Contents

Introduction to Physics Concept of Physics

Defn: Physics is the study of the relationship between matter and energy**.** The people who study physics is called **physicists**

Science

Defn: science is the scientific study of nature. For Example, how cooling effect occurs

Technology

Defn: technology is the application of science. For Example, cooling effect uses in refrigerator to cool different items

Relationship between Physics and Other Subject

Physics is the fundamental subject which other subject uses application of physics; the following is the relation with other subjects

i. **Chemistry**
   Composition and decomposing of matter involves energy. For Example,
   i. Cooking stoves, fuel burn to leased heat energy
   ii. Insect killers and Perfumes packed in container by compressed which comes out with high pressure
   iii. Fertilizer when they syntheses the heat energy should involved
   iv. When tea and other food cooked the heat energy should involved

ii. **Biology**
   Since biology is the scientific subject, which involves living and non-living things, which may be micro and macro organism, it uses application of physics. For Example,
   i. Microscope which made by physicist is used to observe micro organism
   ii. Syringe is based on pressure

iii. **Mathematics**
   Physicist should master mathematics because physics problems may involve calculation

iv. **Astronomy**
   Defn: *astronomy is the scientific study of universe*. Universe composed by moon, sun, stars, comets, planets etc. it uses different instruments to study the universe which are made by physicists. For Example,
   i. Periscope and telescope are used to observe distant objects like stars etc
   ii. Material used to build the space like satellite are determined by physicists

v. **Geography**
   Defn: geography is the study of man and his environment. It includes soil, rainfall, mountains etc. it uses application of physics, for Example,
   i. Many instruments like rain gauge, wind vane developed by physicist
   ii. Barometer which used to measure the atmospheric pressure made by physicist
   iii. Formation of soil and rocks are explained by physics

Applications of Physics in Real Life

Physics influence our lives as follows aspects

1. At home

They include

i. **All tools and machinery**: such as Crowbars, Hammers, door handles, cutlery, hinges, car jack, pulleys, tillage implements etc made by knowledge of physics
ii. Electrical appliances: such as cooker, iron, heater, electric lamps, washing machine etc made by knowledge of physics

2. Medical field

They include;

i. Machines such laser, x-ray, incubators, ultrasound and infrared machines
ii. The knowledge used in handling and even actual use of these machines are based on the knowledge and skills acquired in Physics.

3. Source of energy

They include;

i. Batteries and generators provide electrical energy
ii. bulbs they provide light energy
iii. speaker gives us sound energy

4. Transport
All Vessels used in transportation is results of concept of physics. For Example, **cars**, **ships**, **aeroplane**, **trains** etc

5. Communication
All Devices used in communication systems is results of concept of physics. For Example, **telephones**, **modems**, **television**, **cables** etc

6. Entertainment
Physics enable people to enjoy a variety of leisure activities as is evident in photography, digital appliances, exercise machines and other sport equipment.

7. Industry
Physicists have been able to come up with tools and process that have resulted in advanced technological equipment and new discoveries.

8. in schools
The instruments and apparatus used in school laboratories are made through the application of the knowledge and skill acquired in a Physics class.

Importance of Learning Physics

i. The study of physics enables us to answer many question concerning physical properties of matter
ii. Enable different people to acquire skills that required in different profession. For Example, , engineering, teaching and architecture
iii. Enable us to designing and manufacture different items. For Example, , dry cell, simple machines, mobile phones etc
iv. Enable us to enjoy since we study practically

Introduction to Laboratory Practice

Laboratory

Defn: *laboratory is a working room for scientists*

OR

Laboratory is the special room that have been designed and equipped for carrying out scientific experiments for the purposes of study or research

Feature of Laboratory

The laboratory should have the follows

i. Water supply system
ii. Drainage system
iii. Electricity supply
iv. Well illuminated
v. Well ventilated
vi. Door open out ward
vii. Gas supply

Laboratory Apparatus

Defn: laboratory apparatus is the special tools and instruments commonly used to carry out the experiments in the laboratory**.**

Laboratory Apparatus

Items	Uses
Measuring cylinder	For measuring volume of liquids
Thermometer	For measuring temperature of substances
Stop watch	To measure time
Micrometer screw gauge	For measuring diameter of a wire
Vernier caliper	For measuring depth, length, internal and external diameters of objects
A ruler	For measuring length
Relative density bottle	For measuring relative density
Microscope	For magnifying very small objects
Beaker	Used as container for chemicals and other liquids. Also can be used to estimate the volume of liquids
Calorimeter	Used in experiment aimed at determining the quantity of matter.
Spring balance	For measuring force in Newton
Slotted masses	Used for measuring for the quantity of matter.
Magnets	For demonstrating attraction and repulsion
Ball and ring apparatus	For demonstrating thermal expansion
Bar breaking apparatus	To show forces that can be exerted during thermal expansion and contraction
Tripod stand	For providing a platform for heating for stability
Wire gauze	For providing equal distribution of heat while burning
Bunsen burner	As source of heat
Retort stand	For holding/gripping materials
Triple beam balance	Measuring mass
Flasks	For holding liquids during experiment
Pipette	For transferring specific but small volume of liquids
Burette	For measuring volume of liquid
Electronic balance	For measuring mass in more precise values

Nb:

After experiment, apparatus should be cleaned and return/stored to their position

Physics Laboratory

Defn: *physics laboratory is a working room for physicists*

Laboratory Rules

Defn: laboratory rule is the set of regulation governing physicist to conduct experiment and maintain the laboratory

Laboratory Rules

The follows include laboratory rules

i. Do not enter laboratory without permission
ii. Do not do an experiment without permission
iii. Do not start experiment without procedure information
iv. Follow instruction careful to avoid damage of apparatus
v. Follow instruction careful to avoid wrong result
vi. Handle apparatus with care to avoid damage
vii. Avoid handling apparatus and chemical until you asked by your teacher
viii. Avoid running, screaming or playing in the laboratory
ix. Avoid tasting, eating or drinking anything in the laboratory
x. Keep the window open for any fumes to flow out
xi. Do not touch any electrical equipment with wet hands
xii. Close gas and water taps before leaving the laboratory
xiii. All exits should be cleared of any obstruction
xiv. Arrange in orderly way material you want to use
xv. Report any accident and injuries to the teacher
xvi. Never use bare hand to handle hot object
xvii. Do not use dirty or broken apparatus
xviii. Solid wastes should not be disposed in the sinks
xix. Clean the working areas before leaving the laboratory
xx. Wash your hands with water and soap after perform an experiment

Laboratory Safety

Defn: laboratory safety is the condition in laboratory where physicist protected from danger, risk or injury

Laboratory Safety

The follows include laboratory safety

i. Laboratory should well ventilated and his door should open outward
ii. Fire extinguishers should be fitted in an accessible position with using instruction
iii. Laboratory floors should not have polished to avoid slippery
iv. First aid kit must present in the laboratory
v. Cabinets and drawer must present for storing apparatus
vi. All apparatus should have checked regularly to ensure they are safe to use
vii. Emergence exit should present and easy to access and use

First Aid

Defn: *First aid is the immediate assistance/care given to a sick/injured person before getting professional medical help*

Importance of First Aid

i. It helps to preserve life
ii. It prevents the victim's condition from becoming worse
iii. It promotes recovery by bringing hope and encouragement to the victim
iv. It helps to reduce pain and suffering
v. It prevents infection

First Aid Kit

Defn: *first aid kit is the small box contains items, which used to give help to a sick person***.** Usual labeled as "**FIRST AID**" and stored in a safe and easily accessible place

Items Found in First Aid Kit

Items	Uses
antiseptic soap	washing hands, wounds and equipment
Assorted bandage	Preventing direct contact with victim's body fluids
cotton wool	
Disposable sterile gloves	Preventing direct contact with victim's body fluids
Liniment	Reducing muscular pain
Painkillers	Relieving pain
Adhesive bandage (plaster)	Covering minor wounds
Thermometer	Measure body temperature

Sterile gauze	Covering wounds to protect them from dirty and germs
Safety pins, clips and tape.	Securing bandages or dressing.
Scissors and razor blades	Cutting dressing materials
Petroleum jelly	Smoothening and soothing skin.
Antiseptic solution	Cleaning fresh cuts and bruisers

Causes of Laboratory Accident
1. Slippery floor,
2. Incorrect use and handling of apparatus,
3. Gas leakages from faulty gas taps,
4. Fires,
5. Failure to follow the right experimental procedures and laid down safety rules.

First Aid Procedure
When accident occur we have to help the victim by following the follows procedures, consider the follows accidents

Electric Shock
When dealing with a victim of electric shock, remember to take the following action
1. Do not touch the victim who still in contact with electric current.
2. BREAK the contact by switching off the current at the switch or meter box if can be reached easily
3. If it is not possible to switch off the current, move the person from the current using a dry non-metallic object, for instance a piece of dry wooden plank or a bloom
4. If you suspect that the area has high voltage electricity, call for professional help immediately
5. If the victim is unconscious, check the breathing and pulse rate. If he or she has breathing problem, he prepared to resuscitate if necessary
6. Administer First Aid for shock, burns or other injuries sustained by the victim.
7. Seek medical assistance

Cuts (Or Wounds)
For a small cut or wound:
1. Wash your hands using soap and cleaning water.
2. Put on your gloves.
3. Wash your wounds using salty water and clean cloth.
4. Cover the wounds or cut with an adhesive bandage or plaster.

For a large cut or wounds:
1. Let the victim lay under a shade or allow her to sit comfortably.
2. Wash your hands using soap and clean water.
3. Put on your gloves.
4. Prevent further blood loss by applying pressure over the wound using a folded but clean handkerchief or cloth.
5. Use another cloth to secure the first one in place.
6. Take the injured person to hospital.

Fainting
Fainting is the situation where by victim is weak and unable to stand. It caused by too much heat and congestion

Steps to Help Victim
1. Take the person to a cool place or under a shade
2. Let him lie on his back with his legs raised higher than the head.
3. Loosen his clothes and ensure sufficient supply of air
4. Dip a clean handkerchief in water and press on his forehead.
5. Give him/her clean water to drink when he regains consciousness
6. If not, take the victim to the nearest hospital

Fire
Defn: fire is the state/process of combustion result light, heat, smokes and flame

Fire Triangle
Defn: fire triangle is the components needed to start a fire. This include
i. Fuel
ii. Oxygen
iii. heat

Caused of Laboratory Fire

i. Electrical faults
ii. Smoking materials
iii. Carelessness
iv. Ignorance and negligence

Basic Principles of Fire Prevention

i. No light of open fires near buildings
ii. No smoking in prohibited areas
iii. No interference with electrical installations
iv. all electrical appliances must off after use
v. all sources of heat should not have kept near the bench edge where they can easily be knocked down
vi. all flammable substances should be locked up in drawers or cabinets

Fire Extinguisher

Fire extinguisher is the one in which used to fight/stop fire to continue.

Types of Fire Extinguisher

The follows are types of extinguisher include

i. water/APW extinguisher
ii. Sand extinguisher
iii. Fire Blanket extinguisher
iv. Dry chemical extinguisher
v. Carbon dioxide extinguisher
vi. Halon extinguisher
vii. Foam extinguisher
viii. Wet chemical extinguisher
ix. ABC extinguisher

Mechanism of Fighting for Fire

Fire extinguisher stop fire by prevent one among of the fire components/fire triangle

Class of Fire

Fire classified according to materials burnt; therefore, we have six class of five namely

i. Class A
ii. Class B
iii. Class C
iv. Class D
v. Class E
vi. Class F

Class A

The burning materials is organic/ordinary solid combustible materials such as paper, wood, plastic, wool, clothing etc

Suitable Fire Extinguisher

Use any type of Fire extinguisher except carbon dioxide. However, water is suitable

Why carbon dioxide not suitable

Answer: when molecules of carbon dioxide reach fire gain heat and result lowered its density then escape away for fire and the fire continue.

Class B

The burning materials is flammable liquids such as petrol, paraffin, alcohol, kerosene etc

Suitable Fire Extinguisher

i. Use fire blanket or sand extinguisher if fire is a small
ii. Use dry powder, foam or carbon dioxide extinguisher if fire is large

Nb: water extinguisher is not suitable

Why water not suitable?

Answer: water is denser than flammable liquid so flammable liquids will float over water results the fire continues.

Class C

The burning materials is flammable gas such as methane, butane, propane etc

Suitable Fire Extinguisher

Use dry powder, foam or carbon dioxide extinguisher

Class D

The burning combustible metals such as magnesium, sodium, lithium etc

Suitable Fire Extinguisher

Use dry powder, foam or foam extinguisher

Class E

The burning electrical equipment such as damaged electrical cables, switchboards etc

Suitable Fire Extinguisher

Use carbon dioxide extinguisher

Nb: first switch off power from the mains switch

Class F
The burning cooking appliances with oils and fats at high temperature

Suitable Fire Extinguisher
Use wet chemical extinguishers

Warning Signs
Warning sign is the symbol established to ensure safety in the laboratory and in other field like goods or commodities. This signs should have obeyed to avoid accidents, include the follows

i. Toxic
ii. Irritant/harmful
iii. Flammable
iv. Oxidizing agent
v. Corrosive
vi. Radio active
vii. Danger of electric shock
viii. Fragile
ix. Explosive
x. Careful
xi. Keep away from water

Toxic
Toxic symbol means that a substance is dangerous and can cause death within a short time. Toxic substances containing poisonous ingredients, Example, of toxic substance is jik, mercury etc
Diagram:

Toxic Substance Enter the Body Through

i. Ingestion (by eating and drink)
ii. Inhalation (by breathing)
iii. By injection (by syringe, bite or insect)
iv. Contact (by touching)

Irritant/Harmful
Harmful symbol means that a substance is dangerous and can affect our health for long time. Example, of harmful substance is alcohol, paint, insecticide, tobacco, ammonia etc, mercury etc

Diagram of harmful

Diagram of Irritant

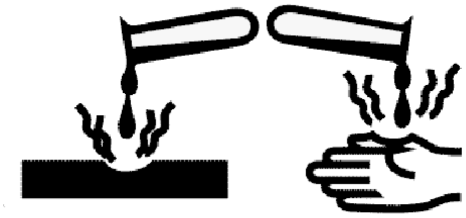
Flammable
Flammable symbol means that the substance can catch fire easily. For Example, , gasoil, kerosene, petrol, butane, methane, spirit, nail polish remover, turpentine etc
Diagram:

Oxidizing Agent
Oxidizing agent symbol means that the substance can speed up the rate of burning. For Example, , oxygen gas, chlorine gas, fluorine gas and hydrogen peroxide
Diagram:

Corrosive

Corrosive symbol means that the substance causes gradual change if contact with various materials. For Example, , concentrated sulphuric acid, concentrated hydrochloric acid, concentrated nitric acid, concentrated sodium hydroxide, concentrated ammonia etc

Diagram:



Radio Active

Radioactive symbol means that the substance emits harmful radiations that penetrate human body and cause damage. For Example, , uranium, plutonium etc

Diagram;

Danger of Electric Shock

Danger of electric shock symbol means that the substance has high voltage which should not touch.

Diagram:

Fragile

Fragile symbol means that the substance should handle with care to prevents them from breaking. For Example, glass etc.

Diagram:

Explosive

Explosive symbol means that the substance can erupt/explode easily. Always sore in a special container

Diagram:

Nb:

Never store explosive material in glass container because when explode pieces of glass would fly all over and injure people

Careful

Careful symbol that is the caution advice you to be carefully

Diagram:

Keep Away from Water

Keep away from water symbol that is the caution advice you to keep item away from the water. For Example, computer, mobile phones, radio etc

Diagram:

Scientific Investigation

Defn: scientific method is a set of techniques used by scientists to investigate a problem/answer question. Also called *scientific procedure or scientific investigation or scientific methods*

Steps of a Scientific Method

The following is the steps followed when carrying out a scientific investigation

i. Problem identification
ii. Asking questions
iii. Formulation a testable hypothesis
iv. Performing an experiment
v. Data collection and analysis
vi. Data interpretation
vii. Data presentation
viii. Draw a conclusion

Problem Identification

In this step the physicist makes a puzzling observation. For Example, change in temperature cause wind

Asking Questions

In this step, the physicist asks a specific question based on what he/she observed and wants to learn. For Example, how change in temperatures cause wind?

Formulation a Testable Hypothesis

A hypothesis is an intelligent guess that tries to explain an observation. The change in temperature causes wind

Performing an Experiment

Defn: *An experiment is the test under controlled conditions*. The aim of experiment is to test whether hypothesis is true or false. It based on variable to test hypothesis

Defn: variable is the condition in which changes to obtain set of values

Types of Variable

There are three types include

i. Dependent variable
ii. Independ variable
iii. Controlled variable

Dependent Variable

Defn: Dependent variable is the condition to measure or observed to obtain the results. For Example, time

Independ Variable

Defn: Independ variable is the conditions manipulate to obtain the results. For Example, wind

Controlled Variable

Defn: Controlled variable is the condition may change (kept constant) to obtain the results. For Example, temperature

Data Collection and Analysis

It Concern recording what you have observed during experiment. Always kept in the table for Example,

Temperature (℃)	**Wind (m/s)**
10	200
20	400
30	600
40	800

Data Interpretation

In this step we look trend or patterns and explain why they occur that way. For Example, from *the table above when temperature increase also winds speed increase therefore temperature is direct proportional to wind speed*

Data Presentation

In this step it involves the uses of mathematics concept to represent the data or results collected. Pie charts, graphs and formulae may use. For Example,

Draw a Conclusion

In this step, it concerning about summary of the experiment. It includes a statement that either proves or disproves the hypothesis. For Example, in our experiment change in temperature cause wind

Application of Scientific Procedure

i. When carrying out experiment: test is done in order to study what happens and gain new knowledge
ii. When carrying out project work: project is a planned piece of work that involves careful study of a subject/problem over a period of time, so as to find information on subject/problem
iii. When carry out field study: a field study involves doing practical work in order to find answer to problems and to test hypothesis. A field study also called field work

Significance of the Scientific Procedure

i. It helps us to solve scientific problems
ii. It helps us to gain new knowledge
iii. It helps us to conduct project work
iv. It helps us to carry out field study
v. It helps us to solve problems or answer scientific questions

Measurement

Defn: measurement is the process of assigning number to event or measurement is the process of assigning number to observation

NB:

i. Every measurement has two parts include
   a/ Number part
   b/ Unit part

   Number Part
   This gives the results or magnitude of the comparison or event or observation

   Unit Part
   This identifies the particular unit used to make the measurement.

   Example,
   30cm
   130 ≡ Number part
   Cm ≡ unit part

ii. Each part of measurement is equally important and must be included if the measurement is to be meaningful and useful
iii. The complete measurement (100km, 1kg or 5s) is called a physical quantity
iv. The international system of unit usually abbreviated as SI Unit and we shall use throughout physics course

Basic Fundamental Quantities

It categories into two include
i. Fundamental quantities
ii. Delivered quantities

Fundamental Quantities

Defn: A fundamental quantity is the quantities in which does not obtained from other physical quantity. Fundamental quantities of include
i. Length
ii. Mass
iii. Time
iv. Temperature
v. Amount of substance (mole)
vi. Electric current
vii. Luminous intensity

Fundamental Quantity and Si Unity

Quantities	SI unit	Unit symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	S
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	Cd

Length

Defn: Length is the distance between two points. Where by distance is the path taken by a particle in space between two points or object. The distance around an object is called perimeter. SI unit of length is metre (m). It is measured by metre rule, tape measure, Vernier calliper and micrometer screw gauge

Metre Rule

Defn: Metre rule is the mainly wooden graduated in 100 centimeters or 1metere. The reading should be perpendicular to the mark otherwise the parallax error occurs

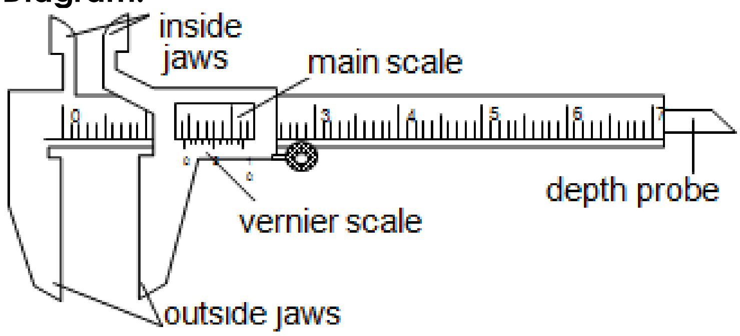
Parallax Error

Defn: parallax error is the apparent motion of one object related to another when the position of the eye is varied

Vernier Calliper

Defn: Vernier calliper is an instrument used to measure length to the nearest accuracy of 0.01cm

Diagram:



i. The inside jaws used to measure internal diameter
ii. The external jaws used to measure external diameter

Scale of Vernier Calliper
It contains two scale namely
i. Fixed/main scale
ii. Vernier scale

Fixed Scale
Fixed scale gives reading in centimeter (cm) or millimeter (mm).

