MAGNETISM:

A magnet is a piece of material that attracts other materials when brought near it. The force exerted by a magnetic field is called magnetism (magnetic force).

Testing for a magnet:

Bring a known pole of a known magnet close to one end of the material. If the pole is repels the end of the material, then the material is a magnet but if the pole attracts the end of the material, then the material could be a magnet or just a piece of magnetic material (iron). However if attraction occurs, test the end again using the opposite pole of the magnet to the one you have been using and if attraction occurs again then it is just a magnetic material but not a magnet.

Properties of a magnet:

- It has two poles (North Pole and South Pole).
- Unlike poles of magnet attract each other while like poles repel each other.
- The magnetic effect of a magnet is greatest at the poles of the magnet.
- When a magnet is suspended, it rests in the north-south direction.

Magnetic materials:

These are materials that can be attracted or repelled by a magnet. There are two types of magnetic materials that is soft magnetic material and hard magnetic material.

Soft magnetic material: This is a magnetic material that is easily magnetized and does not retain its magnetism for a long time. Examples of soft magnetic materials are soft iron, stalloy and mumental. Soft magnetic materials are used in transformers, electric motors, electric bell, loudspeakers, microphone e.t.c

Hard magnetic material: This is a magnetic material that takes long to be magnetized and retains its magnetism for a long time. Examples of hard magnetic materials are steel, nickel, cobalt and alloy of aluminium. Hard magnetic materials are used in moving coil galvanometer, generators, engine plugs e.t.c

There are different magnetic materials and these include the following;

i) **Ferro magnetic materials:** These are magnetic materials that are strongly attracted by a magnet. Ferro magnetic materials are capable of being made into a permanent magnet because they retain magnetic properties when the external field is removed. Examples include Cobalt, Iron, Steel and Nickel.

ii) Non-Ferro magnetic materials: These are magnetic materials that are not attracted by a magnet at all. Non-Ferro magnetic materials cannot be made into a magnet. Examples include Rubber, Plastic, Leather, Mica, Feather, Wood and Paper.

iii) Paramagnetic materials: These are materials that are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed. Paramagnetic properties are due to the presence of some unpaired electrons, and from the realignment of the electron paths caused by the external magnetic field. Examples include Magnesium and Lithium.

iv) Diamagnetic materials: These are magnetic materials that are slightly repelled by a magnetic field. A diamagnetic material does not retain the magnetic properties when the external field is removed. Examples Copper, Silver, Stainless steel, Gold and Brass.

LAW OF MAGNETS:

The law of magnetism states that like poles repel each other while unlike poles attract each other.

Poles of a magnet:

A pole of a magnet is an area on a magnet where the magnetic force is strongest. A magnet has two poles that is the North Pole and the South Pole. Poles of a magnet are found at the ends of a magnet and they occur in pairs of equal strength. When a magnet is dipped in iron fillings, the iron fillings are seen to concentrate at the ends of a magnet which shows that the magnetic attraction is strongest at the ends of the magnet.

Testing for the polarity of a magnet:

- When a magnet is freely suspended it always comes to rest in the North-South direction. The pole that points towards the northern hemisphere (geographical north) of the earth is the north pole of the magnet and the pole that points towards the southern hemisphere (geographical south) of the earth is the south pole of the magnet because the south pole of the earth is in northern hemisphere and the north pole of the earth is in the southern hemisphere.
- A known pole of a magnet is brought near the end of a freely suspended magnet of unknown poles and if repulsion occurs then that end of a magnet is a like pole. If attraction occurs that end is unlike pole or just a piece of magnetic material. The poles of a given magnet therefore can only be tested by repulsion since attraction can either result from unlike poles or a magnetic substance as shown in table below.

	North Pole	**South Pole**	**Magnetic substance**
North Pole	Repulsion	Attraction	Attraction
South Pole	Attraction	Repulsion	Attraction
Magnetic substance	Attraction	Attraction	No effect

MAGNETIC FIELDS:

Magnetic field is an area or a region around a magnet where the magnetic effect is felt. The magnetic field is represented by the magnetic field lines or lines of force which start from the North Pole and end up in the South Pole. Magnetic field line is the path a magnetic pole would follow if it is placed in a magnetic field and the number of field lines is called Magnetic flux. The direction of the field lines at any point is the direction of the magnetic field at that point.

Properties of magnetic field lines:

- They behave as if in tension
- They can pass through non-magnetic substances.
- They do not intersect or cross or touch each other.
- They repel each other side ways
- They begin from North Pole and end on South Pole.
- They are close for strong field and far apart for weak fields.

Magnetic field pattern using iron fillings method:

A bar magnet is placed on a table and then covered with a smooth stiff paper. Iron fillings are then uniformly sprinkled on the paper and tap the paper gently. The iron fillings become magnetized by induction and arrange themselves in curved lines which are magnetic lines of force.

Advantages of using iron fillings method.

- It is quick and all field lines are determined at once
- It can be used for rapidly changing magnetic field.

Disadvantages of using iron fillings method.

- The direction of the magnetic field is not indicated.
- It cannot be used for a weak magnetic field.

Magnetic field pattern using plotting compass method

A bar magnet is placed on a sheet of paper fixed on a soft board. Its outline is marked and its poles indicated on the paper. A plotting compass is then brought near North Pole of the magnet. The direction pointed by the north pole of the plotting compass is marked with pencil dots. The compass is moved until its south pole coincides with the dot marked. The procedure is repeated so that a series of dots is obtained. Join the dots by a smooth curve which represents a magnetic field lines

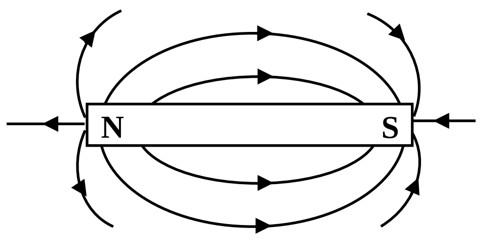
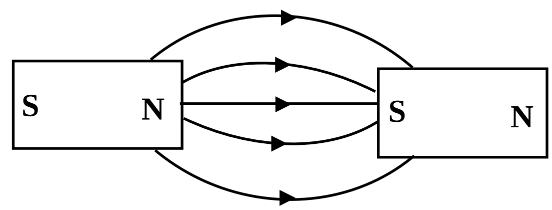
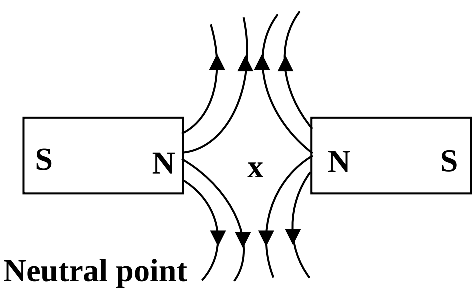
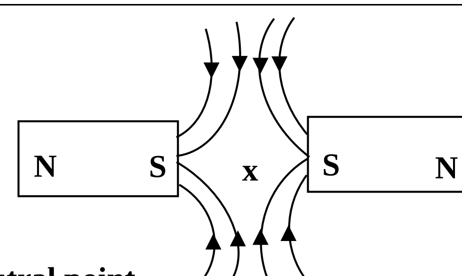
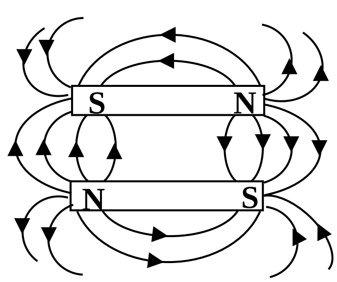
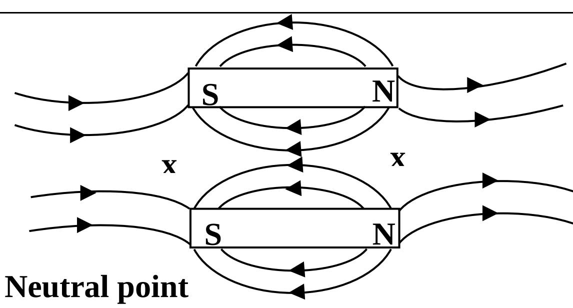
Advantages of using plotting compass method

- The direction of the magnetic field is indicated
- It can be used for a weak magnetic field.

Disadvantages of using plotting compass method

- It is slow and you obtain part of the magnetic field line at a time
- It cannot be used for rapidly changing magnetic field.

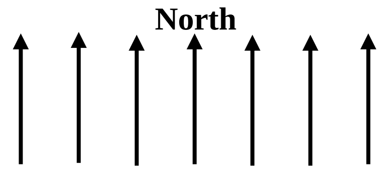
Representing magnetic fields:

Isolated bar magnet	Two unlike poles near each other
	
Two like poles near each other	
Two like poles near each other	South – South Pole
 **X – Neutral point**	 **X – Neutral point**
Two bar magnets lying side by side	
South – North & North – South	North – North & South – South
	 **X – Neutral point**

Neutral point: This is a point in a magnetic field where the resultant magnetic force is zero. There are no magnetic field lines at the neutral point.

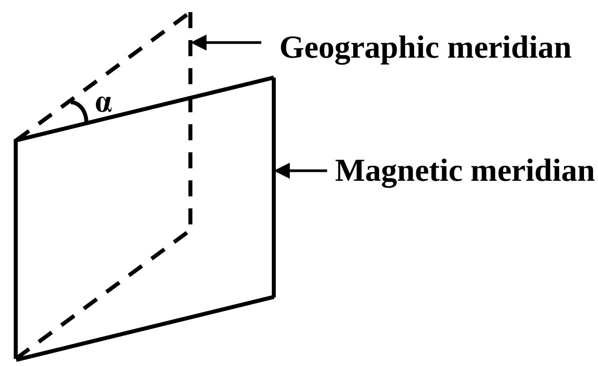
EARTH'S MAGNETIC FIELD:

The earth behaves as though it contains a bar magnet inclined at an angle to its axis of rotation and its field lines are parallel lines pointing towards the north.



The magnetic north pole of the earth is near the geographical south while the magnetic south pole of the earth is near the geographical north. Therefore the magnetic field lines of the earth run from the geographic south (North Pole) to geographical north (South Pole).

Terms used in the earth's magnetic field:

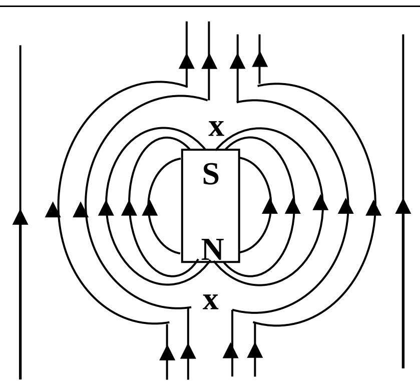
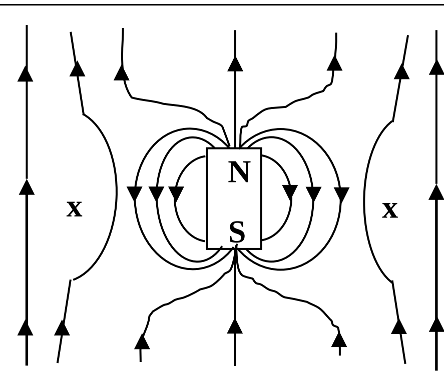


- **Geographic meridian:** This is the vertical plane which passes through the earth's geographic poles
- **Magnetic meridian**: This is the vertical plane in which a freely suspended magnetic needle sets itself.
- **Angle of declination, α:** This is the angle between the geographic meridian and the magnetic meridian.
- **Angle of dip (inclination):** This is the angle between horizontal and the magnetic axis of a magnet free to swing in the magnetic meridian about the horizontal axis.

