time taken to reach the max height

c. The time to reach the ground after the ball is thrown up

d. The velocity reached half way to the max. height

a)



U = 30m/s

V = 0 (at turning point)

a = $^-$g = $^-$10 (upward)

$V^2 = u^2 + 2as$

$V^2 = u^2 - 2gh$

$0^2 = 30^2 - 2 \times 10 \times h$

0 = 900 – 20h

20h = 900

h = 900/20

h = 45m

b) V = u + at

V = u – gt

0 = 30 – 10t

10t = 30

t = 3sec

c) For a stone to reach the ground, it makes the journey from the max point to the ground

U = 0m/s

h =45m

$S = ut + \frac{1}{2} at^2$

$h = ut + \frac{1}{2} gt^2$

$h = 0 \times t + \frac{1}{2} gt^2$

$h = \frac{1}{2} gt^2$

$2h = gt^2$

$t^2 = 2h/g$

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 45}{10}} = \sqrt{\frac{90}{10}}$

$t = \sqrt{9}$

t= 3s

∴ Time = 3s

d) Distance to the half way to the max. height is $h_2 = \frac{h}{2}$

$h_2 = \frac{45\ m}{2} = 22.5m$

$v^2 = u^2 - 2gh$

$v^2 = 30^2 - 2 \times 10 \times 22.5$

$v^2 = 900 - 450$

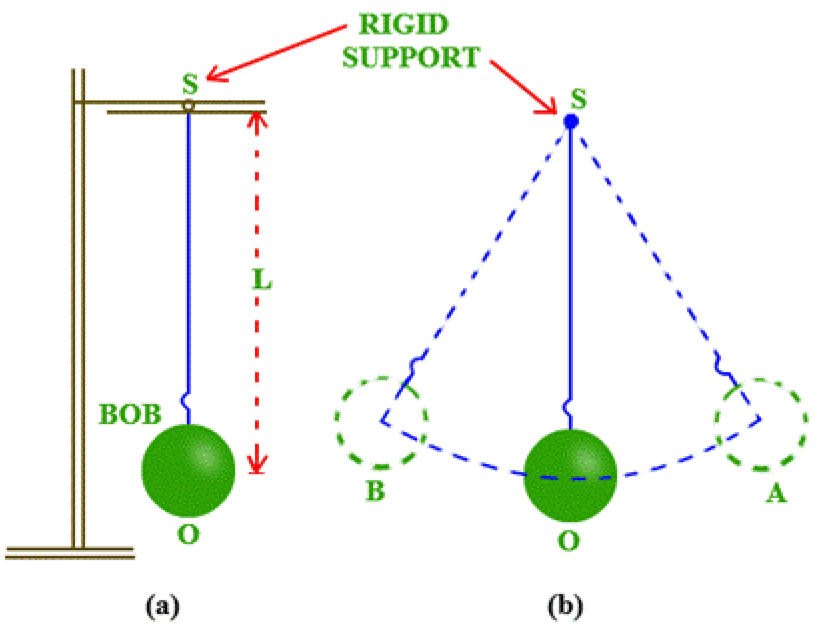
$v^2 = 450$

$v = \sqrt{450}$

$v = 21.2m/s^2$

SIMPLE PENDULUM

Simple pendulum is defined as a small heavy body suspended by a light in extensible string suspended from a fixed support. A simple pendulum is made by attaching a long thread to a spherical ball called a pendulum bob.



Simple Pendulum

(a) Bob at rest in mean position O.
(b) Bob in swinging motion between extreme positions A and B.

If the bob is slightly displaced to position **B** and then released and swings to and fro going to **C** through **O** and back to B through **O.** when the pendulum completes one cycle or revolution, the time taken is called **the period (T)** of the oscillations. The length of the string from the point of attachment to the center of gravity of the pendulum is called **the length of the pendulum** (i.e. AO)

At position **B** or **C**, where the pendulum bob attains the max. Height from **O** (the lowest or resting point) the pendulum bob said to have reached the maximum displacement called the **amplitude** and the angle made by the string and vertical axis is called **angular amplitude**.

It has been observed from the experiments that changing the weight of the bob and keeping the same length of the pendulum, the period is always constant

The period of the single pendulum is given by T = $2\pi\sqrt{\frac{l}{g}}$, where T = period of the single pendulum.

L = length of the extensible string or length of the pendulum, g = acceleration due to gravity.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

.