How to read fixed scale (M.S)
It like metre rule scale so we read as we read main scale of metre rule, the reading should take in the parallel mark between fixed scale and 0 Vernier scale mark

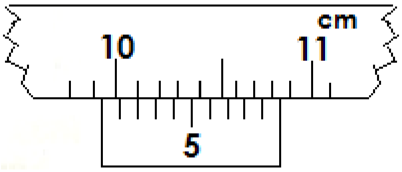
Vernier Scale
Vernier scale gives reading in hundredth of a centimeter (0.01cm) or thousands of millimeter (0.001mm). Vernier scale has 10 divisions which cover 9division of main scale, when this divided into 10 equal intervals the results is the difference between the main scale divisions which called least count
M.s division = 1cm/10 = 0.1cm
V.s division = 9cm/0.1 = 0.09cm
Least count = 0.1 – 0.09 = 0.01cm

How to read Vernier scale (V.S)?
The reading should take in the parallel mark between fixed scale and Vernier scale then convert it to cm or mm

Steps to Read a Vernier Calliper
i. Read main scale (M.S)
ii. Read Vernier scale (V.S)
iii. Sum up the main scale (M.S) and Vernier scale (V.S)
iv. Convert into required unit of length

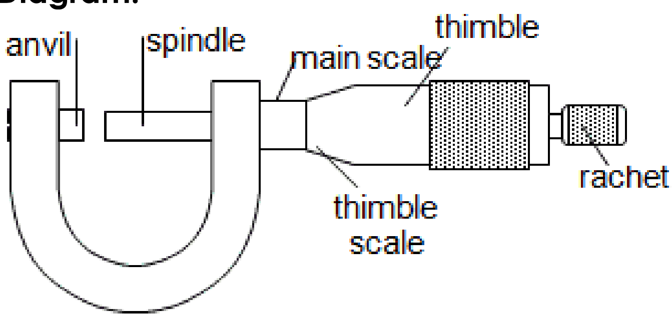
Nb:
i. Before use Vernier calipers close its jaws to determining if it contain zero error
ii. zero error is error arises when scale is not starting from zero mark
iii. Zero error should be added or subtracted from all subsequent reading

Example,
From below diagram, determine the diameter of object.



Solution:
i. Main scale, m.s = 9.9cm
ii. Vernier scale, v.s = 2 x 0.01 = O.02cm
iii. m.s + v.s = (9.9 + 0.02) cm = 9.92cm
iv. the required unit is cm
The diameter is 9.92cm

Micrometer Screw Gauge
Defn: Micrometer screw gauge is an instrument used to measure length to the nearest accuracy of 0.001cm or 0.01mm
Diagram:



Scale of Micrometer Screw Gauge
It contains two scale namely
i. main scale in mm
ii. thimble scale

Fixed Scale
Fixed scale gives reading in centimeter (cm) or millimeter (mm).

How to read main scale (M.S)
It like metre rule scale so we read as we read mail scale of metre rule

Thimble Scale
Thimble scale gives reading in thousandth of a centimeter (0.001cm).

How to read thimble scale (t.S)?
The reading should take in the horizontal or straight line in mark or main scale

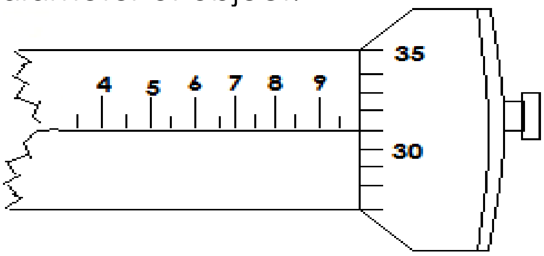
Steps to Read Micrometer Screw Gauge
i. Read main scale (M.S)
ii. Read Vernier scale (V.S)
iii. Sum up the main scale (M.S) and Vernier scale (V.S)
iv. Convert into required unit of length

Nb:

i. before use micrometer screw gauge close its jaws to determining if it contain zero error
ii. zero error is error arises when scale is not starting from zero mark
iii. Zero error should be added or subtracted from all subsequent reading

Example,

From below diagram, determine the diameter of object.



Solution:

i. Main scale, m.s = 9.5mm = 0.95cm
ii. thimble scale, v.s = 31 x 0.001 = O.031cm
iii. m.s + v.s = (0.95 + 0.031) cm = 0.95315cm
The diameter is 0.95315cm

Note

Some distance is large and other is small to cope with this great difference, there other unity obtains from the metre, namely
Kilometre (km)
Centimetre (cm)
Millimetre (mm)
Micrometre (km)
Nanometre (nm)

Their equivalent is as follows

1km = 1000m
1m = 100cm
1cm = 10mm
1mm = 1000μm
1μm = 100nm

Mass

Defn: Mass is the quantity of matter in an object. SI unit of mass is kilogram (kg). It is measured by device or instrument known as beam balance.

Beam Balance

Defn: beam balance is the device used to measure mass of an object

Types of Beam Balance

It categorized into three include

i. Lever arm balance
ii. Triple beam balance
iii. Digital balance

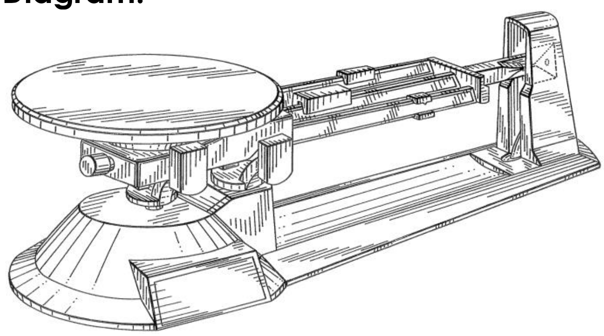
Lever Arm Balance

Lever arm balance uses principle of moment to measure the mass of unknown objects

Triple Beam Balance

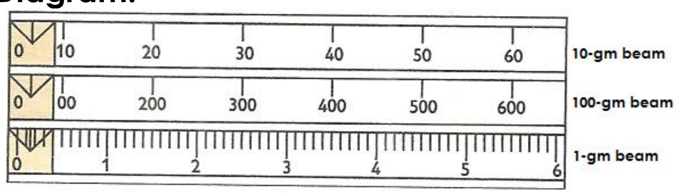
Triple beam balance uses principle of moment to measure the mass of unknown objects in gram.

Diagram:



It contains three (triple) beam with specific standard mass marking namely

Diagram:



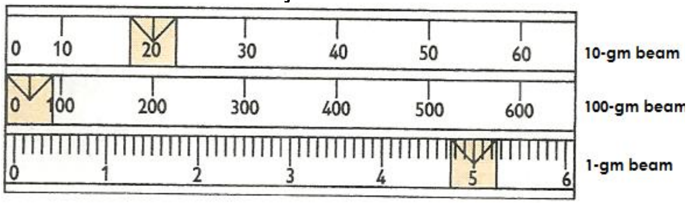
i. 100-gram beam
ii. 10-gram beam
iii. 1-gram beam

How to Use Triple Balance?

Move all three beam left when pan empty until reads zero mark

i. Place object to the pan
ii. Move the 100-gram weight to the right until the indicator just drops below the fixed mark. Move again to the left mark and record the value
iii. Move the 10-gram weight to the right until the indicator just drops below the fixed mark. Move again to the left mark and record the value
iv. Move the 1-gram weight to the right until the indicator just drops below the fixed mark. Move again to the left mark and record the value

Example,
The diagram below shows the measurement of piece of iron. Determine the mass of the object



Solution:
100-gram beam reading is 0g
10-gram beam reading is 20g
1-gram beam reading is 5g
Mass of object is 0g + 20g + 5g = 25g
The mass of object is = 25g

Digital Balance
Digital balance is very sensitive weighting balance. It can measure masses to an accuracy of the thousandth (0.001g) of a gram. The object placed on the pan on top of the balance and the mass read from the digital display
Diagram:

Note:
i. Mass should not be confused with weight
ii. The other unit of mass based on the kilogram are tone (t), gram (g) and milligram (mg)
Their equivalent
1t = 1000kg
1kg = 1000g
1g = 1000mg

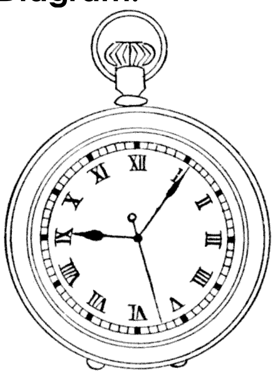
Weight
Defn: weight is the force of gravity acting on an object? SI unit of weight is Newton (N). It is measured by spring balance. It is varying with position
Mathematically:
W = mg
Where:
W = weight
M = mass
g = gravitation force

Different Between Mass and Weight

Mass	weight
Is the quantity of matter in an object	Force of gravity on an object
Is constant	Varies with position
Fundamental quantity	Delivered quantity
Si unit is kilogram (kg)	Si unit is Newton (N)
Measured by beam balance	Measured by spring balance

Time
Defn: Time is the rate at which an event happens. It is measured by using clock or wristwatch or stopwatch

Stopwatch
Defn: stopwatch is a device that is hold in the hand to show time elapsed
Diagram:



Types of Stopwatch
There are two types of stopwatch include
i. Mechanical stopwatch
ii. Digital stopwatch

Mechanical Stopwatch
Defn: Mechanical stopwatch is powered by spring

Digital Stopwatch
Defn: Digital stopwatch is powered by spring. Digital stopwatch is more accurate than mechanical stopwatch. They include date and time

Nb:
The time taken for one complete oscillation can be obtained by period

Period = $\frac{time\ taken\ for\ oscillation}{\text{number of oscillation}}$

T = $\frac{t}{\text{n}}$

Delivered Quantities

Defn: Delivered quantity is the quantity which obtained from physical quantity. It includes

i. Volume
ii. Density
iii. Speed
iv. Velocity
v. Force
vi. Pressure
vii. Weight

Delivered Quantity and Their Si Unit

Quantity	Si unit	Symbol
Area	Square metre	m^2
Volume	Cubic metre	m^3
Wight	Newton	N
Work	Joules	J
Velocity	Metre per second	m/s

Volume

Defn: volume is the quantity of space that an object occupies. Si unit of volume is cubic metre (m^3)

NB:
Other unity obtains from the cubic metre, namely

i. Kilometer (km)
ii. Cubic Centimeter (cm^3)
iii. Cubic decimeter (dm^3)
iv. Milliliter (ml)
v. Litre (l)

Their equivalent is as follows

i. 1l = 1000 cm^3
ii. 1l = 1000 mL
iii. 1L = 1dm^3

Volume of Solid Regular Object

Defn: regular object is the object with known shape. For Example, cylinder, rectangular, cube etc. The volume of regular object is obtained by formula

Formula of Volume

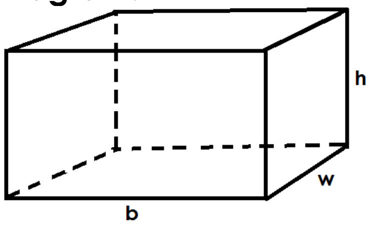
Volume of object is obtained by multiplication of area (A) of regular object and height (h) of regular object

V = A x h

Where:
A = area of regular object
h = height of regular object

Volume of Cube Object

Diagram:



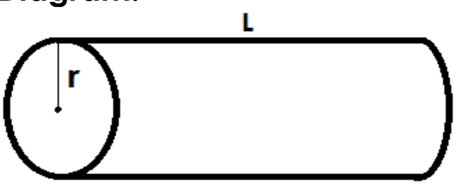
Formula: v = A x h
But: A = l x b
Then: v = l x b x h
Where:
V = volume
l = length of cube
h = height of cube
b = breath of cube
But: for cube l = h = b

Volume of Rectangular Object

Formula: v = A x h
But: A = l x b
Then: v = l x b x h
Where:
V = volume
l = length of rectangular object
h = height of rectangular object
b = breath of rectangular object

Volume of Cylinder Object

Diagram:



Formula: v = A x h
But: A = πr^2
Then: v = πr^2 x h
Where:
V = volume
r = radius of object
h = height of object

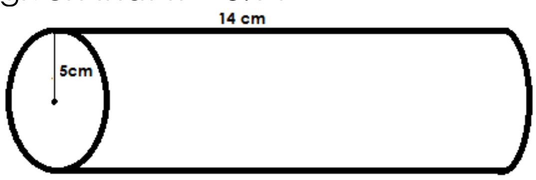
Volume of Sphere Object (h = r)

Diagram:

Formula: v = A x h
But: A = πr^2
Then: v = $\frac{4\pi r^3}{3}$
Where:
V = volume
r = radius of object

Example,
Calculate the volume of rectangular block of sides 15cm, 8cm and 7cm
Data given:
Length of block, l = 15cm
Breath of block, b = 8cm
Height of block, h = 7 cm
Volume of block, v =?
Solution:
From: v = A x h
But: A = l x b
Then: v = l x b x h
v = 15 x 5 x 7
v = 840 cm^3

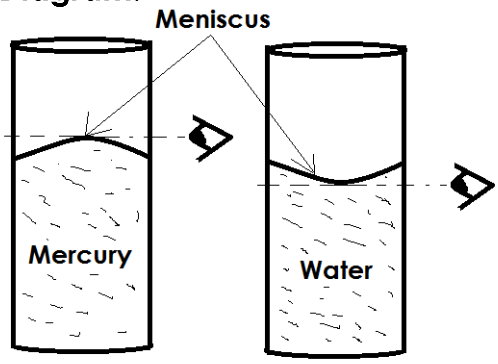
Example,
Calculate the volume of figure below given that π = 3.14



Data given:
Length of cylinder, l = 14cm
Radius of cylinder, r = 5cm
Pie, π = 3.14
Height of block, h = 7 cm
Volume of block, v = ?
Solution:
From: v = πr^2 x l
v = πr^2 x l = 3.14 x 5 x 5 x 14
v = 3.14 x 5 x 5 x 14 = 1099cm^3
v = 1099 cm^3

Volume of Liquid
Litre is the standard unit used for measuring the volume of liquids. The instrument or apparatus used to measure volume of liquids include
i. Burette
ii. Pipette
iii. Volumetric flask
iv. Measuring cylinder

Nb:
During measurement eye should be line with the meniscus of the liquid
Diagram:



Volume of Gas
In order to get volume of gas you have to fills in any container then
i. Measure the volume of gas (Example, by using syringe)
ii. Measure the volume of that container (Example, balloon)

Volume of Solid Irregular Object
Defn: regular object is the object with unknown shape. For Example, stone, human body etc. The volume of irregular object is obtained by displacement method or immersion method

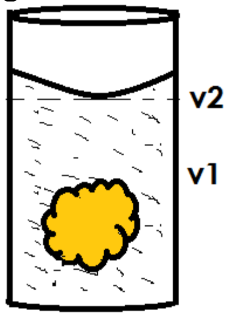
Displacement Method
Volume of irregular object is based on the principle that when an object is completely submerged in water it's displacing a volume of water equal to its own volume. This done by
i. Graduated cylinder
ii. Eureka can or overflow can

Graduated Cylinder
Suppose you want to measure the volume of a small stone. The following steps are necessary
i. Fill graduated cylinder to known mark (let be 30ml)
Diagram:

ii. Record the water volume i.e. 30ml as v1

iii. Gently drop the stone into the water

Diagram:



iv. Record the new volume of water as v2

v. Calculate the different in volume which is the volume of stone, v

v = v2 - v1

Example,

When an irregular solid was immersed in $65cm^3$ of water the water level rises to $81cm^3$. What was the volume of the solid?

Data given

Initial volume, v1 = $65cm^3$

Final volume, v2 = $81cm^3$

Volume used, v = ?

Solution:

From: v = v2 - v1

v = 81 – 65 = 16 cm^3

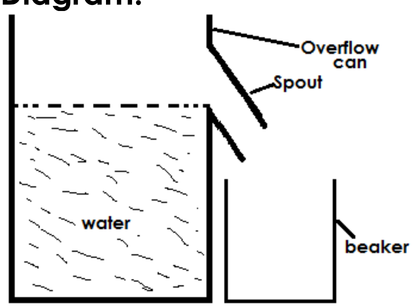
v = 16 cm^3

Eureka Can

If the object is large to fit into graduated cylinder, eureka can common known as an overflow can used. The following steps should be followed

i. Fill the overflow can with water up to the level of the spout

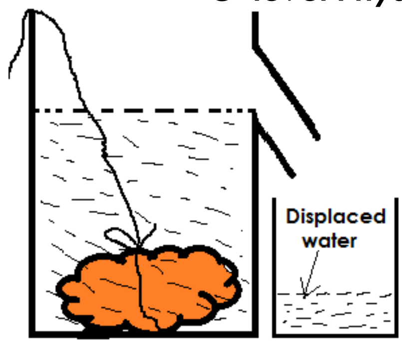
Diagram:



ii. Tie the irregular object with a string; gently drop the irregular object into water using string

iii. The irregular object will displace some water which will be collected in the beaker

Diagram:



iv. Transfer the displaced water into a graduated cylinder

v. Measure the volume of the water, which is the volume of irregular object

Density

Defn: *Density is the mass per unit volume of a substance*. SI unit of kg/m^3 or g/cm^3

Mathematically:

ρ = m/v

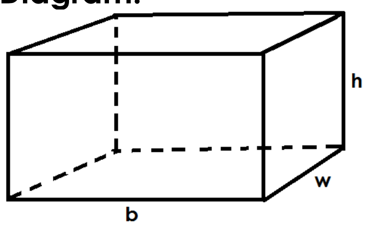
Their equivalent is as follows

1000 kg/m^3 = 1g/cm^3

Density of Solid Regular Object

The density of regular object can be found easily. For Example, to measure the density of rectangular block

Diagram:



Procedure:

i. Measure the mass, m

ii. Measure the volume, v = l x h x b

iii. calculate density, ρ

ρ = m/(h x l x b)

Density of Solid Irregular Object

The density of irregular object can be found difficult. For Example, to measure the density of stone

Diagram:

Procedure:

i. Measure the mass, m

ii. Measure the volume, v

iii. calculate density, ρ

$\rho = m/v$

Table of Density of Different Substance

Substance	Density (g/cm^3)
Aluminium	2.7
Copper	8.3
Gold	19.3
Iron	7.8
Lead	11.3
Glass	2.5
Brass	8.5
Mercury	13.6
Silver	10.5
Steel	7.9
Cork	0.2
Ice	0.92
Alcohol	0.8
Milk	1.03
Kerosene	1.0
Water (pure)	1.0
Water sea (sea)	1.03
Sand	2.5

Example,
The mass of a solid object with an irregular shape is 40g. The solid object is totally immersed in water of volume $50cm^3$ containing in a measuring cylinder rise to $70cm^3$

Data given
Mass of object, m = 40g
Initial volume, $v1 = 50cm^3$
Final volume, $v2 = 70cm^3$
Volume used, v = ?

Solution:
From: $\rho = m/v$
But: $v = v2 - v1 = 70 - 50 = 20\ cm^3$
Then: $\rho = m/v = 40/20 = 2g/cm^3$
$\rho = 2\ g/cm^3$

Density of Liquids
It can be determined by using burette or density bottle by following step

i. Measure the mass of empty burette or density bottle, m1
ii. Fill the liquid in the burette or density bottle and measure its mass, m2
iii. Calculate the mass of liquid by, m = m2 –m1
iv. Either by graduated cylinder or overflow can Measure volume of liquid of liquid, v
v. Calculate density of liquid, ρ
$\rho = m/v$

Example,
In an experiment to determine the density of liquid, y, Sophia a form IC student obtained the following Mass of beaker is 500g, Mass of beaker and liquid is 600g and Volume of liquid, $v = 25\ cm^3$. Find the density

Data given
Mass of beaker, m1 = 500g
Mass of beaker and liquid, m2 = 600g
Mass of liquid, M = (m2 – m1) = 600–500 = 100g
Volume of liquid, $v = 25\ cm^3$
Density of liquid, ρ = ?