NOTE: The angle of dip increases from 0^o at the equator to 90^o at the poles and the earth's magnetic field has two components that is the horizontal component and the vertical component.

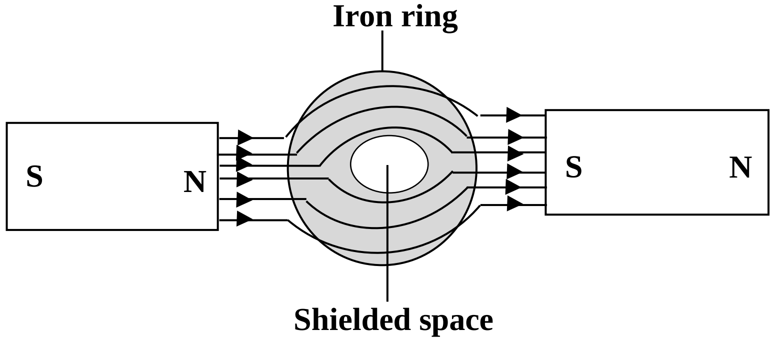
Effect of magnetic field of a bar magnet on the earth's magnetic field:

When a bar magnet is placed horizontally on the earth's surface, the field around the magnet will be a combination of the two fields that is earth's field and magnet's field and the resulting pattern will depend on the direction of the bar magnet as shown in the table below;

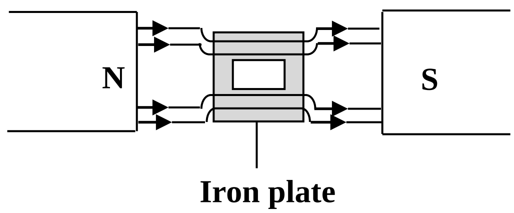
North pole pointing south of the earth's field	North pole pointing north of the earth's field
 **X – Neutral point**	 **X – Neutral point**

MAGNETIC SHIELDING (SCREENING):

Magnetic shielding is a process where magnetic field lines are prevented from reaching certain areas. This is done by enclosing the space with soft iron which is more permeable to magnetic fields than air. This implies that all magnetic field lines from outside will pass through the iron ring leaving enclosed space free from magnetic fields. The iron ring therefore concentrates the magnetic lines of force and causes the lines of force to pass through its walls and no magnetic flux passes the shielded space.

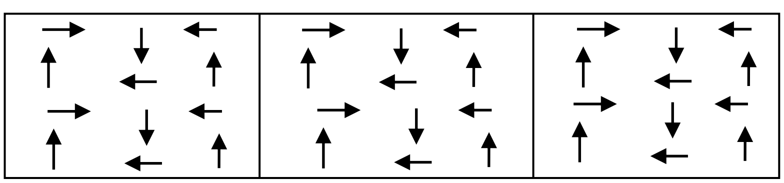


If the iron plate with a space in the middle is placed between two magnets, iron concentrates magnetic field lines within itself since it is more permeable than the space around it.

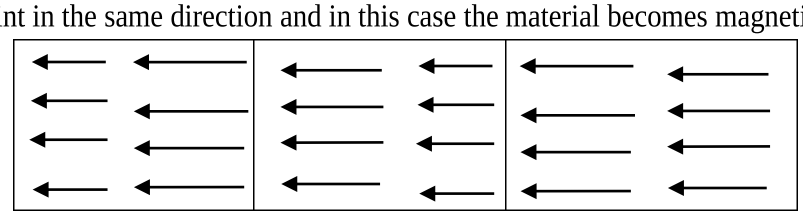


DOMAIN THEORY OF MAGNETISM:

The domain theory of magnetism states that all magnetic substances are composed of tinny magnets each with a north pole and a south pole which are in regions called domains. Each domain has millions of tinny magnets called dipoles that are lined up to point in a particular direction. The tinny magnets do not act individually but act in a group to form a domain. The tinny magnets point in different directions in an un-magnetized magnetic material where the north pole of one is neutralized by the south pole of the other.



When an un-magnetized steel bar is placed in weak magnetic field, the dipoles in some of the domains turn to point in the direction of the field. When the magnetic field is strong enough all the dipoles in all the domains point in the same direction and in this case the material becomes magnetized.



The material is then said to be magnetically saturated and no further magnetization can take place. The point where a magnetic material cannot be magnetized any further is therefore called magnetic saturation. Magnetic saturation is reached when all domains are aligned to face the same direction.

NOTE:

A magnet cannot attract a hot nail because the dipoles of a hot nail are vibrating randomly due to the heat and cannot be aligned by the magnetic field of a magnet hence no attraction. This is so because before a magnet attracts a magnetic material, it first magnetizes it by induction so that the dipoles are aligned in one direction and unlike poles are next to each other hence attraction.

MAGNETIZATION:

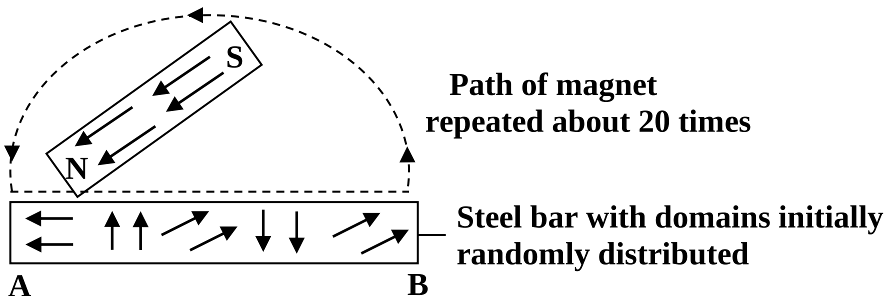
This is a process by which randomly arranged molecular magnets of a ferromagnetic substance are arranged to point in one direction. Magnetization is therefore a process of making a magnet from a ferromagnetic substance. Magnetization occurs when an external field is applied and the dipoles are made to face in one direction. The methods used in magnetization are electrical method and stroking method.

a) Stroking Method

Stroking method is divided into two methods that is single touch method and double touch method.

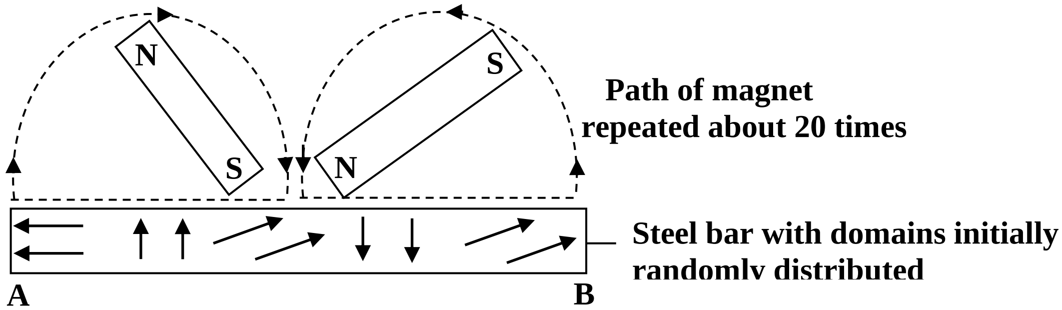
i) Single Touch Method:

The steel bar AB is stroked from end A to end B about 20 times in one direction using only the north pole of a permanent magnet. The pole is lifted at the end B before repeating the stroking so as not to remove any induced magnetism as magnetizing goes on. End B will become a South Pole whereas end A will become a north pole. The permanent magnet hardly loses any of its magnetism while lining up the domains of the steel bar AB.



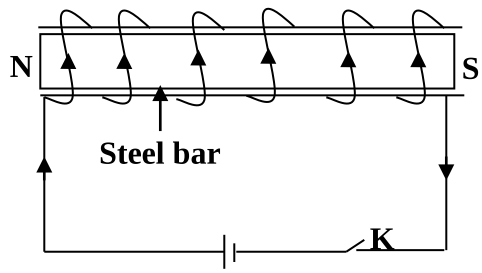
ii) Double Touch Method:

The steel bar AB is stroked from the middle about 20 times in opposite directions using the north pole and south pole of two permanent magnets. The poles are then lifted at the end A and B respectively before repeating the stroking so as not to remove any induced magnetism as magnetizing goes on. End A will become a north pole whereas end B will become a south pole. The permanent magnet hardly loses its magnetism while lining up the domains of the steel bar AB.



b) Electrical method:

Place a steel bar inside a solenoid and connect the solenoid to a d.c source as shown below;



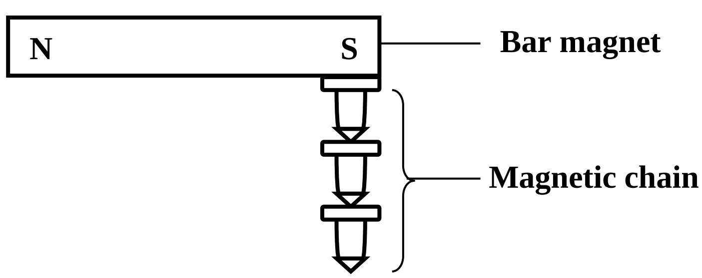
Close switch K for a short time. Remove the steel bar and test it for polarity by using a known pole of a bar magnet. Repulsion shows like poles. Similarly polarity is deduced by viewing the solenoid from one end. If the current flows in clockwise direction that end is the South Pole and if it flows in anticlockwise direction, that end is the North Pole.

Factors that affect the strength of a magnet produced:

- Increasing the amount of current flowing in a solenoid increases the strength of a magnet
- Increasing the number of turns on a solenoid increases the strength of a magnet

Magnetic induction (Induced magnetism):

Magnetic induction is a phenomenon where magnetic material behaves as a magnet when placed near a magnet. A piece of un-magnetized magnetic material in contact or near the pole of a permanent magnet will attract pieces of iron because the material has been magnetized by induction. This is sometimes referred to as induced magnetism. Induced magnetism cannot be used to make a magnet but can be used to form a magnetic chain because the magnetic property exists only as long as the material is near or in contact with the magnet but one the magnet is removed it is just a magnetic material.



The iron nail attached to the magnet becomes magnetised. Each nail added to the chain magnetises the next one by induction. In each case, the induction of magnetism in the nails takes place first and then the attraction occurs between their adjacent unlike poles.

DEMAGNETIZATION:

Demagnetization is a process by which a magnet losses its magnetism. During demagnetization the dipoles vibrate and become disorganized (lose alignment) that is the order of tinny magnets (dipoles) is destroyed.

Methods of demagnetization:

- **Heating:** Heating a piece of magnet in an open flame destroys the alignment of the domains and thereby aligning them randomly causing a magnet to lose its magnetism.
- **Using alternating current:** Using an alternating current produces a magnetic field which drags the magnetic dipoles of the magnet in different directions and this makes a magnet to lose its magnetism.