$T^2 = 2^2 \pi^2 \frac{l}{g}$

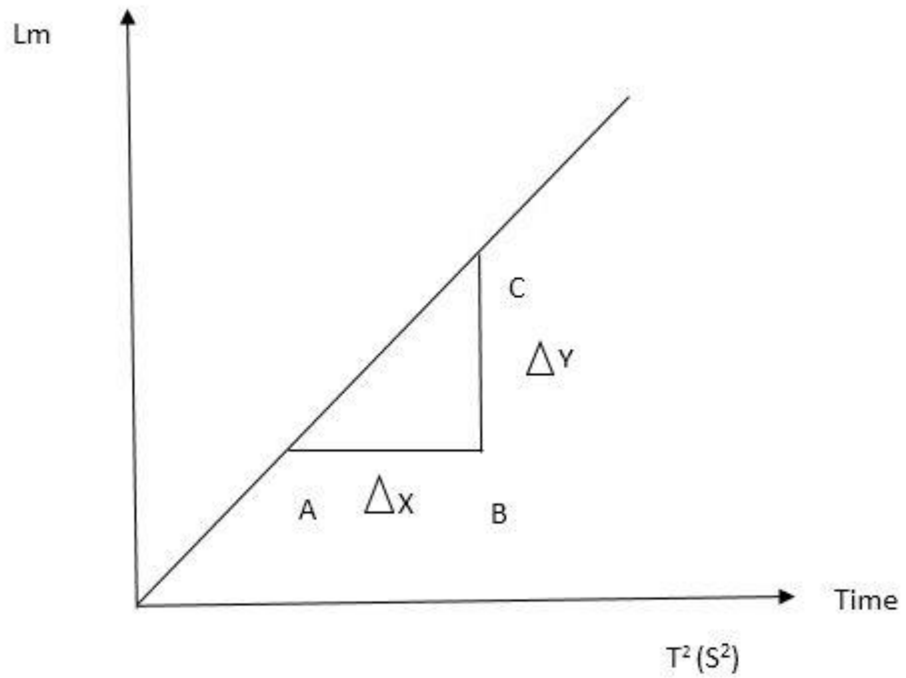
$T^2 = 4\pi^2 \frac{l}{g}$

$T^2 g = 4\pi^2 l$

Make l as a subject

$L = \frac{T^2 g}{4\pi^2}$

This is the equation of straight line with the slope.



Slope of the graph is given by $\frac{BC}{AB}$

From the relationship between l and T^2, the slope $\frac{g}{4\pi^2} = \frac{BC}{AB}$

EXERCISE

1. A plane drops a sack of maize 25kg from a height of 20m to reach the famine stricken areas of Somalia. What is the time taken for the sack to reach the ground and at what velocity.

Solution

Data given

Maize = 25kg
Height = 20m
Final velocity (v) =?
Gravity (g) = $10m/s^2$
Initial velocity (u) = 0m/s

From the third equation $V^2 = u^2 + 2gs$

$V = \sqrt{2gs}$

$V = \sqrt{2 \times 10 \times 20}$

$V = \sqrt{400}$

V = 20m/s

∴ Velocity = 20m/s

Time taken is obtained from first equation

V=u + at where a=g

V=u-gt where u=0

V=gt

20=10t

T=2 seconds

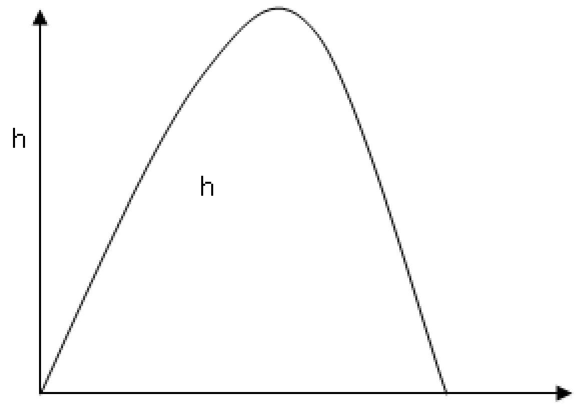
2. A man fires a bullet at ground level, vertically towards the sky. The bullet is ejected with the initial velocity of 200m/s. After how long will the bullet return to the ground? Calculate the maximum height by the bullet.

Solution

Data given

Initial velocity (u) = 200m/s

Gravity (g) = $10 m/s^2$
Final velocity (v) = 0m/s
Maximum height =?
Time (t) =?



$V^2 = u^2 + 2gs$

$V^2 – u^2 = 2gs$

Make s as a subject

$S = \frac{v^2 - u^2}{2g}$

Since s = h

$h = \frac{0^2 - 200^2}{2x10}$

$h = \frac{-40000}{2x10}$

h = $^-$2000m

∴ Height = 2000m

To find time (t)

$a = \frac{v - u}{t}$

Make t as a subject

$t = \frac{v-u}{a}$

But a = $^{-}$g

$t = \frac{v-u}{-g}$

$t = \frac{0-200}{-10}$

$t = \frac{200}{10}$

t = 20s

∴ Time = 20s

THE LAWS OF MOTION AND LINEAR MOMENTUM

INERTIA

Inertia is defined as the ability of a body at rest to resist motion or a body in motion to continue moving in a straight line when abruptly stopped.