Solution
From: $\rho = m/v$
Then: $\rho = m/v = 100/25 = 4g/cm^3$
$\rho = 4\ g/cm^3$

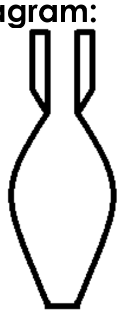
Density of Granules
Granules are difficult to determine the density of very small and fine particles such as sand or lead shots. Density bottle is used to determine the density of granules. Density bottle is used to determine the density of granules.

Diagram:

Procedure to Determine Granules Density

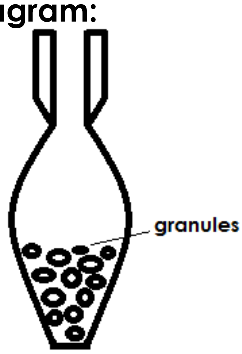
i. Measure mass of empty density bottle, m1

Diagram:



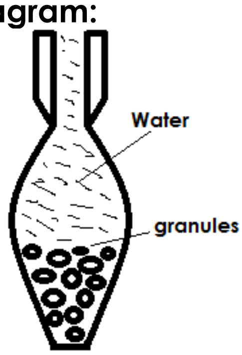
ii. Add a small amount of sand in the density bottle and measure its mass, m2

Diagram:



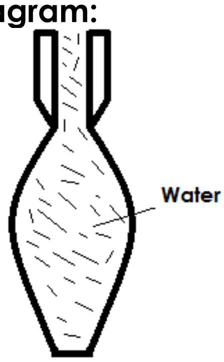
iii. Add water into the density bottle containing granules until it is fully and record the new mass, m3

Diagram:



iv. Remove granules and water from density. Then fill the density bottle with water, measure their mass, m4

Diagram:



v. Calculate the density of granules

Mathematically:

ρ = ms/vs

Where:

ms = mass of granules
vs = volume of granules
mw = Mass of water
vw = Volume of water

But:

Mass of water, mw = (m4 – m1) - (m3 – m2)
Volume of water, vw = (m4 – m1) - (m3 – m2)
Volume of water, vw = (m4 – m1) - (m3 – m2)
Mass of granules, ms = (m2 – m1)
Finally:
ρ = ms/vs = (m2 – m1)/((m4 – m1) - (m3 – m2))

$$\rho = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$$

Example,

Given that
Mass of empty density bottle, m1 = 4g
Mass of density with sand, m2 = 94g
Mass of density bottle with sand and water, m3 = 110g
Mass of density bottle full of water, m4 = 70g
Find the density of sand from above reading

Data given:

Mass of empty density bottle, m1 = 4g
Mass of density bottle and sand, m2 = 94g
Mass of bottle, sand and water, m3 = 110g
Mass of bottle and full water, m4 = 70g
Density of sand, ρ = ?
Solution

From: $\rho = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$

$\rho = \frac{94 - 4}{(70 - 4) - (110 - 94)}$

$\rho = \frac{90}{66 - 16}$

$\rho = \frac{90}{50} = 1.8$

ρ = 1.8 g/cm^3

Relative Density of a Substance

Defn: relative density of a substance is the ratio of the substance density to the water density. It has no SI unit. This shows the times of denser of substance to the water

Mathematically:

R.D = ρs/ρw

Where:

R.D = relative density
ρs = density of substance
ρw = density of water

Since:

ρs = ms/vs - - - - - - - - - - (1)
ρw = mw/vw - - - - - - - - - - (2)
Divide eqn (1) to eqn (2)
ρs/ρw = (ms/vs)/(mw/vw)
ρs/ρw = (ms x vw)/(mw x vs)
When: vw = vs , ρs/ρw = R.D
Then: R.D = ms /mw

Where:

ms = mass of substance
ρs = density of substance
ρw = density of water
vs = volume of substance

mw = mass of water
vw = volume of water
(vw = vs) = its volume is equal to the volume of a substance
R.D = ms /mw

Example,
An empty density bottle weighs 20g. When full of water it weighs 70g and when full of liquid it weighs 60g. Calculate
(a) The relative density of the liquid
(b) Its density
Solution:
(a) **Data given**
Mass of liquid, ms = (60-20) = 40g
Mass of water, mw = (70-20) = 50g
Relative density, R.D =?
Solution
From: R.D = ms /mw
R.D = 40 /50 = 0.8
R.D = 0.8

(b) **Data given**
R.D = 0.8
Density of water, $\rho w = 1\ g/cm^3$
Density of liquid, ρs = ?
Solution
From: R.D = ρs/ρw – make ρs subject
ρs = R.D x ρw
ρs = R.D x ρw = 0.8 x 1
ρs = 0.8 x 1 = 0.8
ρs = 0.8 g/cm^3

Example,
In an experiment to determine the relative density of liquid x, form IB physics students obtained the following results after various measurements
Mass of relative density bottle, m1 = 15g
Mass of relative bottle and liquid x, m2 = 35g
Mass of relative density bottle and water, m3 = 40g
Volume of bottle, $v = 25cm^3$
Calculate
(a) Density of water in kg/m^3
(b) Density of liquid x in kg/m^3
(c) Relative of liquid x
Data given
Mass of relative density bottle, m1 = 15g
Mass of relative bottle and liquid x, m2 = 35g
Mass of relative density bottle + water, m3 = 40g
Volume of bottle, $v = 25cm^3$
Volume of water, $v = 25cm^3$

Solution:
(a) Density of water in kg/m^3
From: ρw = mw/vw
But: mw = m3 - m1= 40 – 15 = 25 g
Then: $\rho w = mw/vw = 25/25 = 1g/cm^3$
But: $1g/cm^3 = 1000kg/m^3$
$\rho w = 1000\ kg/m^3$

(b) Density of liquid x in kg/m^3
From: ρx = mx/vx
But: mx = m2 - m1= 35 – 15 = 20 g
Then: $\rho x = mx/vx = 20/25 = 0.8g/cm^3$
But: $0.8g/cm^3 = 800kg/m^3$
$\rho w = 800\ kg/m^3$

(c) Relative density of liquid x
From: R.D = ρs/ρw
R.D = ρs/ρw = 800/1000 = 0.8
R.D = 0.8

Density of Mixture
Defn: Mixture is compound consist two or more substances which combine physically. Example, water and oil, maize and rice, maize and alcohol etc
NB:
$\rho t \neq \rho 1 + \rho 2$
vt = v1 + v2
mt = m1 + m2

Where:
ρt = density of mixture
ρ1 = density of first substance
ρ2 = density of second substance
vt = volume of mixture
v1 = volume of first substance
v2 = volume of second substance
mt = mass of mixture
m1 = mass of first substance
m2 = mass of second substance

Example,
A crown made of gold and silver has a volume of 60ml and a mass of 1.05kg. Find the mass of gold contained in the crown. (Density of gold 19.3g/ml, density of silver is 10.5g/ml) Just make conclusion
Data given

Density of Crown, ρt = ?
Mass of Crown (total), mt = 1.05kg = 1050g
Volume of Crown (total), vt = 60ml = 60cm^3
Density of gold, ρg = 19.3g/ml
Mass of gold, mg =?
Volume of gold, vg = ?
Density of silver, ρs = 10.5g/ml
Mass of silver, ms =?
Volume of silver, vs = ?

Solution

The crown is mixture
$Vt = vg + vs$ - - - - - - - - - - -(1)
$mt = mg + ms$ - - - - - - - - - -(2)
$\rho t \neq \rho g + \rho s$

But:
$vg = mg/\rho g$
$Vs = ms/\rho s = (vt - vg)$
$Vt = mt/\rho t$
$ms = (vt – vg)\rho s$- - - - - - - - - - - (3)
$mt = mg + ms$- - - - - - - - - - - (4)
$mg = vg \times \rho g$ - - - - - - - - - - - (5)
Substitute eq (3), (4) and (5) into eq (2)
$mt = mg + ms$
$mt = vg \times \rho g + (vt – vg)\rho s$
$mt = vg\rho g + vt\rho s – vg\rho s$ – make vg subject
$vg = (mt – vt\rho s)/(\rho s – \rho s)$
$vg = (1050 – 60 \times 10.5)/(19.3 – 10.5)$
$vg = 47.73$ cm^3
Since: $vg = mg/\rho g$ - make mg subject
$mg = vg \times \rho g = 47.73 \times 19.3 = 921.14g$
$mg = 921.14g = 0.92114$ kg

Example,

250ml of water are mixed with one litre of methylated spirit. Calculate mass of mixture, assuming that there is no change of volume of mixing (relative density of methylated spirit is 0.80)

Data given

Mass of mixture, mt = ?
Mass of water, mw = ?
Mass of spirit, ms = ?
Volume of water, vw = 250ml = 250cm^3
Volume of spirit, vs = 1l = 1000cm^3
Volume of mixture, vt = 1250cm^3
Relative density of spirit, R.D = 0.8
Density of water, ρw = 1g/ml
Density of spirit, ρw = 0.8g/ml

Solution

From: $Vt = vw + vs$ - - - - - - - - - -(1)
$mt = mw + ms$ - - - - - - - - - -(2)
$\rho t \neq \rho w + \rho s$

But: $vw = mw/\rho w$
$Vs = ms/\rho s$
$Vt = mt/\rho t$
$ms = vs \times \rho s = 1000 \times 0.8 = 800g$
$mw = vw \times \rho w = 250 \times 1 = 250$

Then: $mt = mw + ms = 800 + 250 = 1050g$
$mt = 1050g$

Application of Density and Relative Density in Our Daily Life

i. It is used to design of various structure like ship, planes etc
ii. Used to determine density of unknown substance using known density of another
iii. Used to select building materials
iv. Use to design equipment used in swimming and diving

Important of Measurement

1. Used in architecture and engineering in designing bridge and other structures
2. Used in school to determine number of student
3. To identify the space occupied by substance
4. To know the quantity of matter
5. To know when it was in a given position
6. To know the rate of working
7. To identify the size of substance
8. It helps in decision making
9. It helps to tell how it will last

Force

Defn: *force is an influence that changes or tends to change the state of rest or uniform motion*

Or

Defn: *force is a push or pulls experience by an object*. It measured by device/instrument spring balance. The SI Unit of force is Newton (N)

Nb:

Branch of science deals the effect of force on matter is called **Mechanics**

Types of Force

There are types of forces include

i. Fundamental forces
ii. Non fundamental forces

Fundamental Forces

Defn: *Fundamental force is the forces in which the two interacting object are not in physical contact with each other*. Fundamental force is the basic forces in nature that cannot be explained by the action of another force. Also is called interactive force or non-contact forces or action-at-a-distance force or field force. For Example,

i. Gravitational force
ii. Electric force
iii. Magnetic force

Types of Fundamental Force

There are four (4) types include

i. Force of gravity (weight)
ii. Electromagnetic force
iii. Strong nuclear force
iv. Weak nuclear force

Force of Gravity

Defn: *Gravitation force is the force pulls objects toward the Planet*. For Example, all object falls down if thrown up due to force of gravity is pulling the objects toward the earth surface. It represented by letter **g**, it has constant value of **10 N/kg** or **9.8N/kg**. It also called weight

W = mg

Where:

m = mass of object
g = gravitational force

Properties of Force of Gravity

i. It is always attractive
ii. Weakest force among others force
iii. It is central force (it act on object along the line joining the centre of object and planet)
iv. It operates over very long distance

Example,

Rocket moves from the earth to a planet x. if it weighs 10, 000N and 30N on the earth and on plane t x respectively determine the gravitation force on planet x

Data given

Earth Weigh, we = 10, 000N
Planet x Weigh, wx = 30N
Earth force of gravity, ge = 10N/kg
Mass of the rocket, m = ?
Planet x force of gravity, gx = ?

Solution:

From: w = mg
Then: we = mge – find value of m
M = we/ge = 10000/10 = 1000kg
M = 1000kg
Now: wx = mgx – find value of gx
gx = we/m = 30/1000 = 0.03N/kg
gx = 0.03N/kg

Electromagnetic Force

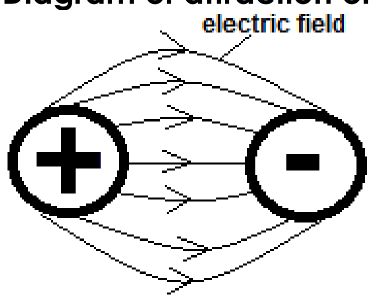
Defn: *Electromagnetic force is the force associated with production field due to movement of electrons*. Include both electric and magnetic forces. For Example, formation of water molecule, Atoms attract each other due to electromagnetic force

Diagram of formation of oxygen gas

$$O + O \Longrightarrow O_2$$

In two charge placed near each other may attract (unlike charge) or repel (like charge) due to electromagnetic force

Diagram of attraction of charge



Properties of Electromagnetic Force

i. it may be attractive or repulsion in nature
ii. It is a central force
iii. It is stronger than gravitational force
iv. It is a long-range (operates over a very long distance)

Strong Nuclear Force

Strong nuclear force is the force which holds the constituents of the atomic nucleus. It acts within the nucleus of the atom. For Example, nuclear energy plant force obtained from the splitting (fission) or fusion of the nucleus of the atom

Diagram of fusion

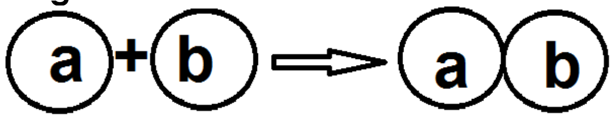
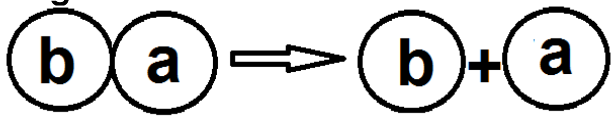


Diagram of fission



Properties of Strong Nuclear Force

i. It is basically an attractive force
ii. It is a short-range (operates only up to distance of the order of 10^{-14}m)
iii. It is a non-central force (it does not act at the centre)
iv. It is stronger than gravitation force

Weak Nuclear Force

Weak nuclear force is the force which involve in certain nuclear. For Example, in formation of water from reaction between oxygen gas and hydrogen gas weak nuclear force is used to bond the water molecules

Properties of Weak Nuclear Force

i. Stronger than gravitation force
ii. Weaker than electromagnetic force
iii. Weaker than strong nuclear force
iv. Operates on small ranges of up to 10^{-17}m.

Non - Fundamental Forces

Defn: *Non fundamental forces is the forces in which the two interacting object are in physical contact with each other.* Fundamental force is the basic forces in nature that can be explained by the action of another force. Also is called non-interactive force or contact forces. For Example,

i. Kicking a ball
ii. Compressing a spring
iii. Pulling a door
iv. Friction
v. Tension
vi. Resistance
vii. Elastic forces etc

Effects of Forces

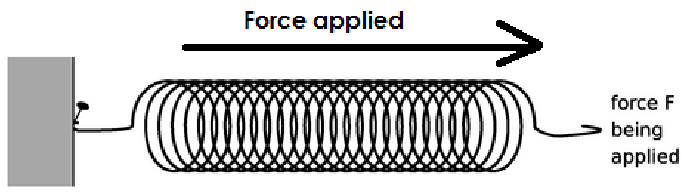
Forces have several effects on object but the follows include the effects in daily life

i. Stretching or tensile
ii. Compression or restoring
iii. Attraction
iv. Repulsion
v. Torsion
vi. Friction
vii. Viscosity
viii. Air resistance

Stretching Force

Defn: *Stretching force is the force produce elongation of object if pulled*. For Example, when spring is pulled the stretching force elongate the spring

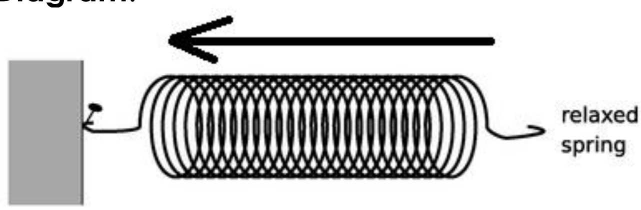
Diagram



Compression Force

Defn: *Compression force is the force produce squeeze of object to original shape and size*. For Example, if stretching force removed elongated spring squeeze to its original size and shape

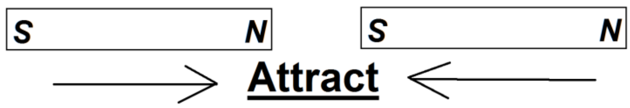
Diagram:



Attraction Force

Defn: *Attraction force is the force that pull object toward each other*. For Example, Magnetic always attract other object like iron.

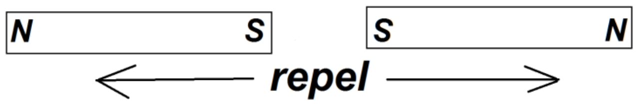
Diagram:



Repulsion Force

Defn: Repulsion is the force that push object against each other. For Example, when the same poles of magnetic are closer it pushes each other

Diagram:



Torsion Force

Defn: Torsion force is a force produced when a solid matter twisted

Friction Force

Defn: *Friction force is the force that prevents a body from sliding or rest*. For Example, an exercise book cannot slid on top of table due to friction between exercise book and table

Importance of Friction Force

i. Friction between feet and the ground enable man to walk
ii. Friction between object on the surface enable it to rest
iii. Friction between match and match stick produce heat
iv. Friction enable stopper to close the bottle of wine, juice etc

Disadvantage of Friction

i. Cause Heat and lead to heat energy which cause the efficiency of machine to be less than 100%
ii. Cause wear and tear of various bodies Example, shoes etc
iii. Cause accident due to wearing of our skin when we slide in rough surface

NB:

The fraction can be reduced by

i. Using lubricant e.g. oil, grease etc
ii. Rollers
iii. Polishing
iv. Watering

v. Balk bearing

Viscosity Force

Defn: *Viscosity force is the friction force of a fluid (liquid + gas) to flow. It involves the resistance to flow*. Water flow easy, cooking oil flow with resistance than water and honey flow with more resistance than cooking oil. Water has low viscosity, cooking oil has high viscosity than water and honey has most viscosity than cooking oil.

Air Resistance

Defn: *Air resistance is the force resists the movement of an object through the air. It is the Example, of viscosity*

Factor Affect Air Resistance

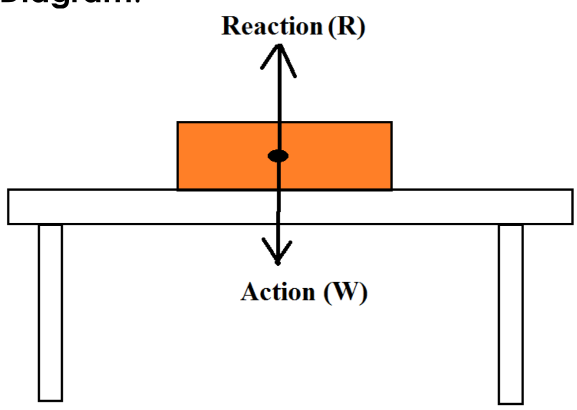
The follows the effect of air resistance

i. Size and shape of the body
ii. The speed of fluid
iii. The density of the fluid

Normal Force

Defn: normal force is the force support force exerted up an object in contact with another stable object **or** normal force is the force equal and opposite direction to weight of a body

Diagram:



Where:

Mg = w = weight of body
N = normal force

Applied Force

Defn: *Applied force is the external force that cause the system or body to change position*

Example,

A conical flask with a base of diameter 7cm is filled to a depth of 10cm with a liquid of density $840kg/m^3$. Find the total force due to the liquid on the base in Newton

Data given

Base diameter, d = 7cm= 0.07m

Base radius, r = 3.5cm= 0.035m

Liquid density, ρ = **$840kg/m^3$**

Liquid depth, h = 10cm = 0.1m

Gravitational force, g = 9.8N/kg

Force due to liquid, F = ?