➢ **Hammering/Dropping/Throwing/Clamping:** When a magnet is hammered/dropped/thrown several times the vibrations of dipoles caused by the impact on a magnet destroys the alignment of the dipoles and thereby aligning them randomly which causes a magnet to lose its magnetism**.**

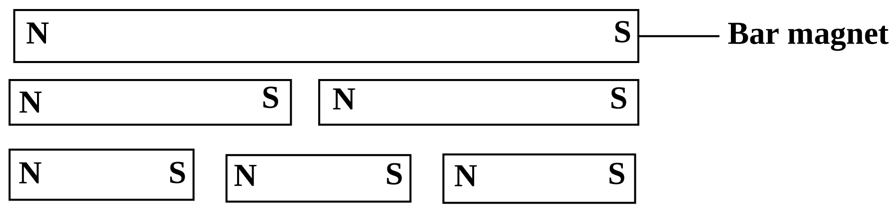
➢ **Keeping like poles of two magnets together for a long time:** This makes magnets to lose their magnetism because when like poles are kept together for a long time, repulsion between like dipoles at the ends of the magnets destroys the alignment and this causes magnets to lose their magnetism.

NOTE:

Magnets tend to become weaker with time due to self demagnetization. When a magnet is left alone for a long time weakens because the like poles of the dipoles at the end of a magnet repel each other and may disorganize the alignment and this causes the magnet to weaken.

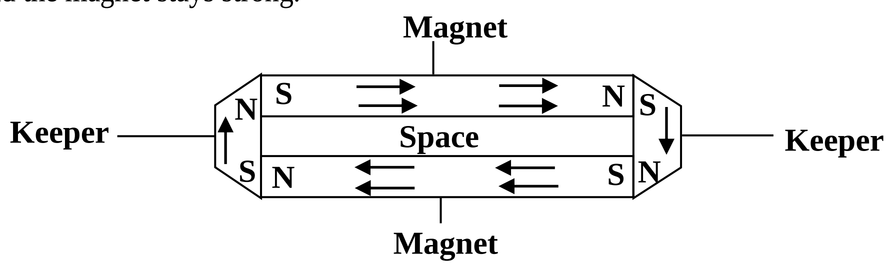
BREAKING A MAGNET:

Every molecule in a magnet is its self a permanent magnet and when a magnet is broken into two portions both will have two unlike poles which appear at opposite ends of each piece. The cutting of a magnet therefore does not separate the two poles of a magnet no matter how many times the magnet is broken, hence a magnet does not lose its magnetism when broken into pieces.



STORING MAGNETS:

To avoid self demagnetization, magnets are stored in pairs with unlike poles adjacent to one another and with small pieces of soft iron bars called keepers placed across their ends. The keepers get induced magnetism with poles opposite to those at the ends where they are attached so that the atomic dipoles in both magnets and keepers form closed chains with no free poles. The chains resist the repulsion between poles of dipoles and the magnet stays strong.



Properties of Iron:

- Iron keeps its magnetism for a short time.
- Iron is used for making electromagnets.
- Iron is easily magnetized and easily demagnetized

Properties of Steel:

- Steel keeps its magnetism for a long time.
- Steel is used for making permanent magnets.
- Steel is not easily magnetized and not easily demagnetized

WORK, ENERGY & POWER

WORK: This is the product of force and distance moved in the direction of force. Work is done when the point of application of force moves in the direction of force.

$$\text{Work} = \text{Force} \times \text{distance}$$

The SI unit of work is a joule (J). A **joule** is the work done when a force of 1N moves a body through a distance of 1m in the direction of force. When a body of mass, m is projected vertically then the force acting on the body is equal to the weight of the body.

$$\text{Work} = F \times d$$
$$F = mg$$
$$W = mgd$$

Examples:

1. An object is pulled through a distance of 2m by a force of 55N. Calculate the work done

$$\text{Work} = F \times d$$
$$\text{Work} = 2 \times 55$$
$$\text{Work} = 110J$$

2. An object is pulled through a distance of 20cm by a force of 1500N. Calculate the work done

$$\text{Work} = F \times d$$
$$\text{Work} = 1500 \times 0.2$$
$$\text{Work} = 300J$$

3. An object of mass 500g moves through a vertical height of 40cm. Calculate the work done

$$\text{Work} = F \times d$$
$$\text{Work} = mgd$$
$$\text{Work} = 0.5 \times 10 \times 0.4$$
$$\text{Work} = 2.0J$$

4. A body of mass 250g climbs 25 steps each of height 20cm. Calculate the work done

$$\text{Work} = F \times d$$
$$\text{Work} = mgd$$
$$\text{Work} = (0.25 \times 10) \times (0.2 \times 25)$$
$$\text{Work} = 12.5J$$

ENERGY:

This is the ability to do work. The SI unit of energy is joule (J).

Forms of energy:

The following are different forms of energy;

- **Heat energy:** This is the form of energy that is transferred from region of high temperature to region of low temperature. This is produced by burning fuels, electric heaters and radiation from the sun.
- **Sound energy:** This is a form of energy produced when particles of the medium are set into vibrations. This form of energy is heard by the ear.
- **Chemical energy:** This is a form of energy that can be converted to heat by burning.
- **Electrical energy:** This is a form of energy due to the flow of charges. This form of energy can be obtained by the conversion of other forms of energy using generators.

- **Light energy:** This is the form of energy produced by hot bodies and travels in a straight line. This form of energy can be converted into other forms of energy and helps us to see.
- **Nuclear energy:** This is form of energy produced when unstable nucleus splits through nuclear fission or two light nuclei fuse together through nuclear fusion.
- **Wave energy:** This is a form of energy which is transferred from one point to another without causing any permanent displacement of medium itself. This form of energy causes a disturbance through the medium.

SOURCES OF ENERGY:

There are two sources of energy that renewable (non – exhaustible) source of energy and non – renewable (exhaustible) source of energy.

Renewable (Non-Exhaustible) sources of energy:

These are sources of energy which can be re-used to produce energy. Renewable sources of energy are generated naturally that is from the sun, wind, rain and tides.

The following are examples of renewable sources of energy;

- **Sun:** The sun produces light energy and heat energy which are used in different ways. Solar energy can be reused to produce heat energy, light energy or other forms of electrical energy.
- **Wind:** Wind is a moving air which can drive turbines to produce electrical energy. Wind energy can be reused to generate electricity by use of wind mills which pump water from the ground.
- **Tidal Power:** Tidal energy is generated through tidal stream generators or by barrage generation.
- **Waves:** Ocean currents can be converted into other forms energy like electrical energy. Energy is generated by ocean surface waves and can be reused to produce electrical energy by pumping water.
- **Water:** Waterfalls may be used to turn turbines in hydro-electric power stations. This generates hydro power and can be reused to produce heat and light energy.
- **Geothermal:** Geothermal is a source of electrical energy in power stations. Energy from geothermal is used to generate electricity which is reused to produce heat energy for cooking at homes.
- **Biomass:** Energy from living and recently dead biological materials can be reused to produce fuel or for industrial production.
- **Nuclear Power:** When unstable nucleus splits nuclear energy is released. Energy from nuclear reactors is used to heat water to produce steam which in turn is converted to mechanical energy.

Advantages of renewable sources of energy

- ✓ Energy is available in large quantities and is obtained freely.
- ✓ Energy does not expire.
- ✓ Energy does not affect our environment.
- ✓ Renewable sources of energy are less costly.
- ✓ Enhance our economy through job creation that is when dams and industries are put in place.

Disadvantages of renewable sources of energy

- ✓ Geothermal can cause environmental changes.
- ✓ Hydro power stations affect the water flow and wild life.
- ✓ Solar energy is used only during day time but not at night or rainy season.

Non-Renewable (Exhaustible) sources of energy: These are sources of energy which cannot be re-used to produce energy. These sources are available in limited quantities and can be regenerated for short period of time like fossil fuels, natural gas, oil and coal.

The following are examples of non – renewable sources of energy;

- **Fossil Fuels:** These are obtained from the remains of ancient animals but cannot be used to produce other forms of energy.
- **Coal:** This is mined from sand witched between layers of rock in the earth and when is burnt produces heat energy.
- **Crude oil/Petroleum:** This is widely used in industries and in transport.
- **Natural Gas:** This is widely used in homes for cooking to produce heat energy.

Advantages of non-renewable sources of energy

- ✓ Non – renewable sources are easy to use.
- ✓ Small amount of the source is needed to produce large amount of energy.
- ✓ They are affordable.

Disadvantages of renewable sources of energy

- ✓ They expire after some time.
- ✓ They affect our environment.
- ✓ They release toxic gases which cause global warming.
- ✓ They don’t have stable prices.

MECHANICAL ENERGY: This is the form of energy possessed by a body due to its motion and due to its position above the ground. This is divided into two forms of energy namely;

i) Kinetic energy.

ii) Potential energy.

Kinetic energy: This is the energy possessed by a body due to its motion. It depends on the speed of the body and mass of the body

$$\text{Kinetic energy} = \tfrac{1}{2}mv^2$$

Where m is the mass of the body and v is the velocity of the body

Examples:

1. A body of mass 3kg moves with a speed of $30ms^{-1}$. Find its kinetic energy

$$K.E = \tfrac{1}{2}mv^2$$
$$K.E = \tfrac{1}{2} \times 3 \times 30^2$$
$$K.E = \tfrac{1}{2} \times 3 \times 900$$
$$K.E = 1350J$$

2. A body of mass 400g moves with a speed of $24ms^{-1}$. Find its kinetic energy

$$K.E = \tfrac{1}{2}mv^2$$
$$K.E = \frac{1}{2} \times \frac{400}{1000} \times 24^2$$
$$K.E = \frac{1}{2} \times 0.4 \times 576$$
$$K.E = \tfrac{1}{2} \times 230.4$$
$$K.E = 115.2J$$

3. An object of volume $100cm^3$ and density $8gcm^{-3}$ moves with a speed of $10ms^{-1}$. Find its kinetic energy

$$K.E = \frac{1}{2}mv^2$$
$$m = \rho \times v$$
$$m = 8 \times 100$$
$$m = 800g$$
$$K.E = \frac{1}{2} \times 0.8 \times 10^2$$
$$K.E = \frac{1}{2} \times 0.8 \times 100$$
$$K.E = \frac{1}{2} \times 80$$
$$K.E = 40J$$

Potential energy: This is the energy possessed by a body by virtue of its position in the gravitational field.

$$\text{Potential energy} = mgh$$

Where m is the mass of the body, h is the height of the body above the ground and g is the acceleration due to gravity.

Examples:

1. Find the potential energy of an object of mass 350g when it is 10m above the ground

$$P.E = mgh$$
$$P.E = 0.35 \times 10 \times 10$$
$$P.E = 35J$$

2. A 5kg mass falls from a height of 20m. Calculate the potential energy lost

$$P.E = mgh$$
$$P.E = 5 \times 10 \times 20$$
$$P.E = 1000J$$

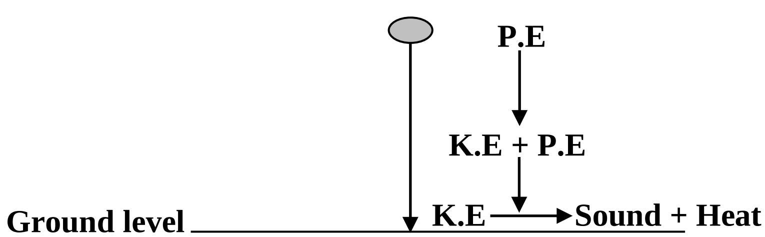
The law of conservation of energy:

It states that energy can neither be created nor destroyed but changes from one form to another.