Newton's first law of motion

It sometimes called "**the law of Inertia**"

It states that "Everybody continues its state of rest or uniform motion in a straight line if there is no external force acting on it"

Momentum

A body is said to be in motion if it changes its position with time and when it has velocity

A body with zero velocity therefore it is not in motion and hence it is at rest

The motion of a body can be measured by multiplying out its mass 'm' and its velocity 'v' the product M.V is known as the **linear momentum** of a body

Linear momentum = Mass X Velocity

= kg X m/s

= kgm/s

∴ The S.I unit of momentum is **kgm/s**

Newton's second law of motion

It states that the "rate of change of linear momentum of a body is directly proportional to the applied force and takes place in the direction of the force"

• Suppose force F acts on a body of mass 'm' for time t. This force causes the velocity of the body to change from initial velocity 'u' to find velocity 'v' in that interval t

•The change in momentum will then be Mv – Mu (kgm/s)

•The rate of change of momentum is $\frac{Mv-Mu}{t}$, by Newton's second law of motion $f \propto \frac{Mv-Mu}{t}$. Hence $f \propto m\frac{(v-u)}{t}$. But $\frac{v-u}{t}$ = a (acceleration of a body). $\mathbf{F \propto Ma}$

•If a constant of proportionality K is introduced in the above relation, then F = kMa. This equation can be used to define unit of force. If m = 1kg and a = 1m/s^2, then the unit of force is chosen in such a way that when F = 1 the constant K = 1, hence F = Ma

•If a mass of 1kg is accelerating with 1m/s^2, then a force 1N is said to be acting on the body. Therefore a force F of 1N can be defined as the force which when acting on the body of mass 1kg produces an acceleration of 1m/s^2, That is 1N = 1Kgm/s^2 then constant of proportionality K will be equal to one.

Thus;

F=Ma

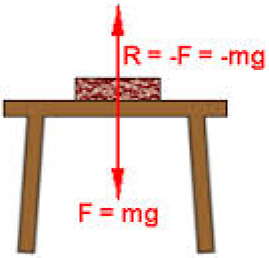
MASS AND WEIGHT

In the earth gravitational field, the acceleration due to gravity is given by the symbol 'g'.

The gravitational force therefore which act on a body of mass 'm' is equal to mg. This is what is known as the weight of the body. This force tends to pull the body towards center of the earth.

Newton's third law of motion

- It states that: "In every action there is an equal and opposite reaction"



•If a body of a mass ‘m’ is placed on a table as shown above, the body presses on the surface of the table with a force mg, the table supports the body with an upward force. The force which is the weight of the body is called the action of force while the upward force provided by the table is known as the reaction force. By Newton’s third law of motion the body does not move upwards or downwards.

Impulse of a force

•When a constant force F acts on a body of mass ‘m’, it produces an acceleration such that F = Ma. If the velocity of the body changes from U to V in time t, then;

$$a = \frac{v-u}{t}$$

From F = Ma

$$F = \frac{m(v-u)}{t}$$

$$F = \frac{mv-mu}{t}$$

Ft = Mv – Mu

The quantity Ft is called the **impulse** of a force. The S.I unit of impulse of a force is the **Newton second (Ns)**

EXAMPLES

1. Find the linear momentum of a body of mass 5kg moving with the velocity of 2m/s.

Solution

Data given

Mass = 5kg

Velocity = 2m/s

Linear momentum = mass X velocity

= 5kg X 2m/s

= 10Kgm/s

2. A football was kicked into hands of a goal keeper at 4m/s. The goal keeper stopped the ball in 2 seconds. If the mass of a ball is 0.5kg, calculate the average force exerted on the goal keeper

Solution

Data given

U = 4m/s
T = 2s
Mass = 0.5kg
V = 0m/s

F = Ma

F = $\frac{m(v-u)}{t}$

F = $\frac{0.5(0-4)}{2}$

F = $\frac{0.5(-4)}{2}$

F = $^{-}1$N

The average force exerted by the goal keeper is 1N

3. What force is required to give a mass of 0.2kg an acceleration of 0.5m/s^2?

Solution

Data given

Mass = 0.2kg
Acceleration (a) = 0.5m/s^2
From F = acceleration X mass
F = 0.2kg X 0.5m/s^2
F = 0.1N

4. What acceleration will be given to a body of mass 6kg by a force of 15N?

Solution

Data given

Mass = 6kg
Force = 15N
Acceleration (a) =?
From force = mass x acceleration

Acceleration = $\frac{\text{force}}{\text{mass}}$

Acceleration = $\frac{15\text{ N}}{6\text{ kg}}$

A = 2.5m/s^2

5. What mass will be given an acceleration of 5m/s^2 by a force 2N?

Solution
A = 5m/s^2
F = 2N
M =?
Force =mass x acceleration

Mass = $\frac{\text{force}}{\text{acceleration}}$

Mass = $\frac{2\text{N}}{5\text{m/s}^2}$

Mass = 0.4kg

CONSERVATION OF A LINEAR MOMENTUM

Consider the case of firing a gun, as the bullet leaves the gun (reaction), the one holding it feels a backward force (reaction from the butt of the gun)

According to Newton's third law of motion, these two forces are equal and opposite. Since these two forces act at the same time, the impulses (i.e. change in momentum) produced must be equal in magnitude and opposite in direction. The sum of the two momentum is equal to zero.