Solution

From: F = mg

But: m = ρv

Also: v = Ah

Then: $A = \pi r^2$

Where: v = volume of water

A = area of base

Then: $F = \rho \pi r^2 hg$

$F = 840 \times 3.14 \times 0.035 \times 0.035 \times 0.1 \times 9.8$

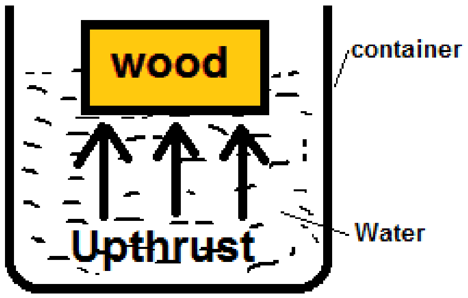
$F = 3.1664388 \approx 3.17N$

F = 3.17N

Archimedes's Principle and Law of Flotation

Archimedes's Principle

Consider the diagram below

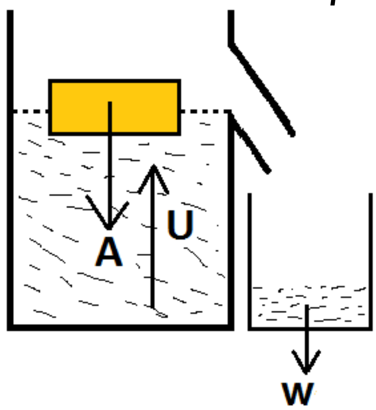


When piece of wood immersed in fluid then floats due to the buoyant force or upthrust. Where by upthrust force is the upward force enable the object to float or at least seem higher

Archimedes Principle

Archimedes principle also called the **law of buoyancy** which state that

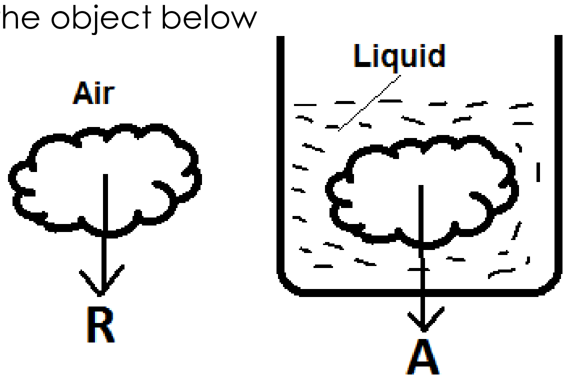
"When a body is partially or totally immersed in a fluid it experiences an upthrust which is equal to the weight of the fluid displaced"



U = W

Relationship between Real Weight and Apparent Weight

Consider diagram of the mass (weight) of the object below



Real Weight is the weight of object in air and **apparent weight** is the weight of object in fluid

Mathematically

U = R - A

Where:

U = Upthrust or Apparent weight loss
A = Apparent weight
R = Real weight

Nb:

i. fluid normally exerts an Upthrust
ii. Upthrust tends to reduce weight of body
iii. 1g of water = 0.01N of water
iv. 1g of water = 1cm^3 = 1ml of water

Example,

Given Weight of body in air is 10.10N weight of body when immersed in water is 9.2N. Find the upthrust.

Data given

Real weight, R =10.10N
Apparent weight, A = 9.2N
Upthrust, U = ?

Solution

From: U = R - A
W = 10.10 – 9.2
W =0.9N

Example,

The weight of a body when totally immersed in a liquid is 4.2N if the weight of the liquid displaced is 2.5N. Find the weight of the body in air.

Data given

Apparent weight, A = 4.2N
Upthrust, U = 2.5N
Real weight, R =?

Solution

From: U = R - A - make W_1 subject
R = U + A
R = 2.5 + 4.2
R =6.7N

Example,

When an object is totally immersed in water, its weight is recorded as 3.1N if its weight in air is 4.9N. Find upthrust.

Data given

Real weight, R =4.9N
Apparent weight, A = 3.1N
Upthrust, U = ?

Solution

From: U = R - A = 4.9 - 3.1

U = 1.8N

Example,

A body immersed in water displaced 1.1N of the liquid if its weight white in the water is 3.3N. Find they weight in air.

Data given

Apparent weight, A = 1.1N

Upthrust, U = 3.3N

Real weight, R =?

Solution

From: U = R - A - make W_1 subject

R = U + A

R = 3.3 + 1.1

R = 4.4N

Relative Density by Using Archimedes Principle

Consider the formula below

R.D = $\frac{\text{ms}}{\text{mw (Vw=Vs)}}$

R.D = $\frac{\text{Ms x g}}{\text{mw x g}}$

Where:

i. mw x g = upthrust = U
ii. Ms x g = real weight = R
iii. R.D = relative density
iv. ms = mass of substance
v. mw (vw = vw) = Mass of an equal volume of water or mass of water displaced

R.D = $\frac{R}{U}$

But: U = R – A

R.D = $\frac{\boldsymbol{R}}{\text{R−A}}$

Example,

A piece of glass weight in air 1.2N and 0.7N when completely immersed in water calculate it's.

(a) Relative density
(b) Density of glass

Data given

Weight of body in air, R = 1.2N

Weight of body in water, A = 0.7N

Density of water, ρw = 10000kg/m^3

Relative density of glass, R.D = ?

Density of glass, ρg = ?

Solution

(a) Relative density of glass, R.D = ?

From: R.D = R/(R - A) = 1.2/ (1.2 - 0.7) = 2.4

R.D = 2.4

(b) Density of glass, d = ?

From: R.D = ρg/ρw = make ρg subject

ρg = R.D x dw = 2.4 x 1000

ρg = 2400

ρg = 2400 kg/m^3

Relative Density of other liquid from water by solid substance in Archimedes Principle

When solid immersed in liquid and water the relative density is given by liquid displaced over water displaced

Mathematically

R.D = $\frac{\text{weight of liquid displaced}}{\text{Weight of water displaced}}$

R.D = $\frac{\text{weight of object in air} - \text{weight of object in liquid}}{\text{weight of object in air} - \text{weight of object in water}}$

R.D = $\frac{\text{upthrust on liquid}}{\text{upthrust on water}} = \frac{U_l}{U_w}$

R.D = $\frac{R - A_l}{R - A_w}$

Where:

U_l= upthrust on liquid

U_w =upthrust on water

A_l= Apparent weight on liquid

A_w = Apparent weight on water

Example,

In an experiment to determine the relative density of a liquid, a solid Q weighted as follows:

Weight **Q** in air, R = 8.6N

Weight **Q** in water, A_W = 6.0N

Weight **Q** in liquid, A_L = 5.4N

Data given

Weight of body **Q** in air, R = 8.6 N

Weight of body **Q** in water, A_W = 6.0N

Weight of body **Q** in liquid, A_L = 5.4N

Solution

From:

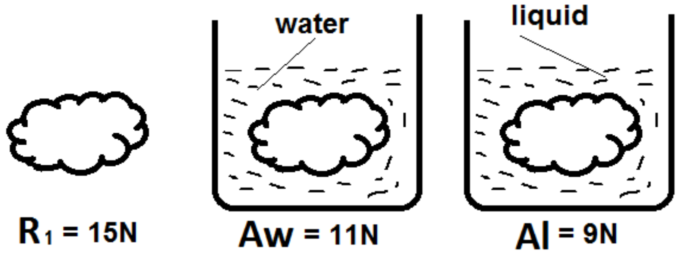
R.D = $\frac{R - A_l}{R - A_w}$

R.D = $\frac{8.6 - 5.4}{8.6 - 6.0}$ = 3.2/2.6 = 1.2

R.D = 1.2

Example,

Using the data shown below and determine the relative density of the liquid



Data given

Weight of body in air, R = 15 N
Weight of body in water, A_w = 11N
Weight of body in liquid, A_l = 9N
Relative density, R.D = ?

Solution

From:

R.D = $\frac{R - A_l}{R - A_w}$

R.D = $\frac{15 - 9}{18 - 11}$ = 6/7 = 1.5

R.D = 1.5

Example,

A body weights 0.52N in air. Total immersed in water it weighs only 0.32N while its weight when immersed in another liquid is 0.36N. The density of water is 1000 kg/m³. What is the density of the other liquid?

Data given

Weight of body in air, R = 0.52 N
Weight of body in water, A_w = 0.32N
Weight of body in liquid, A_l = 0.36N
Density of water ρw = 1000 kg/m³
Relative density, R.D = ?
Density of liquid, ρl = ?

Solution

From:

R.D = $\frac{R - A_l}{R - A_w}$

R.D = $\frac{0.52 - 0.36}{0.52 - 0.32}$ = 0.16/0.2 = 0.8

R.D = 0.8

But: R.D = ρl/ ρw – make ρl subject

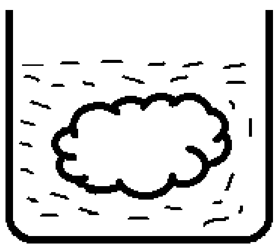
ρl = R.D x ρw = 0.8 x 1000 = 800

ρl = 800 kg/m³

Sinking

Defn: Sinking is the tendency of an object to fall or drop to lower levels in a fluid

Diagram



Condition for Sinking

i. Upthrust exerted by fluid is less than weight of object
ii. Object denser than fluid means object has great density than fluid

Floating

Defn: Floating is the tendency of an object to be suspended in (remain) on the surface of a fluid due to the upthrust

Nb:
The ability of an object to float is called **Buoyancy**

Condition for Floating

i. Upthrust exerted by fluid must be equal or greater to the real weight of the object
   Nb: apparent weight approximately equal to zero
   A ≈ 0 N
ii. The density of body must lees than that of fluid
iii. Volume of submerged object must be large enough to displace a lot of fluid

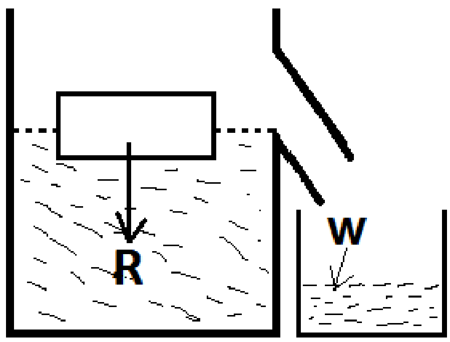
Law of Flotation

The law states that

"A floating body displaces its own weight of the fluid in which if floats"

Nb:
The real weight of the body can be expressed in terms of its density

Diagram



For substance to float, R = U

But: R = m_s x g

Since: m_s = ρ_s x v_s

Therefore: R = ρ_s x v_s x g

Also: U = m_f x g

Since: $m_f = \rho_f \times v_f$
Therefore: $U = \rho_f \times v_f \times g$
But: $v_f = \%S \times v_s$

Then: $\%S = (v_t/v_s) \times 100$

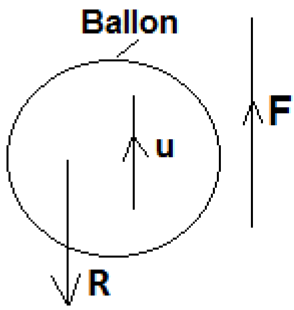
But: $R = U$
Then: $\rho_s \times v_s \times g = \rho_f \times v_f \times g$
$P_s \times v_s \times g = \rho_f \times \%S \times v_f \times g$

$$\mathbf{P_s = \rho_f \times \%S}$$

Where
R = real weight of substance
$U = W$ = weight of fluid displaced
M_s = mass of substance
P_s = density of substance
V_s = volume of substance
M_f = mass of fluid displaced
P_f = density of fluid displaced
V_f = volume of fluid displaced
$\%S$ = percentage of substance submerged
V_t = volume submerged

Application of Flotation
Law of flotation is applicant in various substance include
i. Filling Balloons
ii. Filling Hot air balloon
iii. Submarines
iv. Ships
v. Hydrometer

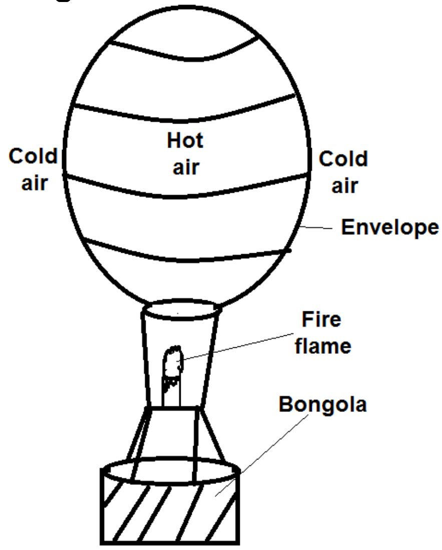
Balloons
Consider the diagram below
Diagram:



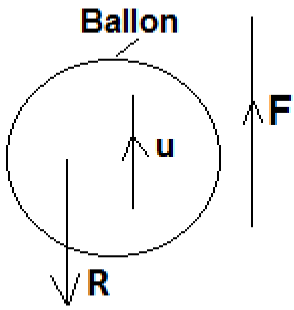
Where:
F = force drift up below
U = upthrust
R = weight of balloon

Mechanism
Balloons is filled with a light gas e.g. **Helium** which displace volume of air equal to its volume. Since filled gas has the light or has low density that than displaced air so the balloon drifted up by a force

Hot - Air Balloon
Diagram



Mechanism
When air heated in the envelope is increased and gas inside expand so its volume increase and mass of gas inside envelope remains Constant so its density lowered as if you compare to the external gas (cold air). This different in density drift the balloon and it's passengers into the air
Consider the diagram below
Diagram



For substance to float, $R = U$
But: $U = Mt \times g$
$U = (M_B + Mc + mh) \times g$
But: $mh = v_h \times \rho_h$
Then: $U = (Mt + v_h \times \rho_h) \times g$ - - - - - 1

Also: $R = m_c \times g$
But: $m_c = v_c \times \rho_c \times g$
Then: $R = v_c \times \rho_c \times g$ - - - - - 2
But: $v_c = v_h = v$

Then: equation 1 = equation 2 ($U = R$)
$(Mt + v_h \times \rho_h) \times g = v_c \times \rho_c \times g$
$(Mt + v_h \times \rho_h) = v_c \times \rho_c$
$Mt + v \times \rho_h = v \times \rho_c$

$Mt + v \times \rho_h = v \times \rho_c$ – make v subject

$v = Mt/(\rho_c - \rho_h)$

$$\mathbf{v = (ml + mb)/\Delta\rho}$$

Where

Total mass = mt = $(M_B + Mc + mh)$

Volume of hot air = v_h

Volume cold air = v_c

Mass of hot air = mh

Mass cold air = m_c

Mass of balloon = m_b

Density hot air = ρ_h

Density cold air = ρ_c

Example,

A hot air balloon including the envelope, gondola, burner and fuel and one passenger has a total mass of 450kg. Air outside balloon is at 20℃ and has a density of 1.29kg/m^3 the air inside at temperature 120℃ has density of 0.90kg/m^3. To what volume must the envelope expand to just lift the balloon into the air?

Data given

Total mass, mt = 450kg

Density at 120℃ , $\rho 2$ = 0.90 kg/m^3

Density at 20℃ , $\rho 1$ = 1.29 kg/m^3

Volume of air displaced, v1 = ?

Solution

From: $v = (ml + mb)/\Delta\rho$

v = 450kg /(1.29-0.9)

v = 450kg /(1.29-0.9)

v = 450/0.39 = 1.15

v = 1.15m^3

Example,

A balloon has a capacity of 20m^3 and it is filled with hydrogen. The balloon fabric and the container have a mass of 2.5kg. What mass of instruments can be lifted by the balloon? (Density of hydrogen = 0.089kg/m^3 and density of air is 1.29kg/m^3)

Data given

Total mass = mt = ml + mb

Volume capacity, v = 20m^3

Volume cold air, v1 =20m^3

Mass of balloon, mb = 2.5kg

Density at v2, $\rho 2$ = 0.089kg/m^3

Density at v1, $\rho 1$ = 1.29kg/m^3

Mass of instrument), ml = ?

Solution

From: $v = (ml + mb)/\Delta\rho$ – make ml subject

$Ml = (v \times \Delta\rho) - mb)$

$Ml = (20 \times (1.29 - 0.089)) - 2.5$

$Ml = (20 \times 1.201) - 2.5$

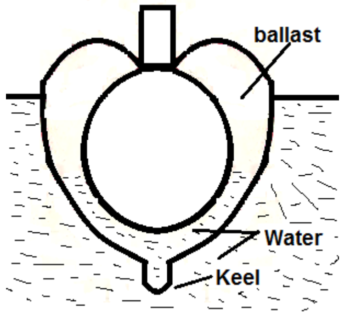
$Ml = 24.02 - 2.5$

Ml = 21.52kg

Sub Marine

Consider the diagram below

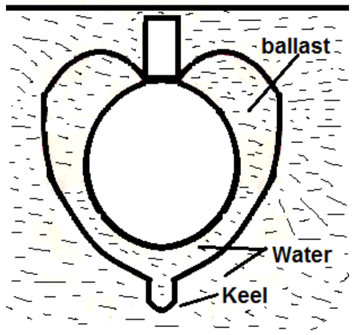
Diagram:



Mechanism

Submarine made with empty space filled with air called ballast in order to increase its volume in order to devise density of submarine and vice versa

Diagram:



When water filled in the ballast the submarine submerged and when balloon admitted to special tank its due and when ballast is filled with air the sub marine floats like other ship

Nb:

When water quantity increased/ filled in the blast is tend to reduce volume hence increase the density of submarine.

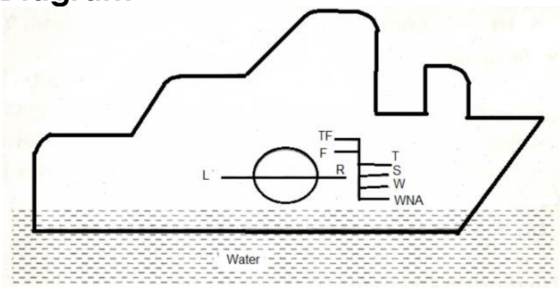
Ship

Ship is made of steel and is expected to sink due to its weight. it contains hollow which increase the volume of ship which help on making less dense that the water

$$\downarrow \rho = \frac{1}{V} \uparrow$$

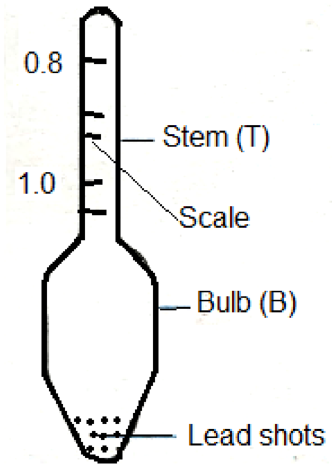
But when load put on ship it tends to increase the density and mass of ship when overloaded the ship sink completely. To check on over wading ships are marked with line or mark called Plimsoll marks.