Energy changes:

1. For a body falling freely the following energy changes take place

P.E ⟶ P.E + K.E ⟶ K.E ⟶ Sound + Heat



Note: For a body falling freely its kinetic energy before impact is equal to potential energy above the ground.

2. When lighting a match box

Chemical energy ⟶ Heat + Light

3. When a boy compresses the spring

Mechanical energy ⟶ Elastic potential energy

4. When lighting a lamp connected to a battery

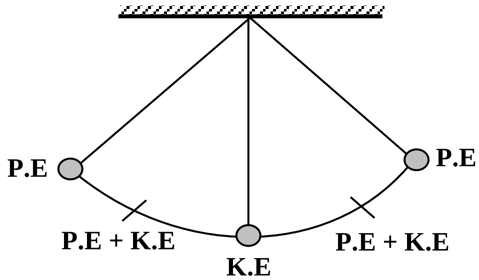
Chemical energy ⟶ Electrical energy ⟶ heat + light

5. Catapult pulled by a person to propel a stone

Mechanical energy ⟶ Elastic potential energy ⟶ kinetic energy

6. For a freely swinging pendulum the energy changes are

P.E ⟶ P.E + K.E ⟶ K.E ⟶ P.E + K.E ⟶ P.E



N.B: The following devices can be used to carry out the following energy changes;

i) Electrical energy to mechanical energy ---------------------------------------Motor

ii) Mechanical energy to electrical energy -------------------------------------Dynamo

iii) Electrical energy to sound energy---Loudspeaker

iv) Sound energy to electrical energy---Microphone

v) Heatenergy to electrical energy ---Thermopile

vi) Electrical energy to heat energy---Electrical heater

vii) Electrical energy to light energy--Electric bulb

viii) Light energy to electrical energy---Photocells

ix) Chemical energy to electrical energy --------------------------------------Cell

x) Electrical energy to chemical energy ---------------------------------------Battery charging

xi) Nuclear energy to heat energy--Nuclear reactor

xii) Electromagnetic to electrical energy -------------------------------------Aerial

Examples:

1. A 200g body falls from a height of 0.2m. Find the kinetic energy just before it hits the ground

K.E gained = P.E lost

K.E = mgh

K.E = 0.2 x 10 x 0.2

K.E = 0.4J

2. A block of mass 2kg falls freely from rest through a height of 20m above the ground. Find

i) The potential energy of the block above the ground

ii) The velocity with which the block hits the ground

Solution:

i) From P.E = mgh

P.E = 2 x 10 x 20

P.E = 400J

ii) From K.E = P.E

$\frac{1}{2} mv^2 = 400$

$\frac{1}{2} \times 2 \times v^2 = 400$

$v^2 = 400$

$v = \sqrt{400} = 20ms^{-1}$

POWER:

This is the rate of doing work

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

Work done = Force x Distance

$$\text{Power} = \frac{\text{Force x Distance}}{\text{Time taken}}$$

$$\text{Power} = \text{Force x } \frac{\text{Distance}}{\text{Time}}$$

Power = Force x velocity

The SI unit of power is a watt (W). **A watt** is the rate of working of one joule per second ($1W = 1Js^{-1}$).

Other units of power include kilowatt (kW) and megawatt (MW).

1kW = 1,000W

1MW = 1,000,000W

Examples:

1. A force of 480N pulls a body through a distance of 4.0m in 30 seconds. Calculate

i) Work done

ii) Power developed

Solution:

i) FromWork = F x d

Work = 480 x 4

Work = 1920J

ii) From Power $= \frac{\text{Work done}}{\text{Time taken}}$

power $= \frac{1920}{30}$

Power = 64W

2. An engine raises 20kg of water through a height of 50m in 5 seconds. Calculate the power of the engine

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

Work done = F x d

Work done = mg x d

Work done = 20 x 10 x 50

Work done = 10,000J

$$\text{Power} = \frac{10,000}{5}$$

Power = 2,000W

3. A boy whose mass is 60kg can run up a flight of 28 steps each 25 cm high in 56 seconds. Calculate the power developed by the boy

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

Work done = F x d

Work done = mg x d

$$\text{Work done} = 60 \text{ x } 10 \text{ x } \left(28\, x\, \frac{25}{100}\right)$$

Work done = 4,200J

$$\text{Power} = \frac{4,200}{56}$$

Power = 75W

SIMPLE MACHINES

A machine is device that enables the force applied at one point to overcome another force at some other point. That is it is a device that simplifies work. The force applied is called the Effort [E] and the force which the machine must overcome is called the Load [L]. The SI unit of effort and load is a newton [N]. The following are examples of simple machines;

i) Pulley systems
ii) Inclined plane
iii) Wheel and axle
iv) Hydraulic press
v) Levers
vi) Screws.
vii) Gears.
viii) Wedges

Terms used:

1. Mechanical advantage [M.A]:

This is the ratio of load to effort.

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

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

Mechanical advantage has no SI unit because it is a ratio of similar quantities.

2. Velocity ratio [V.R]:

This is the ratio of distance moved by the effort to distance moved by the load.

$$\text{Velocity ratio} = \frac{\text{Effort distance}}{\text{Load distance}}$$

$$\text{V.R} = \frac{\text{E.D}}{\text{L.D}}$$

Velocity ratio has no SI unit because it is a ratio of similar quantities.

3. Efficiency [η]:

This is the ratio of useful work done by the machine to the work put into the machine expressed as a percentage.

$$\text{Efficiency} = \frac{\text{Work done by a machine}}{\text{work put into a machine}} \text{ x } 100\%$$

$$\eta = \frac{\text{Load x Load distance}}{\text{Effort x Efort distance}} \text{ x } 100\%$$

$$\eta = \frac{\text{Load}}{\text{Effort}} \text{ x } \frac{\text{Load distance}}{\text{Effort distance}} \text{ x } 100\%$$

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

$$\eta = \frac{\text{M.A}}{\text{V.R}} \text{ x } 100\%$$

NOTE:

- **In practice the efficiency of any machine is less than 100% because of the following reasons;**

i) Some of the energy is wasted in overcoming friction.
ii) Some of the energy is wasted in lifting useless loads
iii) Some energy is wasted in moving the movable parts of the machine

- **However the efficiency of the machine can be increased by;**

i) Using light materials for the useless loads like strings
ii) Reducing friction through oiling, lubricating, ball bearings.

Examples:

1. A simple machine raises a load of 3000N through a distance of 0.5m when an effort of 150N is applied through a distance of 12.5m. Calculate

i) Mechanical advantage

ii) Velocity ratio

iii) Efficiency of the machine

Solution

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

M.A $= \frac{3000}{150}$

M.A = 20

ii) V.R $= \frac{E.D}{L.D}$

V.R $= \frac{12.5}{0.5}$

V.R = 25

iii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{20}{25} \times 100\%$

η = 80%

3. A simple machine of velocity ratio 6 is used to lift a load of 3600N. Given that the efficiency of the machine is 75%. Calculate the

i) Mechanical advantage of the machine

ii) Effort applied

Solution:

i) $\eta = \frac{M.A}{V.R} \times 100\%$

$75 = \frac{M.A}{6} \times 100\%$

M.A $= \frac{75 \times 6}{100}$

M.A = 4.5

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

$4.5 = \frac{3600}{E}$

E $= \frac{3600}{4.5}$

E = 800N

2. A load of 100N is raised through 6cm when an effort of 40N moves through a distance of 24cm. Calculate the

i) Mechanical advantage ii) Velocity ratio iii) Efficiency of the machine

Solution

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

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

M.A = 2.5

ii) V.R $= \frac{E.D}{L.D}$

V.R $= \frac{24}{6}$

V.R = 4

iii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{2.5}{4} \times 100\%$

η = 62.5%

LEVERS

This is a type of machine with a rigid body capable of turning about a fixed point. This fixed point about which a lever turns is called the pivot [fulcrum]. The lever has three major parts i.e the effort, the pivot and the load.

The class of the lever depends on the relative position of the parts. There are three classes of levers and these are;

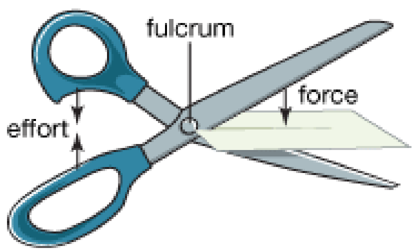
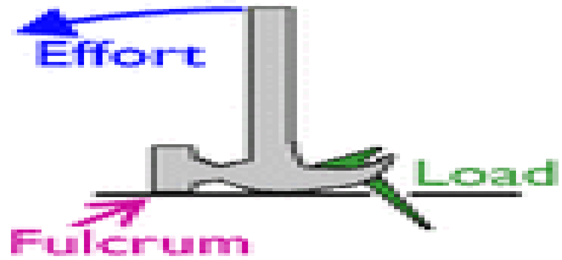
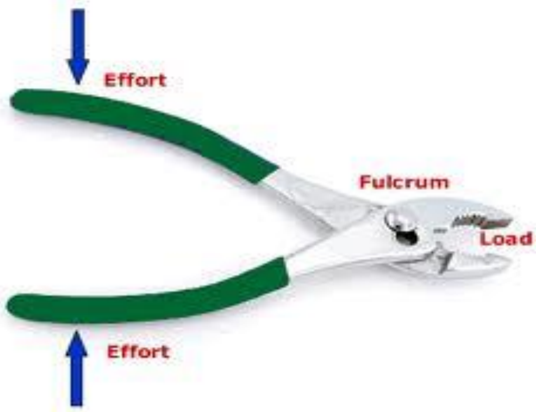
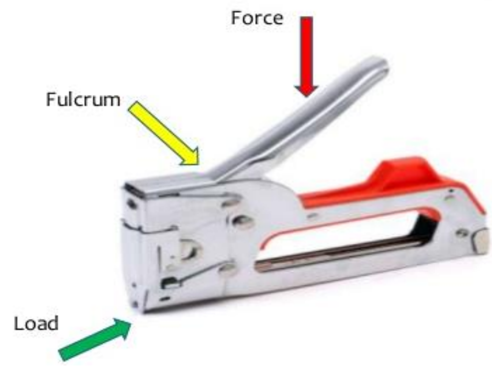
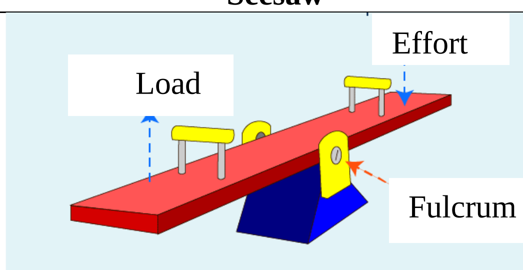
i) First class levers.

ii) Second class levers.