This implies that momentum cannot be produced some where without producing an equal and opposite momentum somewhere else. This is the law of conservation of linear momentum which states that "When two or more bodies act upon each other, their total momentum remains constant provided no external forces are acting"

Consider the collision of two balls moving in a straight line

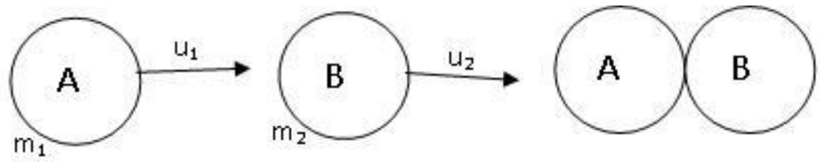


Fig: (a)

Fig: (b)

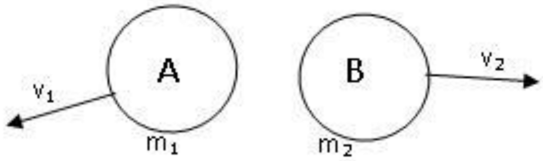


Fig: (c)

The balls have the masses M_1 and M_2 and they are approaching each other with velocity U_1 and U_2 fig (a)

The balls have the velocities V_1 and V_2 after collision fig (b)

Let F_1 and F_2 be the forces acting on M_1 and M_2 during collision.

By Newton's third law of motion the forces are equal and opposite since the two forces act during the same time t, the impulses produced are therefore equal and opposite

$\therefore F_1t = {}^-F_2t$

But $F_1t = M_1V_1 – M_1U_1$

$F_2t = M_2V_2 – M_2U_2$

From;

$F_1t = {}^-F_2t$

$M_1V_1 – M_1U_1 = -M_2V_2 + M_2U_2$

$M_1V_1 + M_2V_2 = M_1U_1 + M_2U_2$

$\mathbf{M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2}$

This shows that the total momentum before collision is equals to the total momentum after collision.

Question

1. A body of mass 8kg moving with velocity of 20m/s collides with another body of mass 4kg moving with a velocity of 10m/s in the same direction. The velocity of 8kg body is reduced to 15m/s after collision. Calculate the final velocity of the 4kg body

Solution

Data given

$M_1 = 8kg$

$U_1 = 20m/s$

$M_2 = 4kg$

$U_2 = 10m/s$

$V_1 = 15m/s$

$V_2 =?$

Apply

$M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2$

$8 \times 20 + 4 \times 10 = 8 \times 15 + 4 \times V_2$

$160 + 40 = 120 + 4V_2$

$200 = 120 + 4V_2$

$200 - 120 = 4V_2$

$80 = 4V_2$

$V_2 = 20m/s$

∴ The final velocity is 20m/s

EXERCISE

1. **Define the term momentum.**

A car of mass 500kg is moving in a straight line with a velocity of 90km/h. calculate the linear momentum of the car

Solution

Momentum - is the product of mass and velocity

Data given

Mass = 500kg

Velocity = 90km/h

Linear momentum = mass X velocity

= Kg X m/s

Velocity = 90km/h

Convert km into m

Velocity = 90m/h = $\frac{90\ m}{60 \times 60s}$

Velocity = 25m/s

Momentum = 500kg X 25m/s

∴ Momentum is 12500kgm/s

2. After striking its target a bullet of mass 50g is brought to rest in 2 seconds by a force of 300N. Calculate the velocity of a bullet before striking a target

Solution

Data given

Mass = 50g

Time = 2s

Force = 300N

Velocity =?

Convert g into kg

50g = 0.05kg

$F = \frac{mv}{t}$

$300 = \frac{0.05v}{2}$

$V = \frac{600}{0.05}$

V = 12000m/s

3. A man of mass 80kg jumps off a trolley of mass 160kg. If the initial speed of the man is 8m/s, at what initial speed will the trolley move?

Solution

Data given

Velocity = 0m/s

Mass (M_1) = 80kg

Speed (U_1) = 8m/s

Mass (M_2) = 160kg

$M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2$

80 X8 + 160 X U_2 = 80 x 0 + 160 x 0

640 + $160U_2$ = 0

$160U_2$ = 640

U_2 = 4m/s

Initial speed = 4m/s

4. What is the linear momentum of a body of mass 6kg caused to move when a constant force of 15N is acting on it for 3s? What is the acceleration developed?

Solution

Data given

Mass = 6kg

Force = 15N

Time = 3s

A =?