Plimsoll line
Plimsoll line on a ship used to show minimum heights (maximum density) above different of water types in different sea as shown in the diagram below
Diagram



Where:
F = for fresh water
S = for sea in summer time
W = for sea in water time
TF = tropical fresh water
WNA = winter in Atlantic
T = Tropical

Hydrometer
Defn: hydrometer is an instrument used for measuring the densities of liquids or hydrometer is an instrument used for determine the relative density of liquids.
Diagram:



Structure of Hydrometer
i. Heavy sinker (bulb): containing mercury or lead shots that keep the hydrometer upright when it floats
ii. Air bulb: it increases volume of displaced liquid and overcomes the weight of the sinker
iii. Stem: stem is thin so that small changes in density (height) give large differences in reading
iv. Scale: inside stem graduated in densities
v. Made up of glass to prevent soaking of the liquid

Nb:
The greater the density of the liquid the shorter the stem of hydrometer immersed

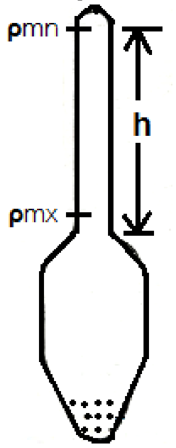
Relative Density of Liquid by Hydrometer
i. When hydrometer floats over water the weight of hydrometer (wg) must equal to the weight of water displaced (ww)
wg = ww

ii. When hydrometer floats over liquid the weight of hydrometer (wg) must equal to the weight of liquid displaced (wl)
wg = wl

iii. since relative density of liquid is given by ratio of density of liquid (ρl) to the density of water (ρw)
R.D = ρl/ρw = wl/vl ÷ ww/vw
Where:
vl = volume of liquid displaced
vw = volume of water displaced
wl = ww
Then: R.D = vw/vl

iv. since cross-section area of the hydrometer is uniform, the volume of water and of liquid displaced are proportional to the lengths immersed in them
R.D = lw/ll
Where:
Lw = length of hydrometer immersed in water
Ll = length of hydrometer immersed in liquid

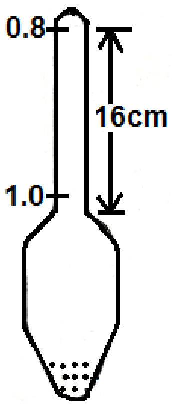
Consider the Diagram Below



Where:
Steam volume, v1 = Ah
Bulb volume, v2 = v
Total volume, vt = v1 + v = Ah + v2
But: R = U

Where:
U = upthrust in liquid
ρmn = minimum density
ρmx = maximum density
R = weight of hydrometer
U = vt x ρmn x g
R = v x ρmx x g
But: R = U
Then: vt x ρmn x g = v x ρmx x g
(Ah + v) x ρmn x g = v x ρmx x g
(Ah + v) x ρmn = v x ρmx
Ah x ρmn + v x ρmn = v x ρmx – make v2 subject
v x ρmx - v x ρmn = Ah x ρmn
v x (ρmx - ρmn) = Ah x ρmn
v = (Ah x ρmn)/(ρmx – ρmn
v = (Ah x ρmn)/(ρmx - ρmn)

Example,
Consider the diagram below used to measure density of liquid between 1g/cm^3 to 0.81g/cm^3 (The area of cross section area of stem is 0.5cm^2). Find the volume of hydrometer below 1.0 g/cm^3 graduated



Data given
Cross section area of stem, A = 0.5cm^2
Height of steam, h = 16 cm
The volume of steam, v1 = Ah = 8 cm^3
Total volume, vt = (8 + v2) cm^3
Minimum density, ρmn = 0.8 g/cm^3
Maximum density, ρmx = 1.0 g/cm^3
The volume of bulb, v2 = ?
Solution
The volume of bulb, v2 = ?
From: v2 = (Ah x ρmn)/(ρmx - ρmn)
v2 = (8 x 0.8)/(1 – 0.8)
v2 = 6.4/0.2
v2 = 32 cm^3

Example, : NECTA form IV 2012 QN: 4
(a) What does a solid body weight more in air than when immersed in a liquid?
(b) An ordinary hydrometer of mass 27g floats with 4cm of its stem out of water. If cross section area of stem is 0.75cm^2 calculate
  i. The total volume of stem just under the surface of the liquid
  ii. The relative density of the liquid

Data given (b):
Mass of hydrometer, mh = 27g
Mass of water displaced, mw = 27g
Area of stem, A = 0.75cm^2
Height of stem, h = 4cm
Density of water, ρw = 1g/cm^3
Density of liquid, ρl = ?
Solution
i. Total volume, vt = v1 + v
Volume of stem, v1 = Ah = 3 cm^3
Volume of bulb, v = mw x ρw = 27 cm^3
vt = v1 + v
vt = Ah + mw x ρw
vt = (3 + 27) cm^3
vt = 30 cm^3

ii. Relative density, R.D = ?
From: R.D = ρl/ρw
But: ρl = ml/vt = 27/30 = 0.9 g/cm^3
Then: R.D = ρl/ρw 0.9/1 = 0.9
R.D = 0.9

Example,
A balloon of volume 2000m^3 is filled with hydrogen of density 0.09 kg/m^3. If the mass of fabric is 100kg and that of the pilot is 75kg,

i. What will be the greatest mass of equipment that can be carried when operation in air is 1.25kg/m^3?
ii. How would this figure change if helium, which has twice the density of hydrogen under the same condition, were to be used?

Solution

i. **For hydrogen**

Data given
Mt total mass = mt = (ml + mb)
Volume of hydrogen, v2 = 2000m^3
Volume surrounding, v1 =20000m^3
Mass of balloon, mb = (75+100) = 175kg
Density at v2, $\rho 2$ = 0.09kg/m^3
Density at v1, $\rho 1$ = 1.25kg/m^3
Density change, $\Delta\rho$ = (ρ2-ρ1) = (1.25 - 0.09) = 1.16kg/m^3

Solution
Mass of instrument), ml = ?
From: v = (ml + mb)/$\Delta\rho$ – make ml subject
Ml = (v x $\Delta\rho$) - mb
Ml = (2000 x 1.16) – 175
Ml = 2320 – 175
Ml = 2145kg

ii. **For helium**

Data given
Mt total mass = mt = (ml + mb)
Volume of helium, v2 = 2000m^3
Volume surrounding, v1 =20000m^3
Mass of balloon, mb = (75+100) = 175kg
Density at v2, $\rho 2$ = 0.18kg/m^3
Density at v1, $\rho 1$ = 1.25kg/m^3
Density change, $\Delta\rho$ = (ρ2-ρ1) = (1.25 - 0.18) = 1.07kg/m^3

Solution
Mass of instrument), ml = ?
From:
v = (ml + mb)/$\Delta\rho$ – make ml subject
Ml = (v x $\Delta\rho$) - mb
Ml = (2000 x 1.07) – 175
Ml = 2140 – 175
Ml = 1965kg

Example,
The mass of a piece of cork (0.25 g/cm^3) is 20g. What fraction of the cork is immersed when it floats in water?

Data given
Mass of cork, mc = 20g
Density of cork, ρc = 0.25 g/cm^3
Density of water, ρw = 1 g/cm^3
Cork Fraction immersed, x = ?
Volume of water displaced, vw = ?
Volume of cork immersed, vc = ?
Solution
From: principle of flotation (vw = vc)
Mc = mass 0f water, mw
20 = vw x 1
Vw = vc = 20 cm^3
But: x = vc/vt
Where: Volume of cork, vt = ?
From: ρc = mc/vt
Vt = mc/ ρc = 20/0.25 = 80 cm^3
Vt = 80 cm^3
X = 20/80 = 1/4
X = 1/4

Example,
The mass of a piece of cork (0.25 g/cm^3) is 20g. What fraction of the cork is immersed when it floats in alcohol?(density of alcohol is 0.8 g/cm^3)

Data given
Mass of cork, mc = 20g
Density of cork, ρc = 0.25 g/cm^3
Density of alcohol, ρa = 0.8 g/cm^3
Cork Fraction immersed, x = ?
Volume of alcohol displaced, va = ?
Volume of cork immersed, vc = ?

Solution
From: principle of flotation (va = vc)
Mc = mass 0f water, mw
20 = vw x 0.8
Vw = va = 25 cm^3
But: x = vc/vt
Where: Volume of cork, vt = ?
From: ρc = mc/vt
Vt = mc/ ρc = 20/0.25 = 80 cm^3
Vt = 80 cm^3
X = 25/80 = 5/16
X = 5/16

Example,
A uniform pencil floats upright in water with 8cm of its length immersed. What length is immersed when its floats in glycerol (density of glycerol is 1.3 g/cm^3)?

Data given
Length of pencil immersed in water,lw = 8cm
Density of glycerol, ρg = 1.3 g/cm^3
Density of water, ρw = 1 g/cm^3

Length of pencil immersed in glycerol, lg = ?

Solution

But: R.D of glycerol = lw/lg

Then: lg = lw/R.D = 8/1.3 = 6.2cm

lg = 6.2cm

Example,

A balloon and the gas in it have a mass of 450g and its volume is 500 litres. What is the maximum load it can lift in air of density 1.3 g/cm^3?

Data given

Total mass, mt = (ml + mb)

Mass of balloon, mb = 450g

Density of gas, ρg = 1.3 g/cm^3

Density change, Δρ = 1.3 g/cm^3

Volume of balloon, vb = 500 litres

Maximum load, ml = ?

Solution

Maximum load, ml = ?

From: v = (ml + mb)/Δρ – make ml subject

Ml = (v x Δρ) - mb

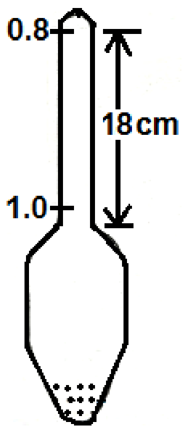
Ml = (500 x 1.3) – 450

Ml = 650 – 450

Ml = 200g

Example, : NECTA 2012

The diagram below shows on form of man hydrometer used to me to measure the densities of liquid over the range of 0.8 to 1.00 g/cm^3. If the area of cross section of the stem is 0.5 cm^2 and the distance between the 0.80 and 100 division is 18cm determine



(a) The volume of hydrometer below 1.00 graduated
(b) The position of the 0.90 graduation

Data given

Cross section area of stem, A = 0.5cm^2

Height of steam, h = 18 cm

The volume of steam, v1 = Ah = 9 cm^3

Total volume, vt = (9 + v2) cm^3

Minimum density, ρmn = 0.8 g/cm^3

Maximum density, ρmx = 1.0 g/cm^3

The volume of bulb, v2 = ?

Solution

(a) The volume of bulb, v2 = ?

From: v2 = (Ah x ρmn)/(ρmx - ρmn)

v2 = (9 x 0.8)/(1 – 0.8)

v2 = 7.2/0.2

v2 = 36 cm^3

(b) What height, h2 of hydrometer when shifted to measure 0.9 g/cm^3

But: weight of hydrometer never change

V3 x 0.9 x 0.01N = 0.36N

V3 = 40 ^{3}

V3 = Ah2

h2 = 8cm

Structure and Properties of Matter

Matter

Defn: matter is anything that has mass and occupies space. Matter can be change state with vary in temperature

State Of Matter

Matter exist in three physical states include

i. Solid state
ii. Liquid state
iii. Gas (vapour) state

Structure of matter

Matter is made up of tiny particles. The particles are either atom or molecules

Atom

Defn: atom is the smallest part of an element, which can take part in chemical reaction. For Example, Sodium atom (Na), hydrogen atom (H) etc

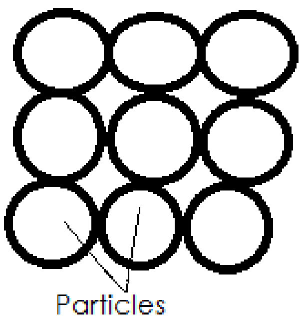
Molecules

Defn: a molecule is a group of atoms. For Example, water molecule (H_2O), hydrogen molecules (H_2)

Solid State

Solid substance has definite shape and definite volume. Particle in solid substance are closely packed together. For Example, of solid substance is Ice, Wood, Stone, Books, Shoes, and Plastic

Diagram



NB:

i. The particles vibrate in fixed position
ii. The particle are not free to move because they held by strong inter particle force

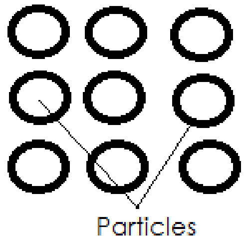
Properties of Solid Matter

i. Particles are closely packed together
ii. Has definite shape and volume
iii. Has strongest inter-particle force
iv. Particle are not free to move
v. Has high density due to small volume
vi. Particle move very slow

Liquid State

Liquid substance has fixed volume but variable in shapes. Particles in liquid are slightly father apart. For Example, water, kerosene, milk etc

Diagram



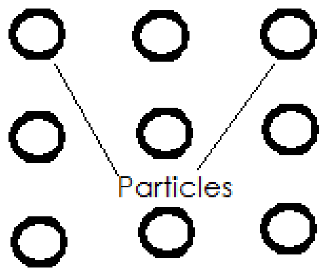
Properties of Liquid Matter

i. Particles are slight father apart
ii. Have definite volume
iii. Have not definite shape
iv. Has medium density due to medium volume
v. Has medium motion
vi. Inter-particle force is weak

Gas State

Gas has not definite shape or size. Particles are moving so fast and are so far apart that they do not interact with each other at all. For Example, oxygen gas, hydrogen gas, nitrogen gas etc

Diagram:



Properties of Gas Matter

i. Has not definite shape
ii. Has not definite volume
iii. Has largest inter particle distance
iv. Has low density due to largest volume
v. Has weakest inter particle force
vi. Particle move at high speed

The Particulate Nature of Matter

Scientist called **Robert brown** used a microscope and observed that pollen grains suspended in water moved short distance in an irregular zigzag manner.

After that observation Robert brown concluded by the law called Brownian motion

Brownian motion

Brownian motion state that

"Matter is made up of tiny particle that are in a state of continuous random motion"

Kinetic Theory of Matter

It describes the physical properties of matter in terms of the behaviour of its component atom or molecules. It state that

"All matter is made up of very small particles that are in constant motion"

NB:

i. Motion of solid particles are in vibration
ii. Motion of liquid and gas particles are in random

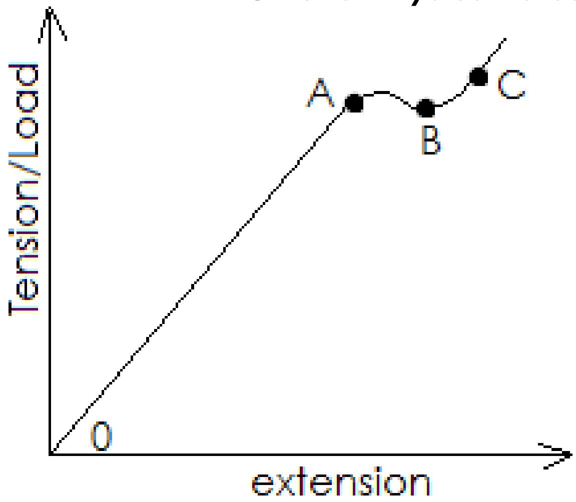
Elasticity

Defn: elasticity is the property/ability of a body to return to its original shape and size when deforming force removed

Nb:

i. A body/substance with ability to undergo elasticity is called elastic substance
ii. Material are elastic to some degree until elastic limit is reached
iii. The materials which do not undergo elastic deformation are called brittle substance. For Example, glass, block etc
iv. When material deformed beyond elastic limit it become plastic, means it will not regain its original shape even though it doe s not break. This type of deformation is called plastic deformation
v. Material which undergoes plastic deformation is called inelastic or plastic materials.

Graph of Tension against Extension



Interpretation

i. Between point O and A
Tension is direct proportional to extension. This was discovered by Hooke and final he comes with law which called Hooke's law

Hooke's Law

It state that

"Within the elastic limit extension is directly proportional to the force applied"

Or

"Provided that the elastic limit of a body not exceeded the extension is directly proportional to the force applied"

Mathematically:

F a e - remove proportionality constant

F = ke – make K subject

k = F/e

Where:

k = elastic force constant

= spring constant

F = force applied

e = extension

SI unit of K is N/m

ii. **At point A**
At point A is called limit proportionality or elastic limit

iii. **Between point A and B**
Between Point A and B is called the region of elastic. In this region a small force produces a large extension which is not directly proportional to the extension

iv. **Between point B and C**
Between Point B and C is called the region of plastic deformation. At this region material will not return to its original shape and size when applied force/tension/load removed

v. **Beyond point C**
Beyond point C the material breaks

Application of Elasticity In Real Life

A. Domestic application

i. Rubber gaskets that seal the refrigerator door
ii. Clothing
iii. Springs in furniture
iv. Rubber bands that hold things together
v. Toys like balloons and ball

B. Transport application

i. Rubber tyres, hoses, belt and shock absorbing spring for car and trucks
ii. Aeroplane wings
iii. Supporting cable for bridges

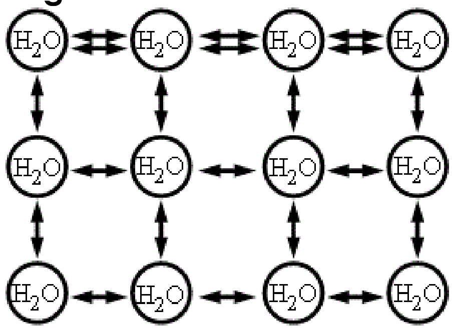
C. Industry application

i. Conveyor belts
ii. Measuring weight
iii. Steel beams in construction
iv. Insulation of vibration and sound

Surface Tension

Defn: surface tension is the ability of a liquid surface to act like stretched elastic skin. Surface tension occurs due to the force of attraction between molecules of liquid

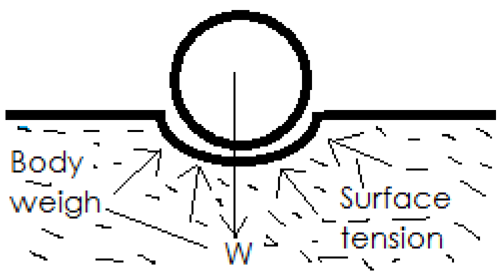
Diagram



How Surface Tensions Occur?

Particles at the surface have no neighbor molecules which tend to possess strongest attraction force up on their nearest neighbouring on the surface, this result elastic nature of the liquids surface. If an object placed on surface of liquid its weight pushes downward cause a deformation, which tends to increase the surface area of the liquid. The surface tension resists that increase in area by pushing upward on the object

Diagram:



Physical Phenomenon Show Presence of Surface Tension

i. **Walking on water**: Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface. **Pond skater (water strider) floats in pond due to surface tension**

ii. **Floating a needle**: A carefully placed small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink. Pin floats over water due to surface tension
iii. razor floats over water due to surface tension
iv. formation of soap bubbles due to surface tension
v. formation of drops of water on leaves of a plant due to surface tension
vi. **Don't touch the wet tent**: Common tent materials are somewhat rainproof in that the surface tension of water will bridge the pores in the finely woven material. But if you touch the tent material with your finger, you break the surface tension and the rain will drip through.
vii. **Clinical test for jaundice**: Normal urine has a surface tension of about 66 dynes/centimeter but if bile is present (a test for jaundice), it drops to about 55. In the Hay test, powdered sulfur is sprinkled on the urine surface. It will float on normal urine, but will sink if the surface tension is lowered by the bile.
viii. **Surface tension disinfectants**: Disinfectants are usually solutions of low surface tension. This allows them to spread out on the cell walls of bacteria and disrupt them.
ix. **Soaps and detergents**: These help the cleaning of clothes by lowering the surface tension of the water so that it more readily soaks into pores and soiled areas.
x. **Washing with cold water**: The major reason for using hot water for washing is that its surface tension is lower and it is a better wetting agent. But if the detergent lowers the surface tension, the heating may be unnecessary.
xi. **Why bubbles are round**: The surface tension of water provides the necessary wall tension for the formation of bubbles with water. The tendency to minimize that wall tension pulls the bubbles into spherical shapes.
xii. **Surface Tension and Droplets**: Surface tension is responsible for the shape of liquid droplets. Although easily deformed, droplets of water tend to be pulled into a spherical shape by the cohesive forces of the surface layer
xiii. **Glass house leaks water inside during the starting of the rain season**, when glass roof partial wetted have poor/not surface tension of glass roof in which water leaks inside but when glass roof total wetted experience surface tension which prevent leaks of water inside the glass house

Factor Affect Surface Tension

i. **Nature of the liquid**
Different liquid have different surface tension, for Example, mercury has higher surface tension than water

ii. **Contamination/impurities**
Impurities in liquid lower the surface tension. The substance which lowers surface tension is called surfactants (acronym for surface active agent). Example, of surface tension lower is detergents

iii. **Temperature**
Surface tension of a liquid decreases with increase in temperature

Application of Surface Tension

i. Cleaning action of soap, e.g. detergent lower surface tension between particles of closes and dirty
ii. Mosquitoes normally lay their eggs in water. When small amount of oil is poured on the water, it lower the surface tension which results sinking of eggs
iii. Surfactants are also used to make emulsion of two liquids like oil and water
iv. It used in extraction of impurities in laboratory
v. Hot soup has lower surface tension as a result soup spread over a large area of the tongue, hence hot soup is tastier that cold one

Adhesion and Cohesion
As we learnt that particle are bonded by force of attraction called intermolecular force

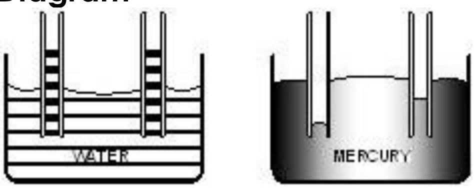
Intermolecular Force
Defn: intermolecular force is force of attraction or repulsion between particles of matter (atom or molecules)

Types of Intermolecular Force
There are two include
i. Cohesive force
ii. Adhesive force

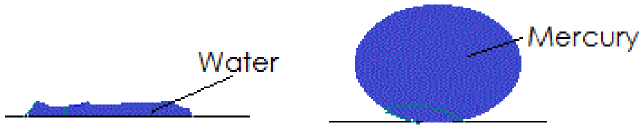
Cohesion
Defn: cohesion force is the force of attraction between the molecules of the same kind. For Example, water and water molecule

Adhesion
Defn: adhesion is the force of attraction between the molecules of the different substance. For Example, water and glass molecules

Effect of Adhesion and Cohesion
i. Mercury form convex (downward) meniscus because it possess strong cohesive force than adhesive force
ii. water form concave (upward) meniscus because it possess strong adhesive force than cohesive force
Diagram

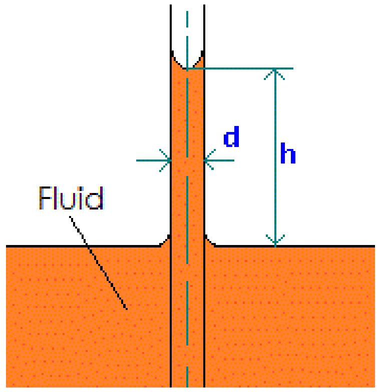


iii. Drop of water on the surface of some leaves is perfect sphere due to strong cohesive force than adhesive force
iv. Drop of mercury on the surface of different material is perfect sphere due to strong cohesive force than adhesive force
v. water spread over glass because it possess strong adhesive force than cohesive force
Diagram

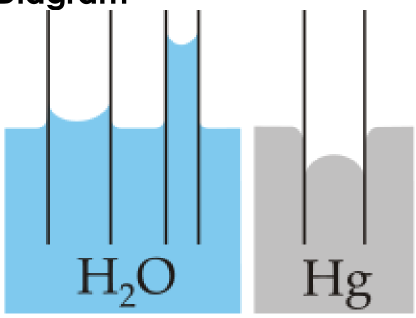


Application of Adhesive and Cohesive
i. Adhesive Used to stick two different objects. For Example, using glue or tape
ii. Plant use the cohesive of tissue to repair damage
iii. Ink stick on paper
iv. Transport of water in plant and animal due to adhesive force
v. Adhesive is the source of friction

Capillarity
Defn: capillarity is the rise or fall of liquid in nallow tube. A tube with a very hole (bore) is called capillary tube
Diagram:



Nb:
i. When you dip a capillary tube in water , the water rise due to greater adhesive force
ii. When you dip a capillary tube in mercury, the mercury fall due to greater cohesive force
Diagram



iii. The greater adhesive and cohesive the greater the capillarity action

Application of Capillarity
i. The raising of oil in the wicks of lamps in the cotton threads
ii. The absorption of water by a towel

iii. Water rises in the soil because the soil is composed of fine particles
iv. It facilitates the transport of water and nutrients from the roots
v. Ink rises into the blotting paper through those fine pores

Osmosis

Defn: osmosis is the movement of a solvent from a region of low concentration to one of high concentration through a semi-permeable membrane. Consider the experiment below

i. Peal a potato
ii. Keep over salts
iii. The potato shrink due to movement of water from potato (low concentration) to salt (high concentration)

Application of Osmosis

i. Absorption of water molecules from soil to plant
ii. Aquatic life is controlled by osmosis
iii. Filtration process

Diffusion

Defn: diffusion is the movement of particles from a region of high concentration to one of low concentration. For Example, perfume

Application of Osmosis

i. Detecting harmful substance in the environment
ii. In the use of refreshers and other sprays
iii. Respiration process, oxygen diffuses into blood stream
iv. Balance concentration of water and nutrients in and out of the cells of living organisms.