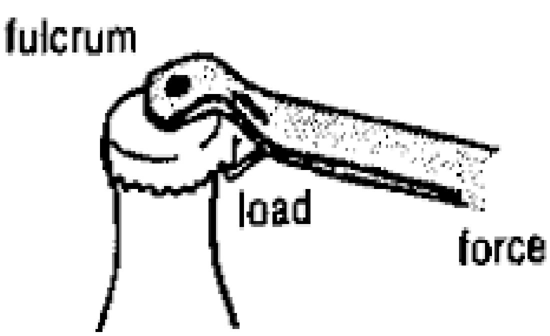
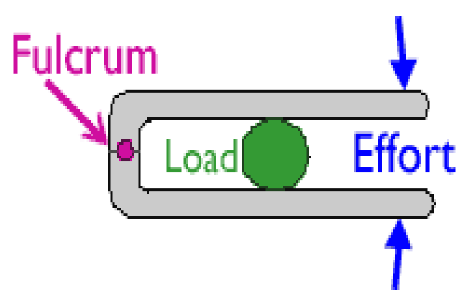
iii) Third class levers

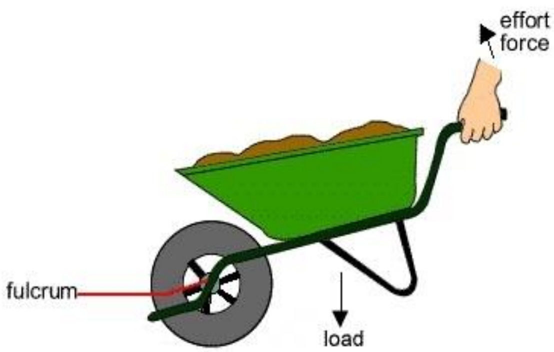
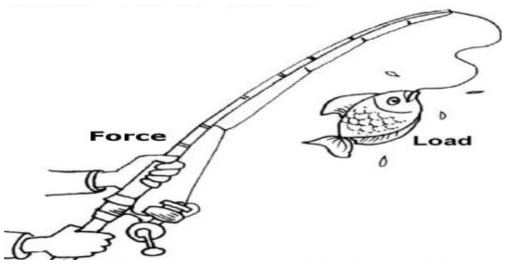
First class levers are type of levers where the pivot is between the effort and the load while second class levers are type of levers where load is between the effort and the pivot and third class levers are type of levers where effort is between the load and the pivot. The table below shows different types of levers;

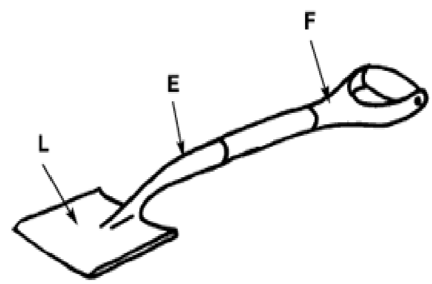
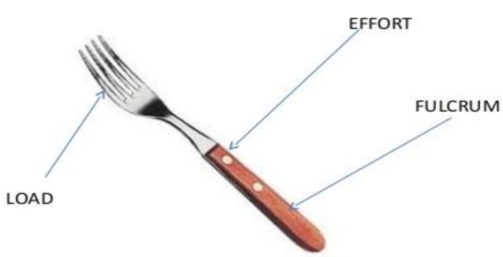
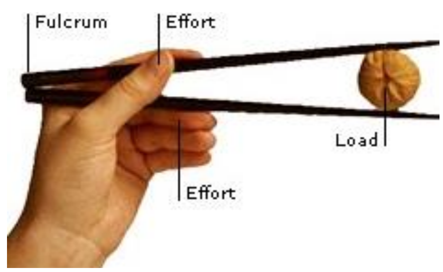
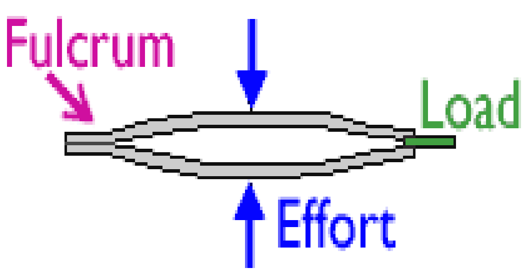
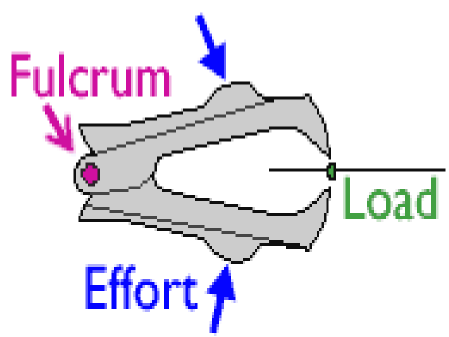
FIRST CLASS LEVERS

Pair of scissors	Claw hammer
 	
Pair of pliers	**Gun Stapler**
 	
Seesaw	**Head**
 	

SECOND CLASS LEVERS

Bottle opener	Nut cracker
 	

<table>
<tr><th>Wheel barrow</th><th>Leg</th></tr>
<tr><td>
</td><td></td></tr>
<tr><th colspan="2">THIRD CLASS LEVERS</th></tr>
<tr><th>Fishing rod</th><th>Spade</th></tr>
<tr><td>

Fulcrum</td><td>
</td></tr>
<tr><th>Fork/spoon</th><th>Pair of tongs</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Pair of tweezers</th><th>Staple remover</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

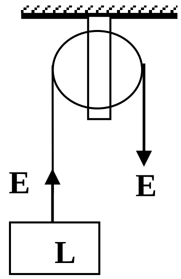
PULLEY SYSTEM:

A Pulley is a wheel with a grooved rim. There are three types of pulley systems and these are;

i) Single fixed pulley
ii) Single movable pulley
iii) Block and tackle pulley

Single fixed pulley:

This is a simple pulley with a fixed wheel and has a rope passing around the groove in its rim. In a single fixed pulley the load is tied to one end and the effort is applied to another end.



If there is no friction and the rope is weightless then at equilibrium

$$L = E$$

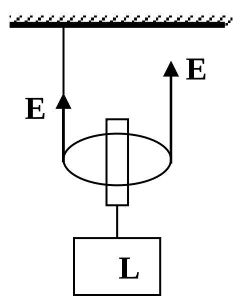
$$M.A = \frac{L}{E} = 1$$

In practice the rope has weight and there is friction in the groove, therefore the effort is always greater than the load. Hence mechanical advantage is always less than 1.However the distance moved by the effort is always equal to the distance moved by the load

$$V.R = \frac{E.D}{L.D} = 1$$

Single movable pulley:

This is a simple pulley with a rope passing around the groove of a movable wheel. In a single movable pulley one end of the rope is fixed and the effort is applied on the other end but the load is tied to the wheel.



If there is no friction and the rope is weightless then at equilibrium

$$L = 2E$$

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

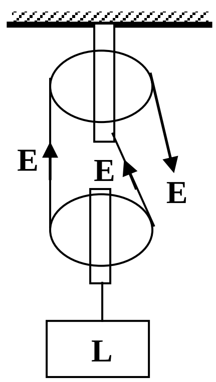
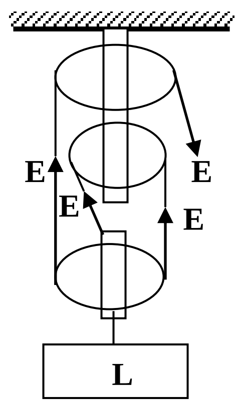
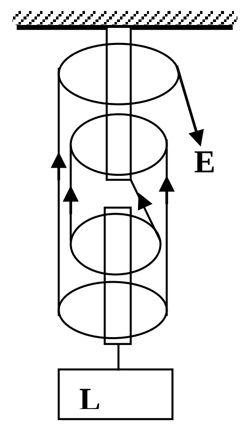
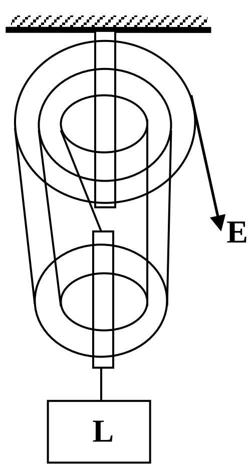
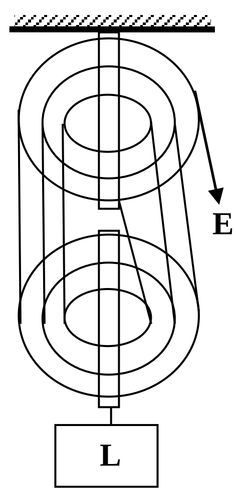
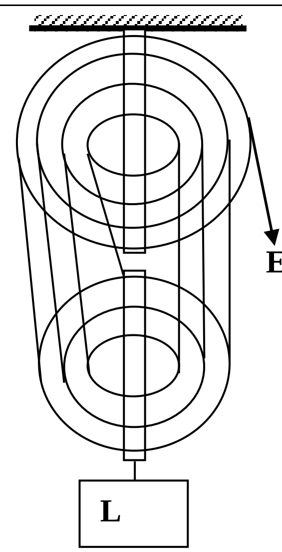
In practice the rope has weight and there is friction in the groove, therefore the effort is always greater than the load. Hence mechanical advantage is always less than 2.However the distance moved by the effort is always twice to the distance moved by the load

$$V.R = \frac{E.D}{L.D} = 2$$

BLOCK AND TACKLE PULLEY SYSTEM:

This is a system where two or more pulleys are combined to form a machine of larger velocity ratio and higher mechanical advantage. It uses very little effort hence difficult tasks can be completed by this machine. In a block and tackle pulley system two or more pulleys are mounted on the same axle to form a block. One set of the block is fixed and the other set of the block is movable. These blocks are joined by a single rope called tackle passing through each pulley in turn.If the number of pulleys is odd then the fixed block has more by one pulley than the movable block and when the pulleys are even the blocks have the same number of pulleys. The velocity ratio is equal to number of strings supporting the movable block which is equal to the number of pulleys of the pulley system.

NOTE: The table below show different pulley systems with different velocity ratios;

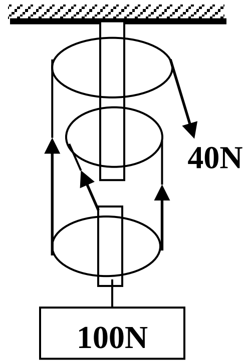
V.R = 2	**V.R = 3**	**V.R = 4**
		
V.R = 5	**V.R = 6**	**V.R = 7**
		

Uses of pulley systems:

- Construction pulleys lift heavy materials from the ground.
- Curtains at the theatre are moved using pulley systems.
- Flag poles use pulleys in order to raise or bring down the flag.
- A crane is a pulley system used in construction.

Examples:

1. The minimum effort required to raise a load of 100N is 40N as shown in diagram below.



Calculate

i) The mechanical advantage

ii) Efficiency

iii) Work done by the load if it is raised through 6m.

Solution

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

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

M.A = 2.5

ii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{2.5}{3} \times 100\%$

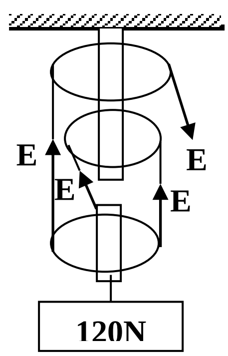
η = 83.3%

iii) Work done = Load x Load distance

Work done = 100 x 6

Work done = 600J

2. In the pulley system below each pulley has a mass of 0.6kg



Calculate the

i) Effort, E

ii) Mechanical advantage

iii) Efficiency of the pulley system above

Solution:

i) E + E + E = 120 + mg

3E = 120 + (0.6 x 10)

3E = 120 + 6

E $= \frac{126}{3} = 42N$

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

M.A $= \frac{120}{42}$

M.A = 2.86

iii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{2.86}{42} \times 100\%$

$\eta = \frac{286}{42}$

η = 95.2%

3. A block and tackle pulley system with a velocity ratio of 5 and 60% efficiency is used to a lift a load of mass 60kg through a vertical height of 2m. What effort must be exerted?