Acceleration = $\frac{force}{mass}$

$= \frac{15\ N}{6kg}$

$= 2.5m/s^2$

Linear momentum = mass X velocity

$a = \frac{v-u}{t}$

$2.5 = \frac{0-u}{3}$

U = 7.5

Linear momentum = 6kg x 7.5m/s

Linear momentum = 45kgm/s

NEWTON'S LAW OF MOTION

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A body with zero velocity therefore it is not in motion and hence it is at rest

The motion of a body can be measured by multiplying out its mass ‘m’ and its velocity ‘v’ the product M.V is known as the **linear momentum** of a body

Linear momentum = Mass X Velocity

= kg X m/s

= kgm/s

∴ The S.I unit of momentum is **kgm/s**

Newton’s second law of motion

It states that the “rate of change of linear momentum of a body is directly proportional to the applied force and takes place in the direction of the force”

• Suppose force F acts on a body of mass ‘m’ for time t. This force causes the velocity of the body to change from initial velocity ‘u’ to find velocity ‘v’ in that interval t

•The change in momentum will then be Mv – Mu (kgm/s)

•The rate of change of momentum is $\frac{Mv-Mu}{t}$, by Newton’s second law of motion $f \propto \frac{Mv-Mu}{t}$. Hence $f \propto m\frac{(v-u)}{t}$. But $\frac{v-u}{t}$ = a (acceleration of a body). **F** $\propto$ **Ma**

•If a constant of proportionality K is introduced in the above relation, then F = kMa. This equation can be used to define unit of force. If m = 1kg and a = 1m/s^2, then the unit of force is chosen in such a way that when F = 1 the constant K = 1, hence F = Ma

•If a mass of 1kg is accelerating with 1m/s^2, then a force 1N is said to be acting on the body. Therefore a force F of 1N can be defined as the force which when acting on the body of mass 1kg produces an acceleration of 1m/s^2, That is 1N = 1Kgm/s^2 then constant of proportionality K will be equal to one.

Thus;

F=Ma

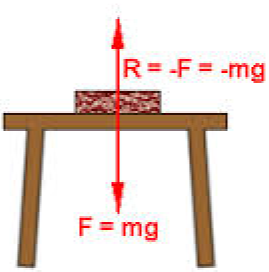
MASS AND WEIGHT

In the earth gravitational field, the acceleration due to gravity is given by the symbol 'g'.

The gravitational force therefore which act on a body of mass ‘m’ is equal to mg. This is what is known as the weight of the body. This force tends to pull the body towards center of the earth.

Newton’s third law of motion

- It states that: “In every action there is an equal and opposite reaction”



•If a body of a mass ‘m’ is placed on a table as shown above, the body presses on the surface of the table with a force mg, the table supports the body with an upward force. The force which is the weight of the body is called the action of force while the upward force provided by the table is known as the reaction force. By Newton’s third law of motion the body does not move upwards or downwards.

Impulse of a force

•When a constant force F acts on a body of mass ‘m’, it produces an acceleration such that F = Ma. If the velocity of the body changes from U to V in time t, then;

$$a = \frac{v-u}{t}$$

From F = Ma

$$F = \frac{m(v-u)}{t}$$

$$F = \frac{mv-mu}{t}$$

Ft = Mv – Mu

The quantity Ft is called the **impulse** of a force. The S.I unit of impulse of a force is the **Newton second (Ns)**

EXAMPLES

1. Find the linear momentum of a body of mass 5kg moving with the velocity of 2m/s.

Solution

Data given

Mass = 5kg

Velocity = 2m/s

Linear momentum = mass X velocity

= 5kg X 2m/s

= 10Kgm/s

2. A football was kicked into hands of a goal keeper at 4m/s. The goal keeper stopped the ball in 2 seconds. If the mass of a ball is 0.5kg, calculate the average force exerted on the goal keeper

Solution

Data given

U = 4m/s
T = 2s
Mass = 0.5kg
V = 0m/s

F = Ma

F = $\frac{m(v-u)}{t}$

F = $\frac{0.5(0-4)}{2}$

F = $\frac{0.5(-4)}{2}$

F = $^{-}$1N

The average force exerted by the goal keeper is 1N

3. What force is required to give a mass of 0.2kg an acceleration of 0.5m/s^2?

Solution

Data given

Mass = 0.2kg
Acceleration (a) = 0.5m/s^2
From F = acceleration X mass
F = 0.2kg X 0.5m/s^2
F = 0.1N

4. What acceleration will be given to a body of mass 6kg by a force of 15N?

Solution

Data given

Mass = 6kg
Force = 15N
Acceleration (a) =?
From force = mass x acceleration

Acceleration = $\frac{\text{force}}{\text{mass}}$

Acceleration = $\frac{15\ \text{N}}{6\ \text{kg}}$

A = 2.5m/s^2

5. What mass will be given an acceleration of 5m/s^2 by a force 2N?

Solution
A = 5m/s^2
F = 2N
M =?
Force =mass x acceleration

Mass = $\frac{\text{force}}{\text{acceleration}}$

Mass = $\frac{2\text{N}}{5\text{m}/\text{s}^2}$

Mass = 0.4kg

CONSERVATION OF A LINEAR MOMENTUM

Consider the case of firing a gun, as the bullet leaves the gun (reaction), the one holding it feels a backward force (reaction from the butt of the gun)

According to Newton's third law of motion, these two forces are equal and opposite. Since these two forces act at the same time, the impulses (i.e. change in momentum) produced must be equal in magnitude and opposite in direction. The sum of the two momentum is equal to zero.