Pressure

Defn: pressure is the force per unit area

Mathematically:

P = F/A

Where:

P = pressure

F = force

A = surface area

Si Unit of Pressure

From: P = F/A

P = F/A = N/m^2

The SI unit is Newton per cubic metre (N/m^2)

Note

Some pressure is higher and lower is small to cope with this great difference, there other unity obtains from the N/m^2, namely

i. Pascal (Pa)
ii. Atmosphere (atm)
iii. Millimetre of mercury (mmHg)
iv. Torre bar (bar)

Their equivalent is

i. 1Pa = $1N/m^2$
ii. 1atm = 760mmHg
iii. 1atm = $100000N/m^2$
iv. 1atm = 1bar

Pressure due to Solid

Pressure on solid depends on force applied and the surface area.

Mathematically:

P = F/A

Example,

A rectangular block weighting 250N has dimension 34cm, 25cm by 10cm. what is the greater pressure and the least (minimum) pressure it can be exerts on the ground

Data given

Maximum area, Amax = 0.25 x 0.34 = $0.058m^2$

Minimum area, Amin = 0.25 x 0.1 = $0.025m^2$

Weight of block, F = 250N

Maximum pressure, Pmax = ?

Minimum pressure, Pmin = ?

Solution

From: P = F/A

Maximum pressure, Pmax = ?

Note: To get maximum pressure the area must minimum

Then: Pmax = F/Amin

Pmax = 250/0.025 = 10000 N/m^2

Pmax = 10000 N/m^2

Minimum pressure, Pmin = ?

Note: To get minimum pressure the area must maximum

Then: Pmin = F/Amax

Pmin = 250/0.085 = $2941N/m^2$

Pmin = 2941 N/m^2

Example,

A woman weighting 500N wear a pair of shoes with heels of area $250m^2$, what is the pressure exerted on the floor by a heel of her shoes?

Data given

Area, A = $250m^2$

Weight of woman, F = 500N

Pressure exerted, P = ?

Solution

From: P = F/A

Pressure exerted, P = ?

Then: P = F/A

P = 500/250 = 2 N/m^2

P = 2 N/m^2

Example, s We Experience Solid Pressure

We can prove the pressure due to solid as the following reasons

i. We experience pain discomfort when we lift a bucket of water made by thin (small area) handle
ii. Sharp edges (small area) of knife or razor cut easily than blunt knife or razor
iii. Sharps pointer (small area) of nail, screw, push pin, spear and an arrow has high penetrating power
iv. Wide wooden or concrete (large area) sleepers are placed below the railway track to prevent railway track to penetrate on ground.
v. Building are constructed with wide (large area) foundation to increase to increase surface are to prevent wall from penetrate on ground
vi. It pain full to walk bare foot on road covered with small stone (small area)
vii. Feet of elephant cannot sink into soft soil even is very heavy due to large surface area over elephant feet

viii. A tractor works on soft ground cannot sink due to large surface area (wide tyres)
ix. Duck cannot sink on soft mud due to large surface area on his webbed feet
x. Potter put some soft material on his/her head for heavy load to increase surface area
xi. The sharp fins inflict pain on an intruder body
xii. It is painful to walk barefoot on a road that is covered by pebbles

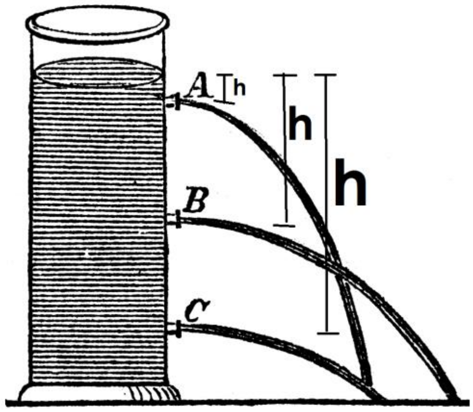
Example,
The tip of the needle with cross section area of 0.000001m^2, if a doctor applied a force of 20N to syringe that is connected to the needle. Find pressure exerted at the tip of the needle
Data given
Area, A = 0.000001m^2
Force applied, F = 20N
Pressure exerted, P = ?
Solution
From: P = F/A
Pressure exerted, P = ?
Then: P = F/A
P = 20/0.000001 = 2 N/m^2
P = 20000000 N/m^2

Pressure due to Liquid
It difficult to obtain the area and force applies on that liquid, in order to solve that problem, we to derive new formula
From: P = F/A
But: F = mg, m = ρv, v = hA
Then: P = ρhAg/A = ρhg
P = ρhg

Note:
i. Since the gravitation force (g) is constant Pressure on liquid depends on
a/ Depth (height liquid rises)
b/ Density of liquid

ii. Pressure on solid depends on
a/ Force applied (F)
b/ Surface area (A)

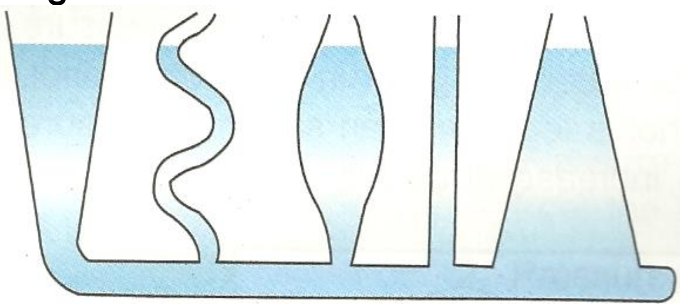
Consider the diagram below



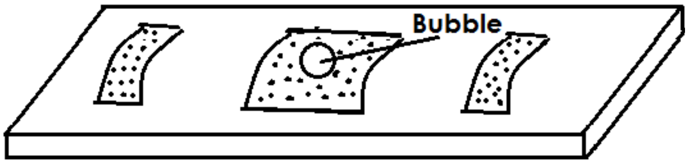
At hole C water pushed in high speed due to high pressure causes by long depth than hole A and hole B, due different in height (depth)

Example, s We Experience Liquid Pressure
We can prove the pressure due to liquid as the following reasons
i. The water bubbles increase its volume if moves from bottom of the pond to the top of the pond (depth decrease)
ii. Water tanks have their outlets fixed at the bottom (large depth)
iii. A person at great height suffers from nose bleeding
iv. A hole at the bottom of a ship is more dangerous than one near the surface
v. A dam is thicker at the bottom than at the top

Communication Vessel
Communication vessel find its own level even though each part has different shape, the liquid will be at the same level in all part
Diagram:



Spirit Level
Defn: spirit level is an instrument used to test whether a surface is horizontal or vertical. It consist of a slightly curved glass tube which is not completely filled with a liquid (yellow in colour) leaving a bubble in the tube
Diagram:



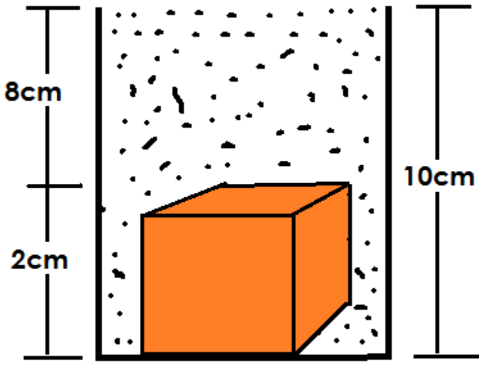
Mechanism
A spirit level works on the fact that a liquid in a vessel will always find its own level.

Spirit level used by
i. Mason
ii. Carpenters
iii. Surveyors etc

Example,
What will the pressure due to column of water of height 4m?
Data given
Height, h = 4m
Density of water, ρ = 1000kg/ m^3 = 1g/cm^3
Gravitation force, g = 10N/kg
Pressure exerted, P = ?
Solution
From: P = ρhg
P = 1000 x 4 x 10 = 40000
P = 40000 N/m^2

Example,
The pressure at a bottom of a well is 98000N/m^2. How deep is the well?
Data given
Density of water, ρ = 1000kg/ m^3 = 1g/cm^3
Gravitation force, g = 10N/kg
Pressure exerted, P = 98000N/m^2
Height, h = ?
Solution
From: P = ρhg - make h subject
h = P/(ρg) = 98000/(1000 x 10)
h = 98000/10000 = 98
h = 98m

Example,
A cube of sides 2cm is completely submerged in water so that the bottom of the cube is at depth of 10cm. find
a) different pressure between top and bottom of the cube
b) different force between top and bottom of the cube
c) weight of water displaced by the cube
Solution
Consider the diagram below



a) Different pressure between top and bottom of the cube, Δρ = ?
Data given
Water density, ρ = 1000kg/ m^3 = 1g/cm^3
Gravitation force, g = 10N/kg
Height at top, h1 = 8cm = 0.08m
Pressure exerted at top, P1 = ?
Height at top, h1 = 8cm = 0.1m
Pressure exerted at bottom, P2 = ?
Solution
Δρ = P2 – P1
But: P1 = ρxh1xg and P2 = ρxh2xg
Then: Δρ = P2 – P1 = (ρxh2xg - ρxh1xg)
Δρ = ρg(h2 - h1) = 1000 x 10 x (0.1 – 0.08)
Δρ = 1000 x 10 x 0.02 = 200
ΔP = 200 N/m^2

b) Different force between top and bottom of the cube, Δf = ?
From: Δf = ΔP x ΔA
Where: ΔA = area between top and bottom
But: A = 2cm x 2cm = 4cm^2 = 0.000m^2
Then: Δf = ΔP x ΔA = 200 x 0.0004 = 0.08
Δf = 0.08N

c) Weight of water displaced, w = ?
But: due to Archimedes principle volume of water displace is equal to volume of cube while due to flotation law weight of water displace is equal to weight of cube
Then: volume of water (cube) = 8cm^3
But: 1g = 1cm^3 = 0.01N/g
Then: 1cm^3 = 0.01N/g
8cm^3 = w?
w = 8 x 0.01 = 0.08N
w = 0.08N

Example,

Calculate the pressure exerted on a diver at a depth of 20m below the surface of water in a sea

Data given

Height, h = 20m

Density of water, $\rho = 1000kg/m^3 = 1g/cm^3$

Gravitation force, g = 10N/kg

Pressure exerted, P = ?

Solution

From: $P = \rho hg$

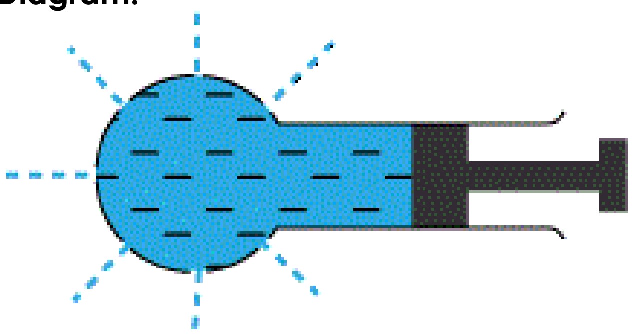
$P = 1000 \times 20 \times 10 = 200000$

P = 200000 Pa

Pascal's Principle

Consider the diagram below

Diagram:

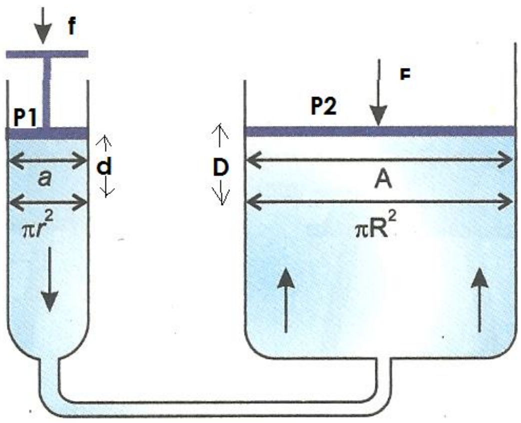


When the container with holes contain water compressed, water will come out with equal force in all directions due to equal force of water come out, it concluded by the Pascal which say that

"Any external pressure to the surface of an enclosed liquid will be transmitted equally throughout the liquid"

Hydraulic Press

Hydraulic press uses a principle of Pascal to multiply an applied effort using the pressure of a liquid or gas. This allows the lifting of a heavy load by applying little effort



According to the Pascal principle pressure will transmitted equally through the fluid (oil)

Then: $P_2 = P_2$

But: $P_1 = f/a$

$P_1 = F/A$

Then: $F/A = f/a$

$\mathbf{F/A = f/a}$

But: $A = \pi R^2$

$a = \pi r^2$

$F/\pi R^2 = f/\pi r^2$

$\mathbf{F/R^2 = f/r^2}$

But: $R^2 = (D/2)^2 = D^2/4$

$r^2 = (d/2)^2 = d^2/4$

$F/R^2 = f/r^2$

$F/(D^2/4) = f/(d^2/4)$

$\mathbf{F/D^2 = f/d^2}$

From: principle of moment

Anticlockwise moment = clockwise moment

$F \times D = f \times d$

Since: $f = p2 \times a$

$F = p1 \times A$

But: $p1 = p2 = p$

$p \times A \times D = p \times a \times d$ - divide by p

Therefore: AD = ad

AD = ad

Example,

In a hydraulic press the area of the piston to which the effort is applied is $5cm^2$. If the press can raise a weight of 2KN when an effort of 400N is applied, what is the area of the piston under the load?

Data given

Small Piston Force, f =200N

Large Piston Force, F = 2KN = 2000N

Small piston area, $a = 5cm^2$

Large piston area, A = ?

Solution:

From: F/A = f/a – make A subject

$A = (F \times a)/f$

$A = (2000 \times 5)/400 = 10000/400 = 25cm^2$

$\mathbf{A = 25cm^2}$

Example,

Hydraulic press has a large circular piston of diameter 0.7m and circular piston to which the effort is applied of diameter 0.21m. A force of 300N is exerted on small piston. Find the force required to lift a heavy load

Data given

Small piston diameter, d = 0.21m
Large piston diameter, D = 0.7m
Small Piston Force, f =300N
Large Piston Force, F = ?

Solution:

From: $F/D^2 = f/d^2$ – make F subject

$F = (D^2 \times f)/d^2$

F = (0.7 x 0.7 x 300)/(0.21 x 0.21) = 147/0.0441

F = 147/0.0441 = 3333.33

F = 3333.33N

Example,

Piston of hydraulic press has their areas given as $0.0003m^2$ and $0.02m^2$ respectively. The 120N is required to push down the small piston, find the force required to push large piston

Small Piston Force, f =120N
Small piston area, a = $0.0003m^2$
Large piston area, A = $0.02m^2$
Large Piston Force, F = ?

Solution:

From: F/A = f/a – make F subject

F = (f x A)/a

F = (120 x 0.02)/0.0003 = 2.4/0.0003 = 8000

F = 8000N

Example,

A hydraulic lift has piston with areas of $0.02m^2$ and $0.1m^2$. A car with a weight of 5000N sits on platform mounted on the large piston

a) How much force applied on small piston
b) How for must small piston fall when large piston raise the car at 0.3m?

Data given

Small piston area, a = $0.02m^2$
Large piston area, A = $0.1m^2$
Large Piston Force, F = 5000N
Large Piston distance moved, d =0.3m
Small Piston distance moved, d =?
Small Piston Force, f =?

Solution:

a) Small Piston Force, f =?

 From: F/A = f/a – make f subject

 f = (F x a)/A

 f = (5000 x 0.1)/0.02 = 500/0.02 = 10000

 f = 10000N

b) Small Piston distance moved, d =?

 From: AD = ad – make d subject

 d = (A x D)/a

 d = (0.1 x 0.3)/0.02 = 0.003/0.02 = 0.15

 d = 0.15m

Example,

A car of mass 8000kg, one of its tyres having an area of $50cm^2$ in contact with ground. Find the pressure of the four wheel car exerted on ground by the car

Data given

Area of one tire, A = $50cm^2$
Area of four tires, at = 4xA = $200cm^2$= $0.02m^2$
Mass of car, m = 8000kg
Gravitation force, g = 10N/kg
Weight of car, F = mg = 80000N
Pressure exerted, P = ?

Solution

From: P = F/A
Pressure exerted, P = ?
Then: P = F/At

 P = 80000/0.02 = 4000000 N/m^2

 P = 4000000 N/m^2

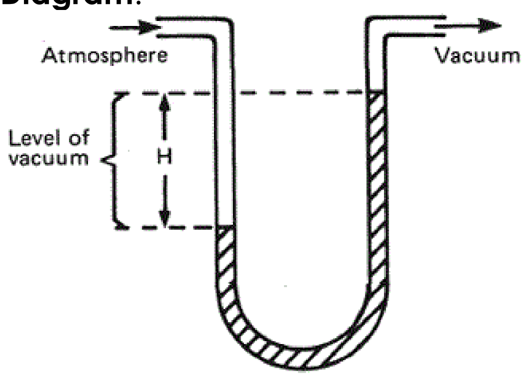
Uses of Hydraulic Press in Daily Life

i. It lifts heavy loads
ii. In ginneries to compress a lump of cotton into small bales
iii. In industries to form car bodies into the required shapes
iv. It used to make hydraulic brakes
v. It used to make hydraulic jack
vi. Extraction of oil from the oil seed

Manometer

Defn: manometer is device for measuring fluid pressure

Diagram:



It is u shaped glass tube, open at both ends and holding liquid (water/mercury)

Mechanism of Manometer

One limb is connected to the fluid supply and the other limb is opened to the atmosphere. The pressure exerts on fluid causes level of water or mercury on manometer to rise at a certain height as shown in the diagram above. The height rise by water or mercury is called liquid head. The pressure is calculate from

P = ρhg

Where:

P = pressure of fluid

ρ = density of water/mercury

g = acceleration due to gravity

Atmospheric Pressure

Defn: Atmospheric pressure is the air pressure due to the force (gravity) per unit area of the air molecules

How Gas Exerts Pressure?