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

$$\eta = \frac{\text{M.A}}{\text{V.R}} \text{ x } 100\%$$

$$60 = \frac{\text{M.A}}{5} \text{ x } 100\%$$

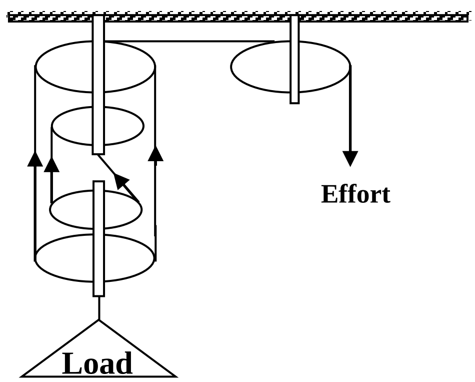
$$\text{M.A} = \frac{60 \text{ x } 5}{100} = 3$$

$$3 = \frac{(60 \text{ x } 10)}{\text{E}}$$

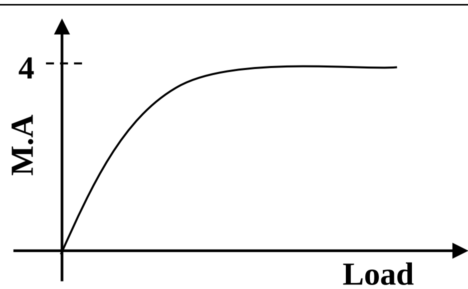
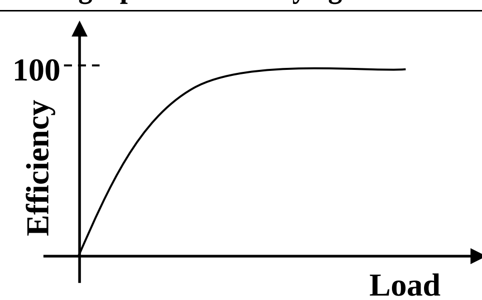
$$\text{E} = \frac{600}{3} = 200\text{N}$$

Experiment to measure the efficiency of the pulley system:

The apparatus is arranged as shown in the diagram below;



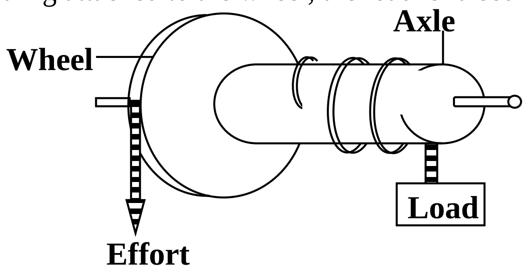
A known load is placed on the load scale pan. Different weights are then added to the effort scale pan until the load just starts to move upwards steadily (uniform speed).The mechanical advantage of the system is then calculated. The experiment is repeated with different loads and different efforts noted. The results are then tabulated.

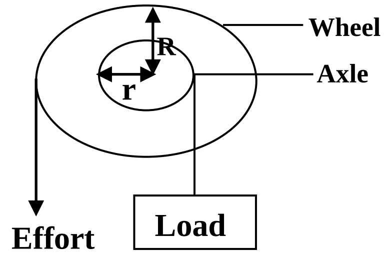
A graph of mechanical advantage against load	**A graph of efficiency against load**
	

When the load is small, large proportion of the applied effort is used to overcome weight of moving parts and friction. This leads to small mechanical advantage and efficiency for small loads. As the load increases, the portion of the effort that does useful work increases, while that which does work against friction and raising the moving parts decreases. Hence mechanical advantage and efficiency increases with the load but mechanical advantage does not exceed velocity ratio of 4 and efficiency does not exceed efficiency of 100%.

WHEEL AND AXLE:

The wheel and axle is a type of machine with a common axis of rotation. When the effort is applied to the string attached to the wheel, the load is raised by a string wound around the axle.





For one complete turn, the effort moves through a distance equal to circumference of a circle described by the wheel, E.D = πD = 2πR while the load moves through a distance equal to the circumference of a circle described by the axle, L.D = πd = 2πr.

$$\text{Velocity ratio} = \frac{\text{Effort distance}}{\text{Load distance}}$$

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

$$\text{V.R} = \frac{D}{d} = \frac{R}{r}$$

$$\text{V.R} = \frac{\text{Diameter of the wheel}}{\text{Diameter of the axle}} = \frac{\text{Radius of the wheel}}{\text{Radius of the axle}}$$

Examples:

1. A machine consisting of a wheel of radius 50cm and axle of radius 10cm is used to lift a load of 400N with an effort of 100N. Calculate

i) Its velocity ratio

ii) Its mechanical advantage

iii) The efficiency of the incline

Solution:

i) V.R $= \frac{R}{r}$

V.R $= \frac{50}{10}$

V.R = 5

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

M.A $= \frac{400}{100}$

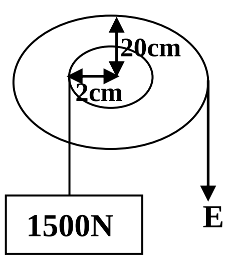
M.A = 4

iii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{4}{5} \times 100\%$

η = 80%

2. The efficiency of the machine below is 75%.



Calculate the

i) Velocity ratio

ii) Mechanical advantage

iii) Effort applied

Solution:

i) V.R $= \frac{R}{r}$

V.R $= \frac{20}{2}$

V.R = 10

ii) $\eta = \frac{M.A}{V.R} \times 100\%$

$75 = \frac{M.A}{10} \times 100\%$

M.A $= \frac{75 \times 10}{100}$

M.A = 7.5

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

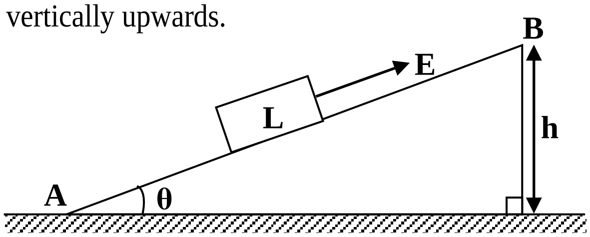
$7.5 = \frac{1500}{E}$

E $= \frac{1500}{7.5}$

E = 200N

THE INCLINED PLANE:

An inclined plane is a slope which allows a load to be raised more gradually by using a smaller effort than when lifted vertically upwards.



Note: The distance moved by the Effort, E is equal to the length, d of the plane AB and the load, L is raised through a vertical height, h.

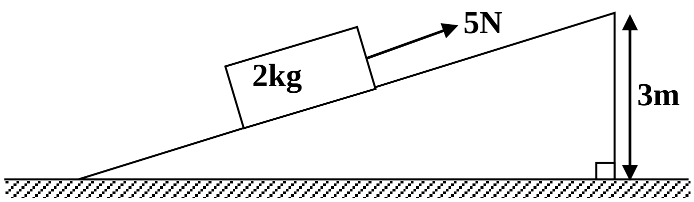
$$\text{Velocity ratio} = \frac{\text{Effort distance}}{\text{Load distance}}$$

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

$$\text{V.R} = \frac{d}{h} = \frac{1}{\sin\theta}$$

Examples:

1. A brick of mass 2kg is lifted to a height of 3m a long a smooth inclined plane 15m long by applying an effort of 5N as shown below.



Calculate the
i) Velocity ratio
ii) Mechanical advantage
iii) Efficiency of the incline

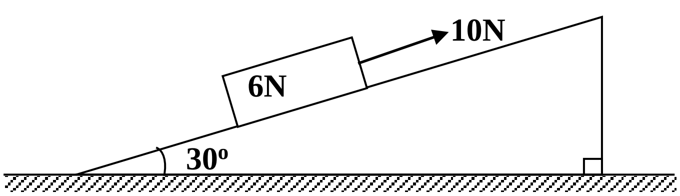
Solution:

i) $\text{V.R} = \frac{d}{h}$, $\text{V.R} = \frac{15}{3}$, $\text{V.R} = 5$

ii) $\text{M.A} = \frac{L}{E}$, $\text{M.A} = \frac{(2 \times 10)}{5}$, $\text{M.A} = 4$

iii) $\eta = \frac{\text{M.A}}{\text{V.R}} \times 100\%$, $\eta = \frac{4}{5} \times 100\%$, $\eta = 80\%$

2. A block of weight 6N is lifted to the top of along a smooth inclined plane at an angle of 30^o to the horizontal by applying an effort of 10N as shown below.



Calculate the
i) Velocity ratio
ii) Mechanical advantage
iii) Efficiency of the incline

Solution:

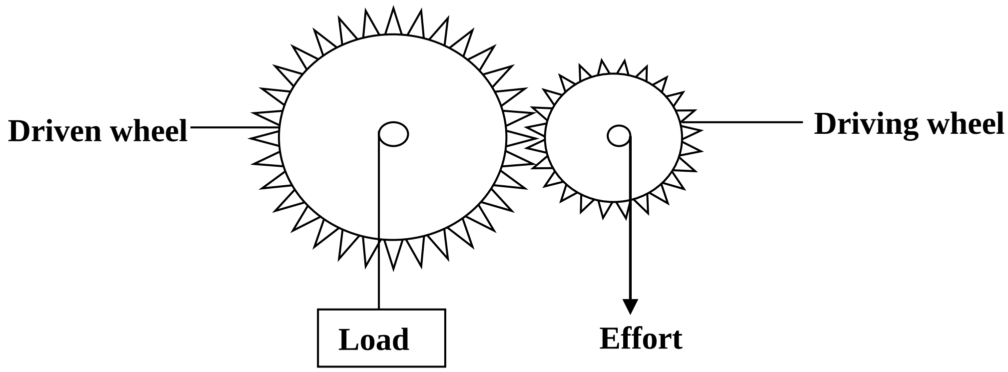
i) $\text{V.R} = \frac{1}{\sin\theta}$, $\text{V.R} = \frac{1}{\sin 30}$, $\text{V.R} = 2$

ii) $\text{M.A} = \frac{L}{E}$, $\text{M.A} = \frac{6}{10}$, $\text{M.A} = 0.6$

iii) $\eta = \frac{\text{M.A}}{\text{V.R}} \times 100\%$, $\eta = \frac{0.6}{2} \times 100\%$, $\eta = 30\%$

THE GEARS:

Gear is simple machine rigidly fixed to the axis and turns with its axis. That is a gear is a wheel which can rotate around its centre and has equally spaced teeth around it. If the effort is applied on a small gear (driving wheel) it drives a large gear (driven wheel) which has a load attached on it.