This implies that momentum cannot be produced some where without producing an equal and opposite momentum somewhere else. This is the law of conservation of linear momentum which states that "When two or more bodies act upon each other, their total momentum remains constant provided no external forces are acting"

Consider the collision of two balls moving in a straight line

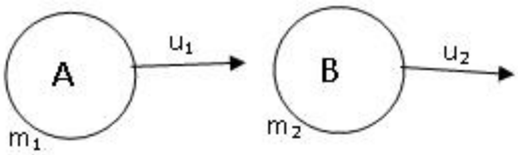


Fig: (a)

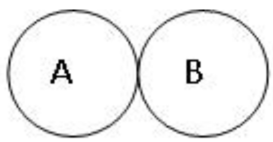


Fig: (b)

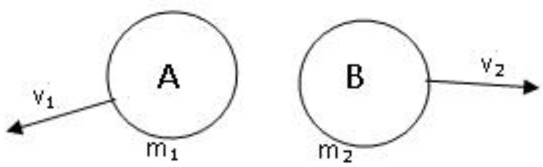


Fig: (c)

The balls have the masses M_1 and M_2 and they are approaching each other with velocity U_1 and U_2 fig (a)

The balls have the velocities V_1 and V_2 after collision fig (b)

Let F_1 and F_2 be the forces acting on M_1 and M_2 during collision.

By Newton's third law of motion the forces are equal and opposite since the two forces act during the same time t, the impulses produced are therefore equal and opposite

$\therefore F_1t = -F_2t$

But $F_1t = M_1V_1 - M_1U_1$

$F_2t = M_2V_2 - M_2U_2$

From;

$F_1t = {}^-F_2t$

$M_1V_1 – M_1U_1 = -M_2V_2 + M_2U_2$

$M_1V_1 + M_2V_2 = M_1U_1 + M_2U_2$

$\mathbf{M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2}$

This shows that the total momentum before collision is equals to the total momentum after collision.

Question

1. A body of mass 8kg moving with velocity of 20m/s collides with another body of mass 4kg moving with a velocity of 10m/s in the same direction. The velocity of 8kg body is reduced to 15m/s after collision. Calculate the final velocity of the 4kg body

   Solution

   Data given

   $M_1 = 8kg$

   $U_1 = 20m/s$

   $M_2 = 4kg$

   $U_2 = 10m/s$

   $V_1 = 15m/s$

   $V_2 =?$

Apply

$M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2$

$8 x20 + 4 x 10 = 8 x 15 + 4 x V_2$

$160 + 40 = 120 + 4V_2$

$200 = 120 + 4V_2$

$200 – 120 = 4V_2$

$80 = 4V_2$

V_2 = 20m/s

∴ The final velocity is 20m/s

EXERCISE

1. **Define the term momentum.**

A car of mass 500kg is moving in a straight line with a velocity of 90km/h. calculate the linear momentum of the car

Solution

Momentum - is the product of mass and velocity

Data given

Mass = 500kg

Velocity = 90km/h

Linear momentum = mass X velocity

= Kg X m/s

Velocity = 90km/h

Convert km into m

Velocity = 90m/h = $\frac{90\ m}{60 \times 60s}$

Velocity = 25m/s

Momentum = 500kg X 25m/s

∴ Momentum is 12500kgm/s

2. After striking its target a bullet of mass 50g is brought to rest in 2 seconds by a force of 300N. Calculate the velocity of a bullet before striking a target

Solution

Data given

Mass = 50g

Time = 2s

Force = 300N

Velocity =?

Convert g into kg

50g = 0.05kg

F = $\frac{mv}{t}$

300 = $\frac{0.05v}{2}$

V = $\frac{600}{0.05}$

V = 12000m/s

3. A man of mass 80kg jumps off a trolley of mass 160kg. If the initial speed of the man is 8m/s, at what initial speed will the trolley move?

Solution

Data given

Velocity = 0m/s

Mass (M_1) = 80kg

Speed (U_1) = 8m/s

Mass (M_2) = 160kg

$M_1U_1 + M_2U_2 = M_1V_1 + M_2V_2$

80 X8 + 160 X U_2 = 80 x 0 + 160 x 0

640 + 160U_2 = 0

160U_2 = 640

U_2 = 4m/s

Initial speed = 4m/s

4. What is the linear momentum of a body of mass 6kg caused to move when a constant force of 15N is acting on it for 3s? What is the acceleration developed?

Solution

Data given

Mass = 6kg

Force = 15N

Time = 3s

A =?