Gas exerts pressure on wall of its container by the movement of its particles due to kinetic energy hence momentum increased which produce high force/pressure, which they have frequencies striking the wall, creates pressure on the wall of its container

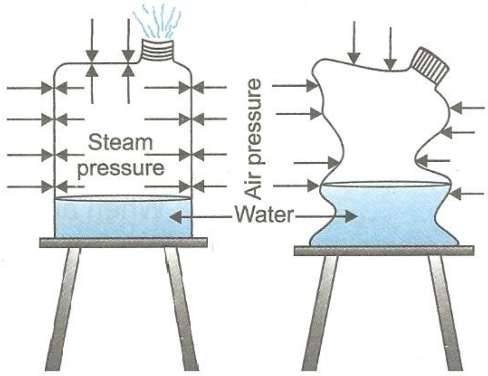
Experiment Demonstrate Atmospheric Pressure

i. If there is no air between the card and water in the glass tumbler full filled with water when be upside down the card holds on the tumbler due to the existence of atmosphere

ii. When the bottle poured by hot water and cork the bottle tightly and allowed to cool , the bottle crushed due to atmospheric pressure

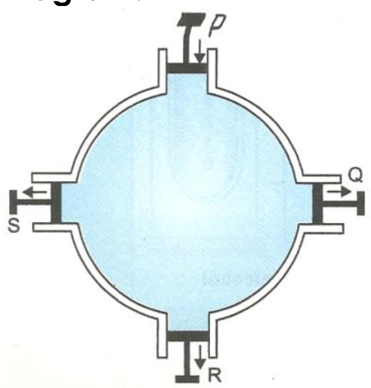
Mechanism

In vacuum (no air) there is no pressure. When bottle has hot water and vapour water particle are apart and when condensed by cooled it leaving partial vacuum inside the bottle which tend to cause bottle to crush



iii. When air pumped out of the Magdeburg hemispheres a vacuum is created inside the hemispheres and the pressure of the atmosphere exert a greater force on the surface of the sphere. Hence it will be found impossible to pull the hemispheres apart. If air is allowed to enter into the hemisphere it becomes easily to pull the hemisphere apart

Diagram:



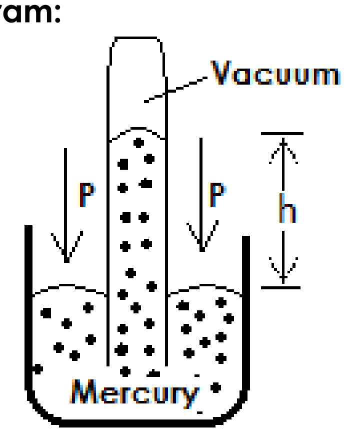
Barometer

Defn: Barometer is an instrument used to measure atmospheric pressure

Simple Barometer

Simple Barometer is the most fundamental of the other types of barometer. The barometer liquid used is mercury

Diagram:



The atmospheric pressure is given by:

$P = \rho hg$

Where:

P = atmospheric pressure

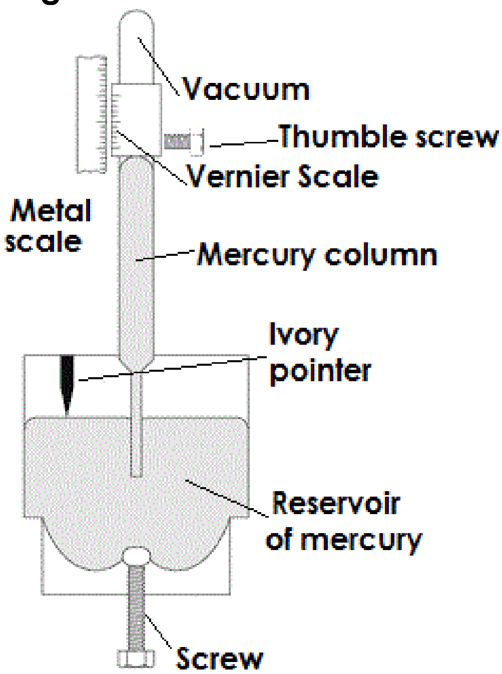
h = height raised by mercury

ρ = density of mercury

Fortin Barometer

Fortin Barometer is the modified simple barometer. It is a very accurate type of mercury barometer for measuring air pressure. It perform function like simple barometer

Diagram:



i. Vertical tube (mercury column) contain mercury with a vacuum above it
ii. Reservoir bag at the base as a reservoir of mercury
iii. ivory pointer with a sharp point at the bottom which correspond to the zero error
iv. Metal and movable Vernier scale for reading the height of the mercury level accurately

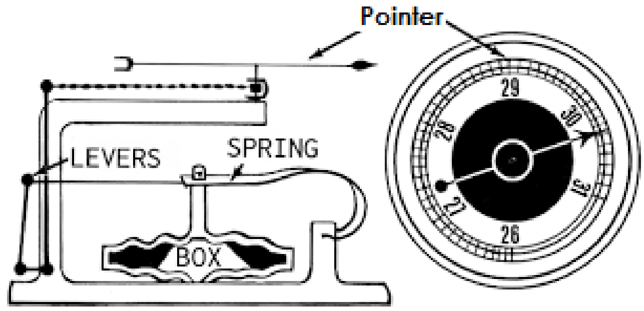
Question:

i. Why barometer uses mercury instead of water?

Aneroid Barometer

Aneroid Barometer does not use any liquid. It consists of an evacuated metal box connecting a system of levers and a pointer. It is compact and portable

Diagram:



Mechanism

When the atmospheric pressure increase, the centre of the partially evacuated box moves inwards and this small movement is magnified by a system of levers. The chain attached to the end lever moved the pointer. The large spring prevents the box from collapsing

Disadvantage of using forting barometer

i. Mercury is expensive
ii. Aneroid barometer is portable
iii. Forting barometer must be mounted in a vertical position

Nb:

Aneroid barometer which used in aircraft to show the height at which the plane is flying is called Altimeter

Application of Atmospheric Pressure

There are a variety of common and even simple device that make use of the atmospheric pressure to work. There include

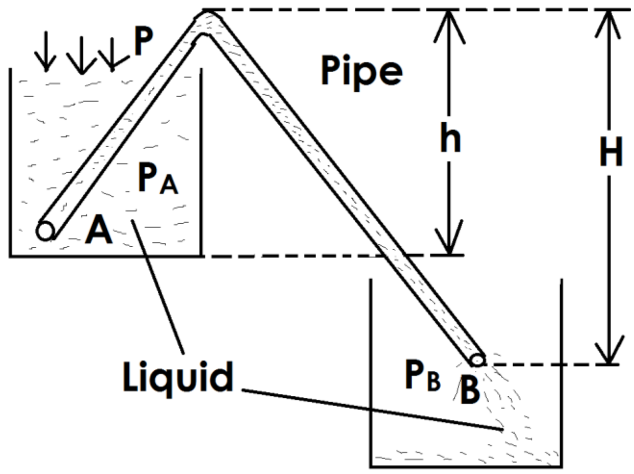
i. Siphon
ii. Lift pump
iii. Force pump
iv. Syringe
v. Bicycle pump

Siphon

Defn: Siphon is a tube or pipe used to transfer liquid from one to another container by using atmospheric pressure to make liquid flow

Mechanism

Consider the diagram below



Where:

Pa = pressure on container a
P = atmospheric pressure
Pb = pressure on container b
D = density of liquid
h = height raised by container a
H = height raised by container b

At point A the pressure (P_A) due to height, h is small as if you compare to pressure(P_B) due to height, H, at point B, due to the different pressure the fluid (water) drifted from point A to point B

Nb:

Siphon can lift water about 10m below the ground

Application of Siphon

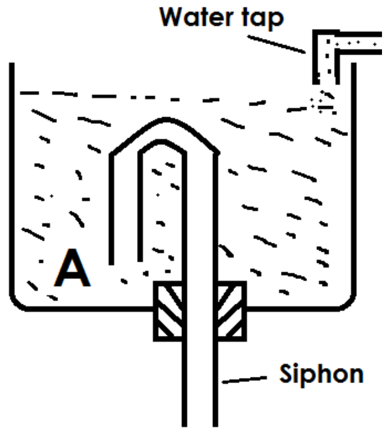
Siphon is applied in many areas and devices that we use every day include

i. Chain and ball flushing tank
ii. automatic flushing tank
iii. A siphon cup is a reservoir attached to a gun
iv. It is used in some drainage system to drain water to another point

Automatic Flushing Tank

It is used in special rain gauge called siphon rain gauge which are able to automatically drain out excess water

Diagram:



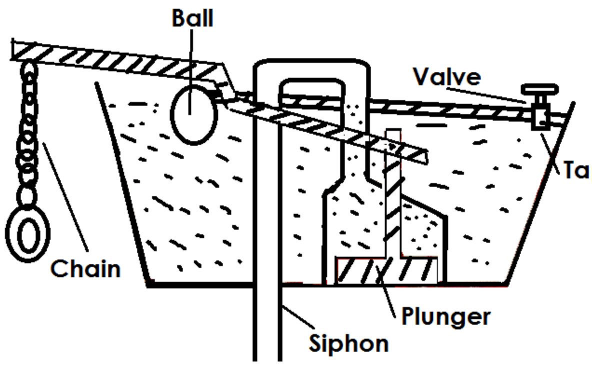
Mechanism

Water flows slowly from the tap into the tank, raises above the top of the siphon tube to complete the height, h. The siphon flushes water until it reaches the bottom of the shorten limb at A. this action is repeated after every few minutes. This kind of appliance is used in places which have to be kept clean continually. E.g. urinating places

Chain and Ball Flushing Tank

It consist ball associated with incomplete of height of water which tend to create pressure which flushes water

Diagram:



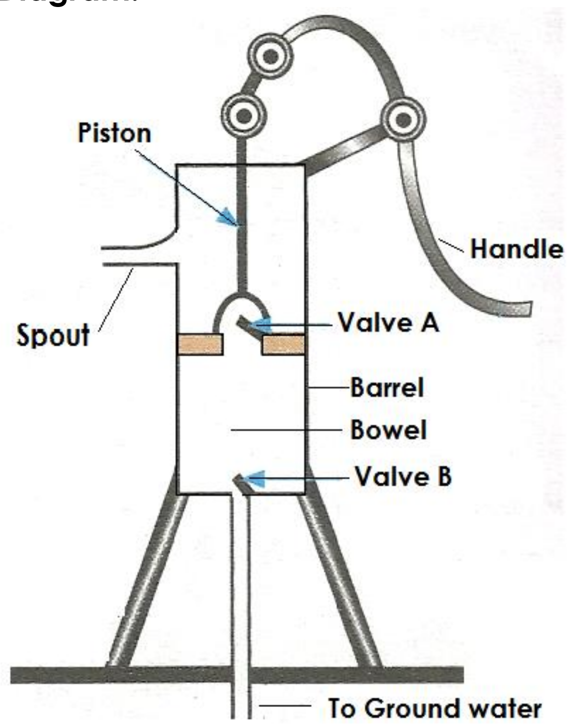
Mechanism

As water increase, the ball float (moves up) until it reaches at the top which close the valve tap to prevent completes of the height. The siphon action is start when the chain is pulled to complete the height, the chain pulls the plunger pushes water into the bend of the siphon which complete the height which flashes water

Lift Pump

Lift pump is used to raise water from underground water sources. Lift pump is a pump that used to lift the liquid rather than force liquid up

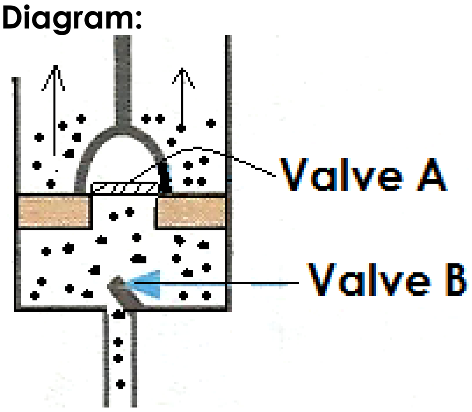
Diagram:



Mechanism

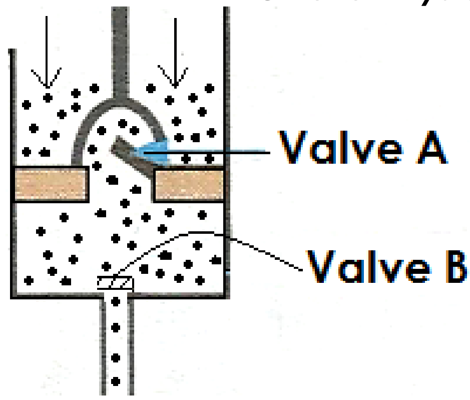
When a piston is raised (upstroke) valve A closed and valve B opens, which create partial vacuum between valve A and the piston and the atmospheric pressure pushes water up the pipe into the bowel.

Diagram:



When the piston is lowered (down stroke) valve A open and valve B closed due to the weight of water, the valve A allow water to rise over barrel. Repetition of stokes the water can collected on spout

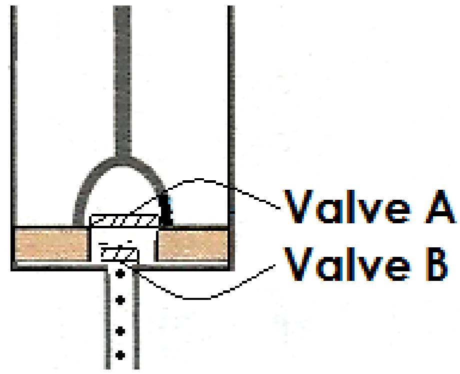
Diagram:



Nb:

The lift pump starts with the piston at the bottom of the empty cylinder and both valves closed

Diagram:



Limitation of Lift Pump

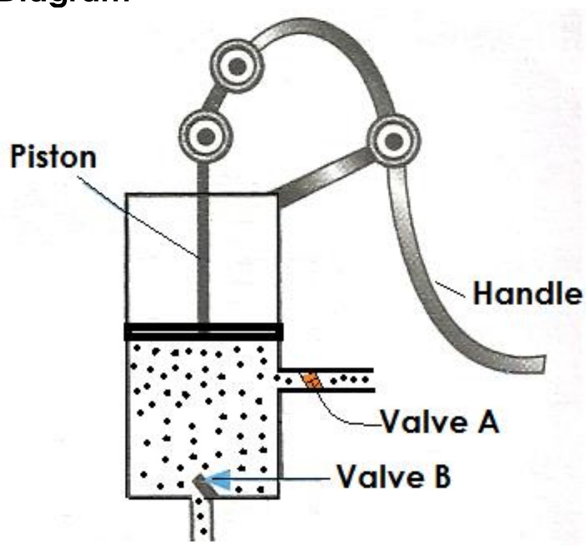
i. It can lift water up to height of 10m
ii. Few strokes are required

Force Pump

Force pump is a modified of lift pump

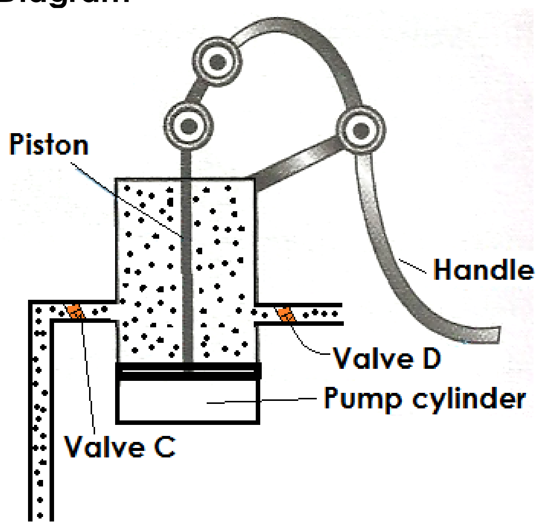
Mechanism

Diagram



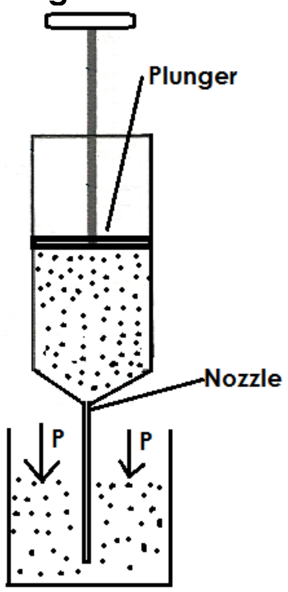
During up stoke of piston, a partial vacuum (low pressure) is formed between valve A and the piston. This cause valve A to close and pressure forces water into the barrel through valve B. during down stroke water is compressed, valve B closes and valve A opens. As a result water is forced by piston along the spout

Mechanism
Diagram



During upstroke of piston the valve C closes and the valve D open, this force the water in the cylinder out of the pump. During down stroke the valve C open and valve D closes due to the low pressure created between piston and the valve C, this tend to draw water from the external source into the pump cylinder

Syringe
Diagram:

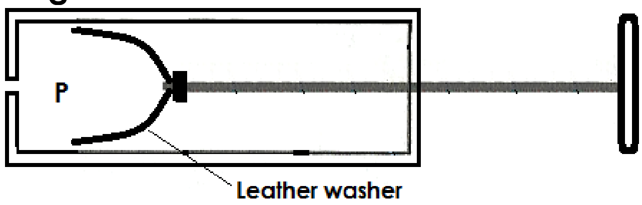


P = atmospheric pressure

Mechanism
When the plunger is withdrawn a partial vacuum is formed in the barrel, atmospheric pressure pushes water through the nozzle up into the barrel. Water will be forced out when the plunger is pushed down again

Uses of the Syringe
1. Used for medical purpose e.g. Injecting vaccines
2. They are used to measure liquids and gases in the laboratory
3. Used to apply certain compound such as glue or lubricant

Bicycle Pump
Diagram:



Mechanism
When the piston is pushes forward, air in the space p is compressed; the pressure pushes back the leather washer on the wall of barrel, taking an air tight seal, the tyres valve opens and air is forced into tyres. When the piston is pulled back, the tyres valve closes and a low pressure is created in the space, P. Air at atmospheric pressure forced its way past the leather washer and fill space p with air. In this way the tube

Work, Energy and Power

WORK

Defn: Work is the forces acts on a body and the moves in the direction of force

Or

Defn: Work is the product between force applied and the distance in the same direction

Mathematically:

w.d = F x d

SI unit of work

SI unit of work is Joule abbreviated as J

Where:

w.d = work done

F = force applied

d = distance in the same direction

Joule

Defn: one joule of work done is a force of 1N moves an object through a distance of 1m in the same direction

Equivalent Unit of Work

1Nm = 1Joule = Kgm^{2}S^{-2} = 0.001KJ

Nb:

i. If there not force no work done, F = 0N
   w.d = F x d = 0 x d = 0J
ii. If there not force no distance in the same direction, d = 0m
   w.d = F x d = F x 0 = 0J
iii. When the body moves in the opposite direction with the force applied there are work is done by the object
iv. When the body moves in the same direction with the force applied there are work is done by the force applied

Example, s of Phenomenal

i. When the person push a wall, d = 0m. there no work done
ii. When you carry a load on your head or arm, d = 0m. there no work done
iii. When a farmer carrying a hole, d = 0m. there no work done
iv. Holding load, d = 0m. there no work done
v. Lift jerry can, d > 0m. work is done
vi. Lift a pen, d > 0m. work is done
vii. Lift a cup, d > 0m. work is done

Example,

A sack of maize which weights 800N is lifted to height of 2m. What work done against gravity

Data given

Wight, w = 800N

Distance, d = 2m

Work done, w.d = ?

Solution

From: w.d = F x d

w.d = 800 x 2

w.d = 1600J

Example,

How much work is done to lift a 7kg object a distance of 2m and hen hold it at that height for 10s

Data given

Mass, m = 7kg

Force of gravity, g = 10N/kg

Wight, w = (7 x 10)N = 70N

Distance, d = 2m

Work done, w.d = ?

Solution

From: w.d = F x d

w.d = 70 x 2

w.d = 140J

therefore work done used to lift 7kg about 2m in the same direction is 140J and the work done used to hold (d = 0m) for 10s is 0J

Example,

A force of 80N pulls a box along a smooth and level ground a distance of 5m. Calculate the work done by force.

Data given

Wight, w = 80N

Distance, d = 5m

Work done, w.d = ?

Solution

From: w.d = F x d

w.d = 80 x 5

w.d = 400J

Energy

Defn: energy is an ability of doing work. SI unit of energy is Joule like work.