For one complete turn of the driven gear, the driving wheel makes $\frac{N}{n}$ number of turns which is equal to the velocity of the gears. That is N is the number of teeth on the driven gear while n is the number of teeth of the driving gear

$$\text{Velocity ratio} = \frac{\text{Number of teeth of the driven wheel}}{\text{Number of teeth of the driving wheel}}$$

$$V.R = \frac{N}{n}$$

Examples:

1. A driving wheel of 25 teeth engages with a second wheel of 100 teeth and has an efficiency of 85%. Calculate

i) The velocity ratio

ii) The mechanical advantage of the machine

Solution:

i)

$$V.R = \frac{\text{Number of teeth of the driven wheel}}{\text{Number of teeth of the driving wheel}}$$

$$V.R = \frac{N}{n}$$

$$V.R = \frac{100}{25}$$

$$V.R = 4$$

ii)

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

$$85 = \frac{M.A}{4} \times 100\%$$

$$M.A = \frac{85 \times 4}{100}$$

$$M.A = 3.4$$

2. A certain gear has 60 teeth and drives another gear with 150 teeth. How many revolutions will the driven gear make when the driving gear makes 200 revolutions?

$$V.R = \frac{N}{n}$$

$$V.R = \frac{150}{60}$$

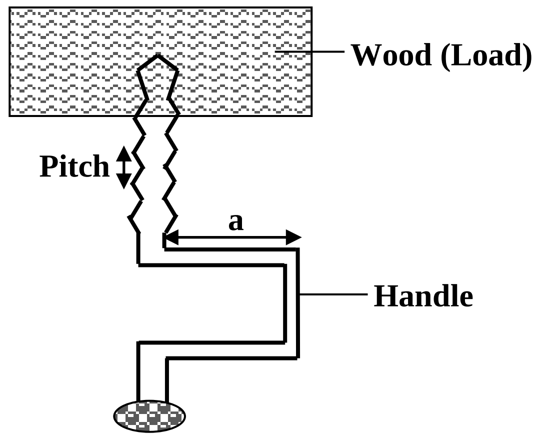
$$V.R = 2.5$$

$$\text{Number of revolutions} = \frac{200}{2.5}$$

$$\text{Number of revolutions} = 80$$

THE SCREW:

The screw is a device used for the purpose of holding things together. The distance between successive threads of the screw is called **the pitch**. When the effort is applied on the screw by means of the handle with a lever of length, **a** it enters the wood (Load) by a distance equal to the pitch, **P** after turning the handle through one complete turn. Therefore the effort moves a distance equal to the circumference of the circle described by the handle and the load moves a distance equal to the pitch.



$$V.R = \frac{\text{Effort distance}}{\text{Load distance}}$$

$$V.R = \frac{\text{Circumference of a circle of radius,a}}{\text{Pitch}}$$

$$V.R = \frac{2\pi a}{P}$$

Examples:

1. A screw jack of pitch 4.0cm is operated by a force of 480N acting at a distance of 14cm from the axis about which the handle rotates and lifts a load weighing 960kg. Calculate the

i) Velocity ratio

ii) Mechanical advantage

iii) Efficiency of the machine

Solution:

i) $V.R = \frac{2\pi a}{P}$

$V.R = \frac{2 \times \frac{22}{7} \times 14}{4}$

$V.R = 22$

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

$M.A = \frac{(960 \times 10)}{480}$

$M.A = 20$

ii) $\eta = \frac{M.A}{V.R} \times 100\%$

$\eta = \frac{20}{22} \times 100\%$

$\eta = 90.9\%$

2. A screw of pitch 5cm is used to lift a load of 890.8N in a car jerk. The lever makes a circle of circumference 10cm and has an efficiency of 85%. Find the

i) Velocity ratio

ii) Mechanical advantage

iii) Effort applied to the handle

Solution:

i) $V.R = \frac{2\pi a}{P}$

$V.R = \frac{10}{5}$

$V.R = 2$

ii) $\eta = \frac{M.A}{V.R} \times 100\%$

$85 = \frac{M.A}{2} \times 100\%$

$M.A = \frac{85 \times 2}{100}$

$M.A = 1.7$

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

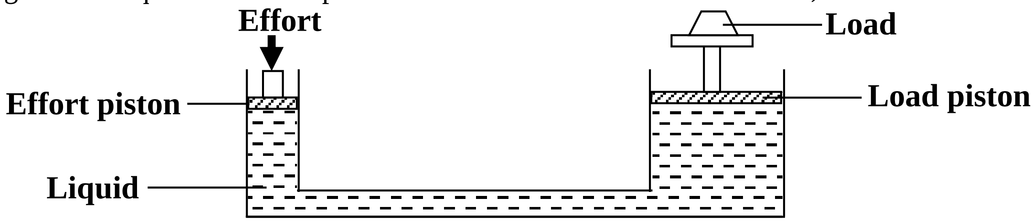
$1.7 = \frac{890.8}{E}$

$E = \frac{890.8}{1.7}$

$E = 524N$

HYDRAULIC PRESS/LIFT:

This is the device that uses the principle of transmission of pressure in liquids. When a force is applied on the effort piston of cross sectional area $A_1$and radius, r the pressure exerted by the force is then transmitted throughout the liquid to the load piston of cross sectional area $A_2$and radius, R.



Note: The volume of the liquid leaving the effort cylinder is equal to the volume entering the load piston when the force is applied on the effort piston.

Let X be the distance moved by the effort piston and Y be the distance moved by the load piston. Therefore X is the distance moved by the effort and Y is the distance moved by the load.

Volume leaving $= X \times A_1$

Volume entering $= Y \times A_2$

$$XA_1 = YA_2$$

$$\frac{X}{Y} = \frac{A_2}{A_1}$$

$$\text{Velocity ratio} = \frac{\text{Effort distance}}{\text{Load distance}} = \frac{X}{Y}$$

$$V.R = \frac{A_2}{A_1}$$

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

Where D is the diameter of the load piston and d is the diameter of the effort piston

Examples:

1. The area of the effort piston of a hydraulic lift is $24cm^2$ while that of the load piston is $120cm^2$. This machine is used to raise a load of 480N when an effort of 160N is applied on the effort piston. Calculate the

i) Velocity ratio ii) Mechanical advantage iii) Efficiency of the machine

Solution:

i) $V.R = \frac{A_2}{A_1}$, $V.R = \frac{120}{24}$, $V.R = 5$

ii) $M.A = \frac{L}{E}$, $M.A = \frac{480}{160}$, $M.A = 3$

iii) $\eta = \frac{M.A}{V.R} \, x\, 100\%$, $\eta = \frac{3}{5}\, x 100\%$, $\eta = 60\%$

2. The radius of the effort piston of a hydraulic lift is 1.4cm while that of the load piston is 7.0cm. This machine is used to raise a load of 120kg at a constant velocity through a height of 2.5m. Given that the machine is 80% efficient. Calculate the

i) Velocity ratio ii) Mechanical advantage iii) Effort needed

Solution:

i) $V.R = \frac{R^2}{r^2}$, $V.R = \frac{7^2}{1.4^2}$, $V.R = 25$

ii) $\eta = \frac{M.A}{V.R}\text{ x}100\%$, $80 = \frac{M.A}{25}\text{ x } 100\%$, $M.A = \frac{80 \times 25}{100} = 20$

iii) $M.A = \frac{L}{E}$, $20 = \frac{(120 \times 10)}{E}$, $E = \frac{1200}{20} = 60N$

MOMENTS:

Moment is a turning effect of the force about the fixed point. The fixed point about which the body turns is known as the pivot [Fulcrum]

Moment of a force:

This is the product of the force and the perpendicular distance of the line of action of the force from the pivot.

Moment of a force = Force x its perpendicular distance

Moment of a force = F x d

The SI unit of moment of the force is newton metre (Nm). Moment of a force is the vector quantity whose direction is the direction of force.

The moment of the force depends on the following factors;

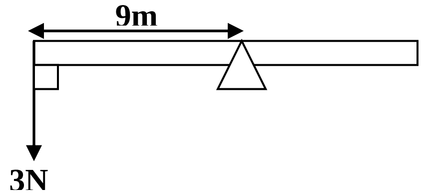
i) The magnitude of the force.

ii) The perpendicular distance from the pivot

Examples:

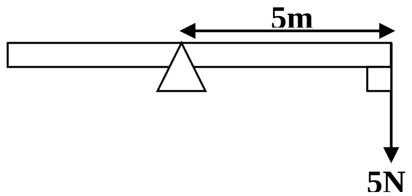
1. Find the moments of the following forces

a)



Moment of a force = F x d
Moment of a force = 3 x 9
Moment of a force = 27Nm

b)

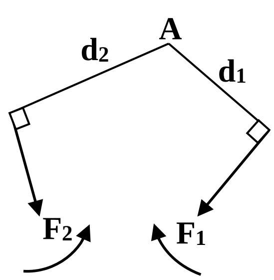


Moment of a force = F x d
Moment of a force = 5 x 5
Moment of a force = 25Nm

The principle of moments:

It states that when a body is in equilibrium the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point. Therefore the algebraic sum of the moments about the fixed point is equal to zero.

Consider forces F_1 and F_2 acting on a body at distances d_1 and d_2 respectively from point



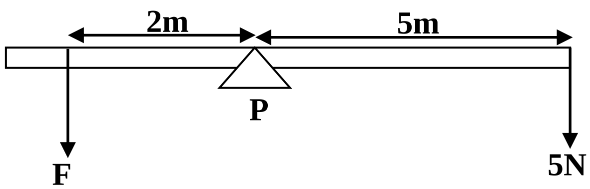
Taking moments about point A
Clockwise moments = $F_1 \times d_1$
Anticlockwise moments = $F_2 \times d_2$

NOTE:

When calculating moment of a force about a point (pivot) all distances should be measured from that point (pivot) and should be at right angles (perpendicular) to the force.

Examples:

1. Forces of 5N and F act of the body which is in equilibrium. Calculate the value of F



Taking moments about point P

Clockwise moments = 5 x 5

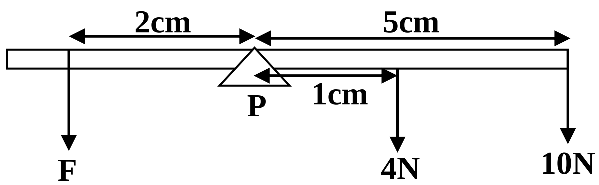
Anticlockwise moments = F x 2

At equilibrium, Clockwise moments = Anticlockwise moments

25 = 2F

F = 12.5N

2.



If the above body is in equilibrium, calculate the value of F

Taking moments about point P

Clockwise moments = 10 x 5 + 4 x 1

Anticlockwise moments = F x 2

At equilibrium, Clockwise moments = Anticlockwise moments

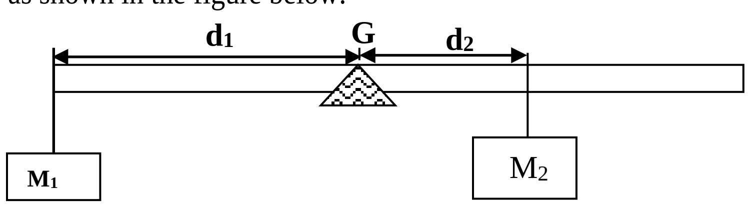
54 = 2F

F = 27N

Experiment to verify the principle of moments:

Balance a metre rule horizontally on the knife edge and mark point, G where the metre rule balances which is its centre of gravity.

A mass M_1 is suspended at one end of the metre rule and is balanced with mass, M_2 at point from the other end of the metre rule as shown in the figure below.



Length, d_1 of the mass, M_1 from knife edge is noted and the length, d_2 of the mass, M_2 from the knife is also noted.

The experiment is repeated with different masses and different distances d_1 and d_2 are obtained and noted.

Taking moments about the knife edge then clockwise moments = anticlockwise moments ($M_1gd_1 = M_2gd_2$).

It is noted that clockwise moments are always equal to anticlockwise moments hence verifying the principle of moments.

CENTRE OF GRAVITY:

This is the point of application of the resultant force due to the earth's attraction on it. This is where the resultant force due to gravity on the body is acting. Hence it is the point on the body where force of gravity seems to act and therefore it is a point on the body where its weight is concentrated.