Acceleration = $\frac{\text{force}}{\text{mass}}$

= $\frac{15\ \text{N}}{6\text{kg}}$

= 2.5m/s^2

Linear momentum = mass X velocity

$a = \frac{v-u}{t}$

2.5 = $\frac{0-u}{3}$

U = 7.5

Linear momentum = 6kg x 7.5m/s

Linear momentum = 45kgm/s

TEMPERATURE

TEMPERATURE

Temperature is a property of a body which decides which way heat will flow when it is placed in contact with another body i.e. **Temperature** is the degree of hotness or coldness.

Temperature must not be confused with heat itself. **Heat** is a transfer of energy due to temperature energy. The S.I unit of temperature is **Kelvin** known as the **"absolute"** or "**thermodynamic scale**" on this scale temperature is measured on **Kelvin**. Its symbol is **K**

Commonly thermometers encounter the unit "**Celsius degree**" with symbol **^{0}C**. Another scale is called "**Fahrenheit scale**"

MEASUREMENT OF TEMPERATURE

A reliable measurement of temperature is done by using **thermometer**.

Thermometers use measurable physical properties that change linearly with temperature to give temperature readings

Physical properties that change with temperature are called "**thermometric properties of a thermometer**" which include;

i) •Expansion of liquid when heated (e.g. alcohol and mercury).

ii) •Expansion of compound strip of two metals.

iii) •Thermometric property change in which when junction of two different metals is heated an electric current is generate.

iv) •Change of resistance of a wire e.g. platinum , resistance thermometer.
•We can investigate some of thermometric properties by studying expansion of mercury in an evacuated tube in the experiment shown below.

EXPERIMENT

To investigate thermometric properties of mercury.

APPARATUS

Water, heater and mercury evacuated narrow tub.

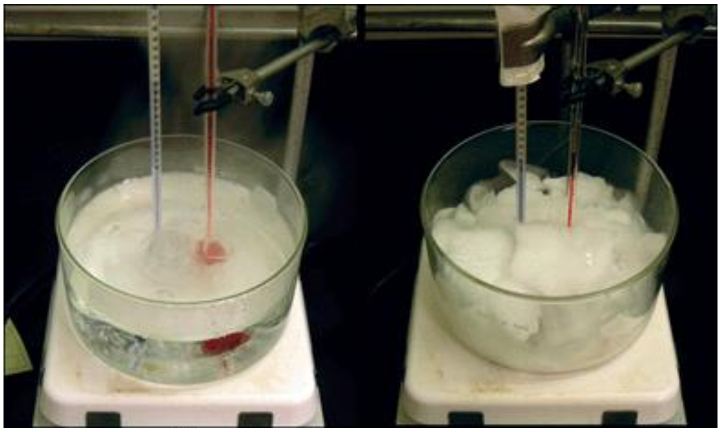
PROCEDURES

1. Put crushed ice in a filter funnel and insert the ice shown below.

2. Put the beaker underneath the funnel to collect the water.

3. Wait until the mercury in the thermometer stops falling.

4. Mark the position of mercury meniscus.



OBSERVATIONS

The marked position of the meniscus is the upper fixed point of the thermometer, in Celsius scale, the upper fixed point is **100^0C** or **373K**.

FUNDAMENTAL INTERVAL OF TEMPERATURE

When you want to construct a thermometer, you must establish two constant temperatures called "**fixed points**".

The two temperatures are called **upper fixed points** and **lower fixed points**. The fundamental interval of thermometer is the difference between the upper fixed point and the lower fixed point of the thermometer.

The upper fixed point is the temperature of pure steam from water boiling at standard pressure of **760mmHg**. Carefully here we use "**pure steam**" and not boiling water because boiling water has inclusion of impurities and local overheating of the vessel which may alter the boiling point. The lower fixed point is the temperature of pure melting ice.

Note: Impurities lower the melting point of the ice.

Observation

The marked position of the meniscus is the upper fixed point of the thermometer. In Celsius temperature scale, the upper fixed point is 100^0C or 373K.

LIQUID IN GLASS THERMOMETER

The working of this thermometer is based on the fact that liquid expands when heated and contracts when cooled e.g. mercury and alcohol thermometers. These two thermometers are called;

1 1. Mercury – in - glass thermometer

2 2. Alcohol - in – glass thermometer

These thermometers have bulbs which are reservoirs of liquids and stems with fine bores through which liquid rises and falls during the variation of temperature.

The liquids used in the thermometers are called **thermometric liquids**.