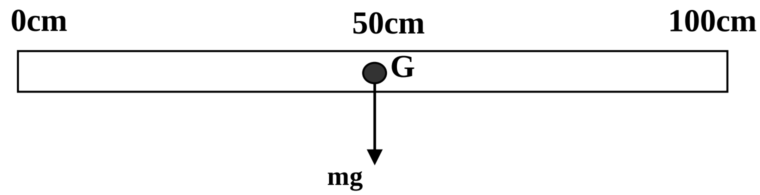
Finding the centre of gravity:

a) Regular object

The weight of a regular object is evenly distributed and therefore its centre of gravity is at its centre.

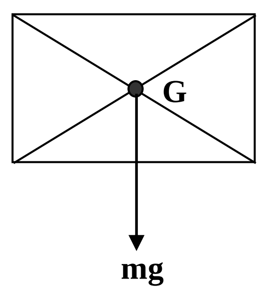
i) Uniform metre rule

Its centre of gravity, G is at 50cm mark



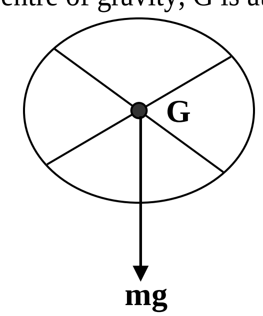
ii) Square

Its centre of gravity, G is in the middle



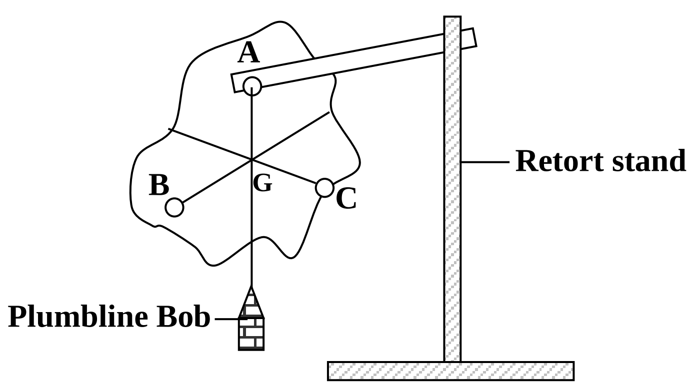
iii) Circle

Its centre of gravity, G is at its centre



b) Irregular object:

An irregular object in form of a cardboard or lamina is used



To determine center of gravity of irregular object, three holes A, B and C are made on an irregular object in different corners.

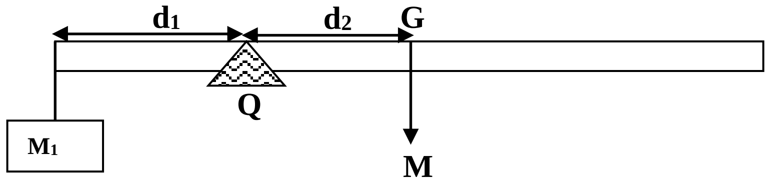
The object and plumbline bob are made to swing through hole A and when swinging stops a line is marked along the string on the object

The experiment is repeated with holes B and C and where the three lines meet is the Centre of gravity, G of the object.

Experiment to measure the mass of a uniform metre rule by principle of moments:

Balance a metre rule horizontally on the knife edge and mark a point, G where the metre rule balances which is the centre of gravity of the metre rule.

A mass M_1 is suspended at one end of the metre rule and the metre rule is balanced again at point, Q as shown in the figure below.



Length, d_1 of the mass, M_1 from the knife edge is noted and length, $d_2$of the centre of gravity, G from the knife edge is also noted.

Taking moments about Q then;

Sum of clockwise moments = Sum of anticlockwise moments

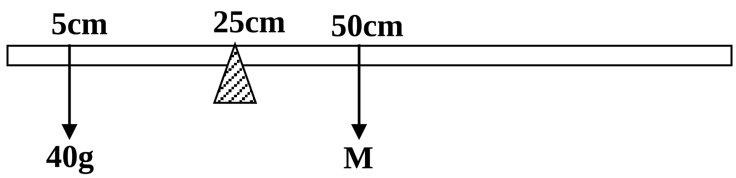
$M \times d_2 = M_1 \times d_1$

$M = \frac{M_1 d_1}{d_2}$

Hence mass M of the metre rule can be calculated

Examples:

1. A uniform metre rule is pivoted at 25cm mark and balances horizontally when a body of mass 40g is hung at 5cm mark. Calculate the mass of the metre rule



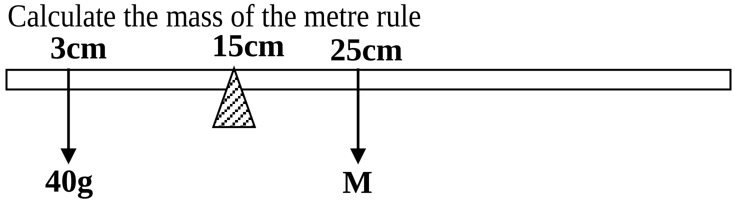
Taking moments about point P

Clockwise moments = anticlockwise moments

$M \times 25 = 40 \times 20$

$M = 32g$

2. A uniform half metre rule is pivoted at 15cm mark and balances horizontally when a body of mass 30g is hung at 3cm mark. Calculate the mass of the metre rule



Taking moments about point P

Clockwise moments = $M \times 10$

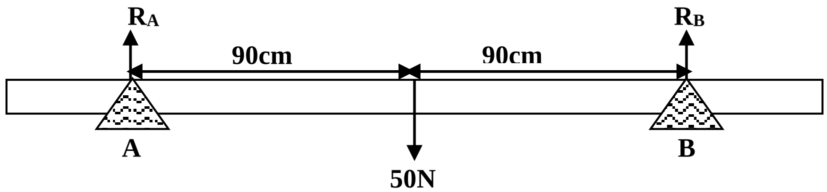
Anticlockwise moments = 40×12

At equilibrium clockwise moments = anticlockwise moments

$10M = 480$

$M = 48g$

3. Two laborers A and B carry a uniform pole of weight 50N. If the pole is 2m long. Find the reactions at A and B. Given that each labourer is 10cm from each end



Sum Upward forces = sum down ward forces

$R_A + R_B = 50$ ....[1]

Taking moments about A

$R_B \times 180 = 50 \times 90$

$180R_B = 4500$

$R_B = 25N$

From [1] $R_A = 50 - 25$

$R_A = 25N$

EQUILIBRIUM AND STABILITY:

The body is said to be in equilibrium if forces act on it and the body does not move. Therefore the resultant force on the body is zero. Hence the body is in a state of stability.

Conditions for a body in equilibrium:

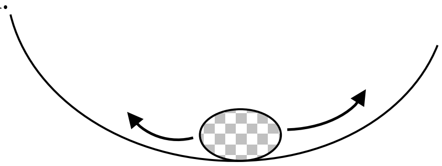
i) The sum of the forces in one direction is equal to the sum of the forces in opposite direction
ii) The sum of clockwise moments about any point is equal to the sum of anti-clockwise moments about the same point

TYPES OF EQUILIBRIUM:

There are three states of equilibrium;

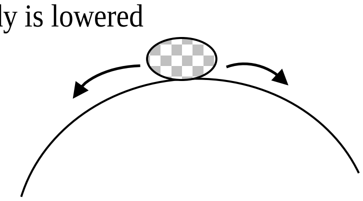
1. Stable equilibrium:

When a body is slightly displaced and then released, the body returns to its original position and its centre of gravity of the body is raised.



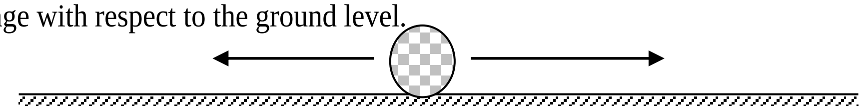
2. Un-stable equilibrium:

When a body is slightly displaced and then released, the body moves farther away from its original position and its centre of gravity of the body is lowered



3. Neutral equilibrium:

When a body is slightly displaced and then released, the body moves but the centre of gravity of the body does not change with respect to the ground level.



The stability of the body can be increased by;

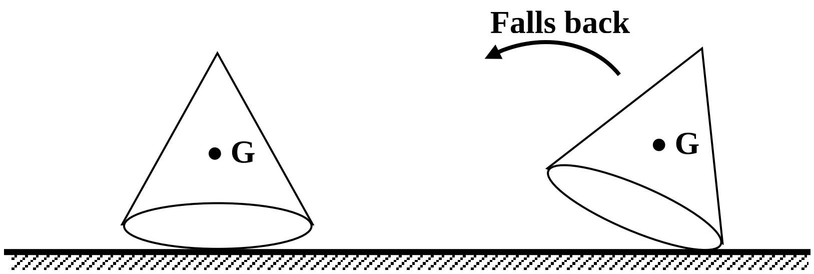
i) Lowering its centre of gravity

ii) Increasing the area of the base of the body

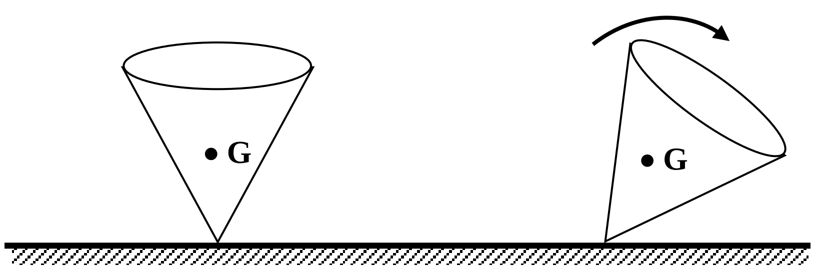
This explains why a bus carrying luggage on its roof racket wobbles more than a bus when its luggage is below its seats because its centre of gravity is lowered and the bus becomes more stable when the luggage is below the seats but its centre of gravity is raised and the bus becomes unstable when the luggage is on its roof racket.

NOTE:

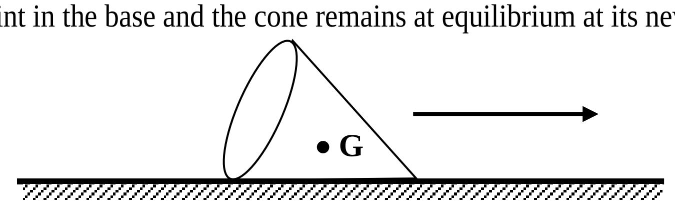
a) A cone standing on its base is said to be in stable equilibrium because when the cone is tilted from its position through a small angle, the vertical line through its centre of gravity will still fall within its base and therefore the force of gravity pulls back the cone to its initial position as shown below



b) A cone standing on its tip is said to be in unstable equilibrium because when the cone is given a slight push, the cone topples over even with a slightest push.



c) A cone lying on its one side is said to be in neutral equilibrium because when the cone is pushed so that it rolls on the bench, its centre of gravity remains at the same level and the line through it continues to pass through the same point in the base and the cone remains at equilibrium at its new position.



Comparison of states of equilibrium:

Stable Equilibrium	**Un-stable Equilibrium**	**Neutral Equilibrium**
• Wide base • Low centre of gravity • When pushed centre of gravity is raised from the base • When pushed slightly it falls back to its initial position	• Narrow base • High centre of gravity • When pushed the centre of gravity is lowered. • When pushed slightly it falls	• Base is a straight line • Centre of gravity at its lowest point • When pushed the centre of gravity remains at the same level • When pushed it remains at rest in its new position