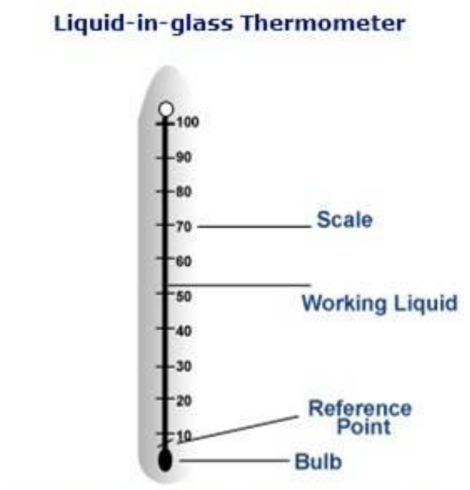
COMPARISON OF TWO THERMOMETRIC LIQUIDS

NO	Mercury	Alcohol
1	It is a good conductor of heat	It is fairly good conductor
2	It expands linearly	It expands rapidly (not linearly)
3	It is clearly seen	It is colorless
4	It boils at 360^0C	It boils at 78^0C
5	It freezes at -39^0C	It freezes at -112^0C
6	Does not wet the glass	It wet the glass

MODE OF ACTION OF LIQUID – IN – GLASS THERMOMETER

The working of this thermometer is based on the expansion of the liquid in bulb. When the bulb touches a hot body the liquid contained warms up and expand there by rising through the bore and into the stem proportionally to the amount of temperature felt. When the bore touches something cold the liquid in the stem contracts proportionally to the amount of temperature felt and it falls into the bulb.

By this rise and fall of the liquid level in the steam the different temperature reading can be obtained. The figure below shows mercury – in – glass thermometer that can be found in the Hospitals, Laboratories, and even Homes.



SUSTAINABLE ENERGY SOURCES

SUSTAINABLE ENERGY SOURCES

Sustainable energy sources are the natural resources that are used in production of electricity without polluting the environment.

Examples of these resources are;-

The sun, water, wind, sea waves and geothermal fields. These sources occur naturally and are readily available.

When we use oil and natural gas as the sources of energy there are lot of disadvantages. They pollute the environment and their supply is limited.

1. **Water energy**

Hydroelectric power is the production of electricity by using water energy. In Tanzania we use water from Kidatu and Mtera hydroelectric power plants.

Production of electricity by using water

A dam is built to trap water. Water is allowed to flow using tunnels in the dam.

In the tunnels they cause turbines to generator and generator produce electricity.

2. **Solar energy**

Is the energy from the sun. It is considered renewable energy because sunlight is unlimited, it is estimated that, the sun will shine for at least another five billions of years

We can convert sunlight to electricity by using special devices called solar cells.

Solar cells

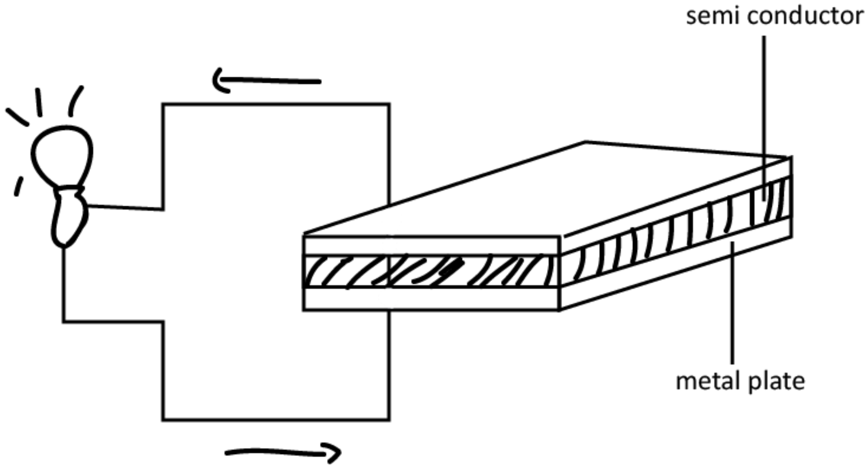
Solar cells are devices that use sunlight to produce electricity; The central part of solar cells is made of two thin layers of substances called semiconductors. A semiconductor is an element that conduct better than non-metal though not as well as a metal.

These layers are placed between metal contacts that connect the solar cells with an electricity circuit.

Glass or any transparent materials are used to cover the solar cells.

When sunlight strikes the solar cell, some electron gains enough energy to break free from atoms in the semiconductor. This electron flow creates an electric current through the electric circuit.

A Solar cell



Wind energy

When the sun heats the atmosphere some area which are close to the sun become warmer than the other. The warmer air rise and cold air moves to replace them. That is the formation of wind.

Wind mill

Wind mill is a device which is used to convert wind energy into electric energy.

Wind mill is a tall structure with a larger propeller on top.

When the wind blows it rotates the propeller which causes the attached generators to produce electricity. For more electricity to produce more propellers are needed. The best places for construction of wind mill are the coastal area and the top of rounded hills.

Sea waves

This is the production of electricity by using sea waves, water pushed by the sea waves cause turbines to turn as the result turbines turn the generator. The production of electricity by this method is similar to the production of electricity by HEP (Hydro electric power).

Geothermal energy

Geothermal energy is the energy generated by the flow of heat from the surface of the earth it is associated with area of frequent earthquakes and high volcanic activities

The heat from the inside of the earth is used to heat water into steam. The steam is used to turn turbines and as the result this cause turbines to turn generator and produce electricity.