Forms of Energy

Energy can be exists in various forms, include

i. Chemical energy

ii. Heat energy
iii. Electromagnetic energy
iv. Sound energy
v. Electric energy
vi. Nuclear energy

Chemical Energy
It is the energy stored in the food and other fuels. Human get energy from the food that they eat

Thermal/Heat Energy
It can obtained at fire places

Electromagnetic Energy
It is associated with movement (acceleration) of electric charge. Include;
i. Infrared radiation
ii. Light energy
iii. Ultraviolet radiation
iv. Solar energy etc

Nb:
Radiant light is the most common form of electromagnetic energy

Sound Energy
It is the energy transfers in form of waves. Microphone converts sound energy to electrical energy. Loud speaker convert electrical energy to sound energy

Electric Energy
It is due to the movement of charge in a current and also it can produce field whether attract or repulsion when two wire are near or far apart each other.

Nuclear Energy
Nuclear energy is the energy from the weak and strong nuclear force. It can produce by
i. Nuclear fission (splitting)
ii. Nuclear fusion (joining)
iii. Radioactive decay

Nb:
i. Solar energy obtained from the sun by use of solar cells, also is known as radiant energy
ii. sources of energy can be divided into non-renewable energy and renewable energy

Renewable/Sustainable Energy
Defn: renewable is the energy that can be replaced within a short period of time. For Example, wind energy, thermal energy etc

Non Renewable Energy
Defn: renewable is the energy that cannot be replaced within a short period of time. For Example, natural gases, biomass etc

Types of Energy
Energy they can be in motion or in position. Example, electric energy is in moving and chemical energy is not in moving (on position). So we have about two main types
i. Kinetic energy
ii. Potential energy

Kinetic Energy
Defn: kinetic energy is the energy due to motion possessed by a body. For Example, of kinetic energy is
i. Wind energy
ii. Water moving
iii. Ocean Waves
iv. Ocean Tides
v. Moving machines
vi. Falling bodies

Mathematically:
$\mathbf{k.e = \frac{1}{2}mv^2}$

Example,
An object has a mass of 5kg. What is its kinetic energy if its speed is (a) 5m/s (b) 10m/s
Data given
Mass, 5kg
Speed, va = 5m/s
Speed, vb = 10m/s
Solution
(a) Kinetic energy, k.e = ?
From: $k.e = \frac{1}{2}mv^2$
$k.e = \frac{1}{2} \times 5 \times 5^2$
$k.e = \frac{1}{2} \times 5 \times 25$
$\underline{k.e = 22.5J}$

(b) Kinetic energy, k.e = ?

From: k.e = $\frac{1}{2}mv^2$

k.e = $\frac{1}{2}$ x 5 x 10^2

k.e = $\frac{1}{2}$ x 5 x 100

k.e = 250J

Example,
What is the kinetic energy of a 12g bullet travelling at 320m/s?

Data given
Mass, 12g = 0.12kg
Speed, v = 320m/s
Kinetic energy, k.e = ?

Solution
From: k.e = $\frac{1}{2}mv^2$

k.e = $\frac{1}{2}$ x 0.12 x 320^2

k.e = 6144J

Example,
Anna has a mass of 80kg. If she runs at a speed of 10m/s. calculate her kinetic energy

Data given
Mass, m = 80kg
Speed, v = 10m/s
Kinetic energy, k.e = ?

Solution
From: k.e = $\frac{1}{2}mv^2$

k.e = $\frac{1}{2}$ x 80 x 10^2

k.e = 4000J

Potential Energy
Defn: potential energy is the energy due to position possessed by a body. For Example, of potential energy
i. Energy stored in food
ii. Gravitational potential energy etc

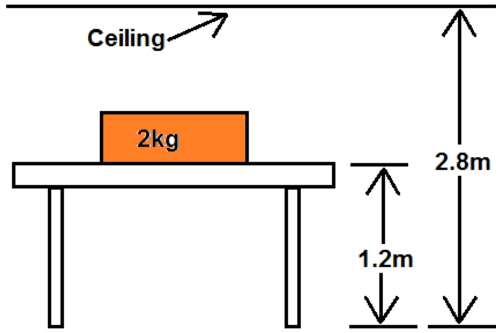
Mathematically:
p.e = mgh

Example,
A stone of 2kg falls from a height of 25m above the ground. Calculate potential possessed by the stone

Data given
Mass, m = 2kg
Height, h = 25m
Gravitational force, g = 10N/kg
Potential energy, p.e = ?

Solution
From: p.e = mgh
p.e = mgh = 2 x 25 x 10
p.e = 2 x 25 x 10
p.e = 500J

Example,
A 2kg object is at rest on a table 1.2m above the floor. The ceiling in the room is 2.8m above the floor



What is the potential energy of the object relative to?
{a} Top of the table
{b} The floor
{c} The ceiling

Data given
Mass, m = 2kg
Height of object relative to ceiling, h1 = -1.6m
Height of object relative to top of table, h2 = 0m
Height of object relative to table, h3 = 1.2m
Gravitational force, g = 9.8N/kg
Potential energy of object relative to top of table, p.e1 = ?
Potential energy of object relative to ceiling, p.e2 = ?
Potential energy of object relative to table, p.e3 = ?

Solution
From: p.e = mgh
{a} p.e1 = ?
p.e1 = mgh = 2 x 0 x 9.8
p.e1 = 0J

{b} p.e2 = ?
p.e2 = mgh = 2 x -1.6 x 9.8
p.e2 = -31.36J
NB: negative means p.e is below the ceiling

{c} p.e3 = ?
p.e = mgh = 2 x 1.2 x 9.8
p.e = 23.52J

Transformation of Energy

Energy can be changes from one form to another by the device known as **transducer**

Transducer

Defn: transducer is a device used to transform energy from one to another form. For Example,

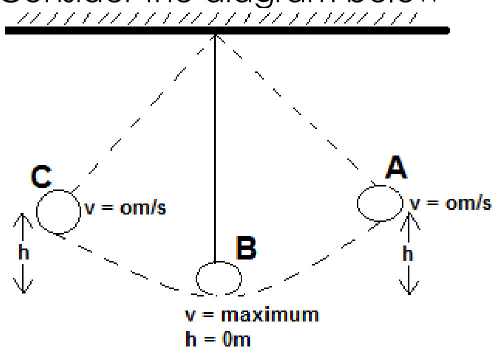
i. Battery convert chemical energy to electrical energy
ii. Generator convert mechanical energy to electrical energy
iii. A motor convert electrical energy to mechanical energy
iv. A microphone convert electrical energy to sound energy
v. Solar panel convert solar energy to electrical energy
vi. Heater convert electrical energy to heat energy

Principle of Conservation of Energy

The law of conversation of energy states that

"Energy can neither be created nor destroyed but can be transferred from one form to another"

Consider the diagram below



At point A and C

Velocity, v = o. K.e = 0J
Height, h = maximum. P.emax = mgh
Since: energy cannot destroyed
E = k.e + p.e
E = 0 + mgh
E = mgh
Where:
E = total energy
k.e = kinetic energy
p.e = potential energy

At point B

Velocity, v = maximum. K.emax = $\frac{1}{2}mv^2$
Height, h =0. P.e = 0mgh
Since: energy cannot destroyed
E = k.e + p.e
E = $\frac{1}{2}mv^2$ + 0
E = $\frac{1}{2}mv^2$
Where:
E = total energy
k.e = kinetic energy
p.e = potential energy

NB:

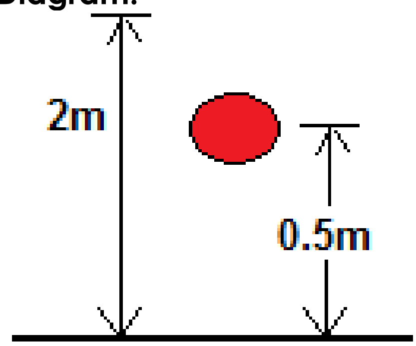
At any point the total energy (mechanical energy) is equal to the sum of kinetic energy and potential energy

E = p.e + k.e

Example,

A stone of mass 2kg is released from a height of 2m above the ground. Find
{a} Total energy
{b} Potential energy at heat of 0.5m
{c} Kinetic energy at height of 0.5m
{d} Velocity acquired at 0.5m

Diagram:



{a} Total energy, E = ?
Maximum height, h = 2m
Mass of object, m = 2kg
Gravitation force, g = 10N/kg
Minimum velocity, v = 0m/s
From: E = p.e + k.e
E = mgh + **0**
E = mgh = 2 x 10 x 2
E = 40J

{b} Potential energy, p.e = ?
Height, h = 0.5m
Mass of object, m = 2kg
Gravitation force, g = 10N/kg
From: p.e = mgh
p.e = mgh = = 2 x 10 x 0.5
p.e = 10J

{c} Kinetic energy, k.e = ?

From: E = p.e + k.e – make k.e subject

k.e = E - p.e

k.e = 40 - 10

k.e = 30J

{d} Velocity acquired at 0.5m

Velocity acquired at 0.5m, v1 = ?

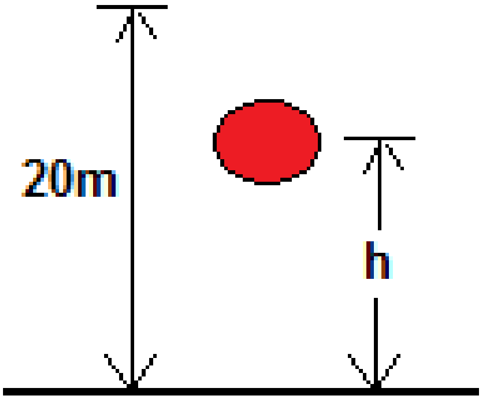
From: k.e = $\frac{1}{2}mv^2$ – make v subject

v = $\sqrt{\frac{2k.e}{m}} = \sqrt{\frac{2 \times 30}{2}} = \sqrt{30}$

v = 5.48 m/s

Example,

A ball of mass 0.2kg is dropped from a height of 20m. On impact with the ground it loses 30J of energy. Calculate the height which it reaches on the rebound



Total energy, E = ?

Maximum height, h = 20m

Mass of object, m = 0.2kg

Gravitation force, g = 10N/kg

Minimum velocity, v = 0m/s

Energy loss at height (h), k.e= 30J

From: E = p.e + k.e

E = mgh + **0**

E = mgh = 0.2 x 10 x 20

E = 40J

Height, h = ?

From: E = p.e + k.e

E = mgh + k.e – make h subject

h = (E - k.e)/mg

h = (40 - 30)/(0.2 x 10) = 10/2 = 5m

h = 5m

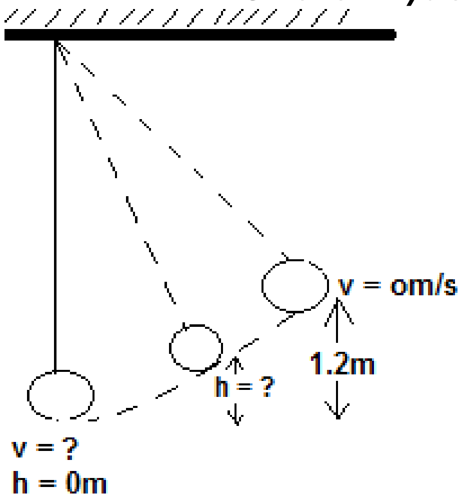
Example,

A its highest point A 1.2m a pendulum of mass 0.8kg is reached what.

{a} Velocity swings at lowest point

{b} Velocity at 0.9m

{c} **Height at 2m/s**



Solution

{a} Velocity swings at lowest point, v = ?

{b} Total energy, E = ?

Maximum height, h = 1.2m

Mass of object, m = 0.8kg

Gravitation force, g = 10N/kg

Minimum velocity, v = 0m/s

From: E = p.e + k.e

E = mgh + **0**

E = mgh = 0.8 x 10 x 1.2

E = 9.41J

Then:

Energy at highest = energy at lowest

K.e = p.e = 9.41J

From: k.e = $\frac{1}{2}mv^2$ – make v subject

v = $\sqrt{\frac{2E}{m}} = \sqrt{\frac{2 \times 9.41}{0.8}}$

v =4.85 m/s

{c} Velocity at 0.9m, v1 = ?

From: E = p.e + k.e

E = mgh **+** $\frac{1}{2}mv1^2$ – make v1 subject

V1 = $\sqrt{\frac{2(E-mgh)}{m}} = \sqrt{\frac{2(9.41-0.8x10x0.9)}{0.8}}$

V1 = 2.4 m/s

{d} Height at 2m/s, h1 = ?

From: E = p.e + k.e

E = mgh **+** $\frac{1}{2}mv^2$

E = m(gh + $\frac{1}{2}mv^2$)

9.41 = 0.8(10xh1 + $\frac{1}{2}$x2x2)

9.41/0.8 = 10h1 + 2

10h1 = 11.7625 – 2 = 9.7625

h1 = 9.7625/10

h1 = 0.9.7625 = 1m

h1 = 1m

Power

Defn: power is the rate of doing work or power is the rate at which energy is consumed. Its SI unit is Watt (w)

Mathematically:

P = w.d/t

P = E/t

Unit Equivalent

1W = 1J/s

1h.p = 750W or 746W

1KW = 1000W

1MW = 1000000W

Where:

h.p = horse power used by engineering

KW = kilowatt

MW = megawatt

Example,

A pump raises 100kg of water through a height of 30m in 10s. What is the power developed by the pump

Data given

Mass, m = 100kg

Height, h = 30m

Time taken, t = 10s

Gravitation force, g = 10N/kg

Power, p = ?

Solution

From: P = w.d/t

But: W.d = Fxd and F = mg

Then: P = mgd/t

P = (100x10x30)/10 = 30000/10 = 3000W

P = 3000W

Example,

How much power is required to accelerate a 1000kg car from rest to 26.7m/s in 8s?

Data given

Mass, m = 1000kg

Initial velocity, u = 0m/s

Final velocity, v = 26.7m/s

Time taken, t = 8s

Power, p = ?

Solution

From: P = E/t = k.e/t = $\frac{1}{2}mv^2/t$

P = ($\frac{1}{2}$ x1000 x 26.7^2)/8

P = ($\frac{1}{2}$ x1000 x 26.7^2)/8

P = 44500W

Example,

A 50kg girl runs up a staircase of 50 steps each step is 15cm in height in 5s. Find

i. Work done against gravity by the girl

ii. Power she use to run

Data given

Mass, m = 50kg

Steps, n = 50

Height of each step, h = 15cm = 0.015m

Total Height, d = n x s = 50 x 0.015m

Total Height, d = 0.75m

Time taken, t = 10s

Gravitation force, g = 10N/kg

Work done, w.d = ?

Power, p = ?

Solution

i. Work done, w.d = ?

From: w.d = F x d = 0.75 x 50

w.d = 0.75 x 50 = 37.5

w.d = 37.5J

ii. Power, p = ?

Then: P = w.d/t

P = (37.5)/5

P = 7.5W

Light Part I

LIGHT

Defn: light is an invisible form of energy that causes the sensation of vision in us through eyes

Sources of Light

Sources of light is the original or initial of light in which the light are comes from whether natural or artificial

Types of Sources of Light

i. Natural sources of light. Example, sun, star and lighting
ii. Artificial sources of light. For Example, torch, candle, kerosene lamp etc

Properties of Light

i. Light radiates (spread out) from its source
ii. Light travels in straight lines
iii. Light transfers energy. Object gain energy when they absorb light. For Example, solar cells(panel)
iv. Light travels in vacuum
v. Light travels at the fasters speed, about 300,000,000m/s

NB:

i. All objects which give out its own light is called luminous object. e.g. star, sun, torch, candle, electric bulb etc
ii. All objects that do not emit their own light instead became visible when they reflect light from another source is called non luminous objects. E.g. moon
iii. All objects that emit light as a result of being heated are called incandescent object. e.g. light bulb, fire flame, candle flame etc
iv. The spreading of light from its source to the environment in straight lines is referred as rectilinear propagation of light

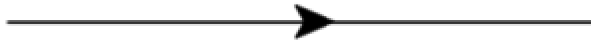
Propagation of Light

Since a light travels in a straight line, the path travel and by a light is called Ray. More than one rays is called beam

Ray

Defn: Ray is the path travel by a light. Ray is represented in a diagram by full straight line with an arrow to show the direction of light.

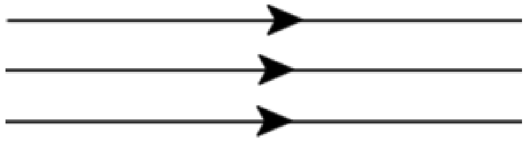
Diagram:



Beam

Defn: Beam is the collection of rays

Diagram:



Types of Ray

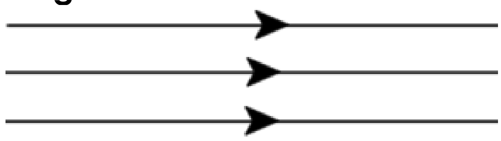
The beam of light is transfer in straight line which can be

i. Parallel rays
ii. Converging rays
iii. Diverging rays

Parallel Rays

Defn: Parallel ray is the collection of rays which are perpendicular to each other and can never cross each other

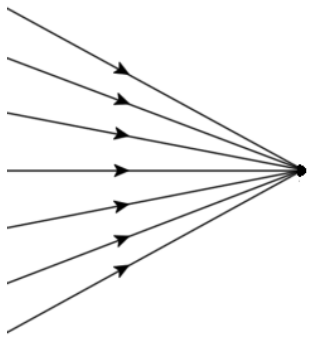
Diagram



Converging Rays

Defn: Converging ray is the collection of rays to one point

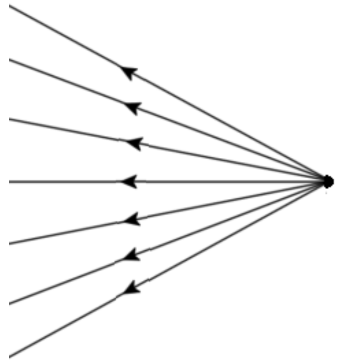
Diagram



Diverging Rays

Defn: Diverging rays is the spread out of rays from one point

Diagram



Transmission of Light

Light travel in the different material, for Example, it can travel from air to vacuum. But sometimes it can undergo obstacles when they travel from one object to another. This object are grouped as

i. Opaque object/material/substance
ii. Translucent object/material/substance
iii. Transparent object/material/substance

Opaque Object

Defn: Opaque object is the object which do not allow light to pass through them. For Example, stone, wood, concrete walls, books etc

Translucent Object

Defn: Translucent object is the object which allow small amount of light to pass through them. For Example, oiled paper, tinted glass, some plastic materials etc

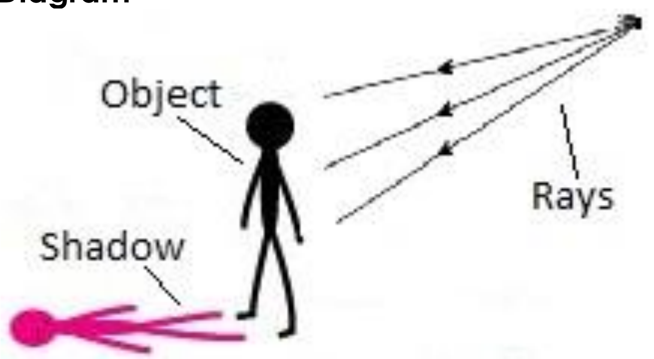
Transparent Object

Defn: Transparent object is the object which allows all light to pass through them. For Example, glass, pure water, air etc

Shadow

Defn: shadow is the dark area behind the opaque body when light pass through the opaque bodies.

Diagram



Types of Shadow

We have about two types of shadow include

i. Umbra shadow
ii. Penumbra shadow

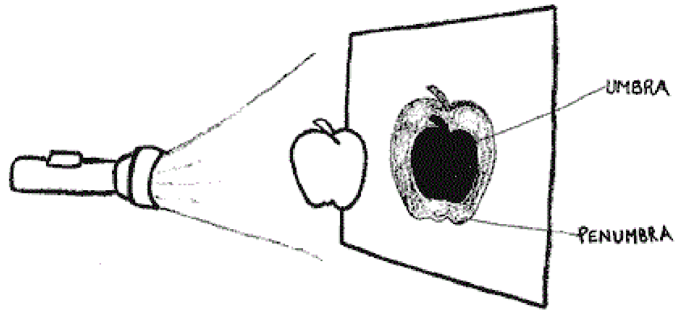
Umbra Shadow

Defn: Umbra shadow is the total shadow formed behind the opaque bodies. It receives no light at all from the source.

Penumbra Shadow

Defn: Penumbra shadow is the partial shadow formed behind the opaque bodies. It receives some light from the source

Diagram



NB:

When source of light are small than opaque only umbra are formed

Eclipse

Defn: eclipse is the shading or shading of one heavenly in the shadow of another.

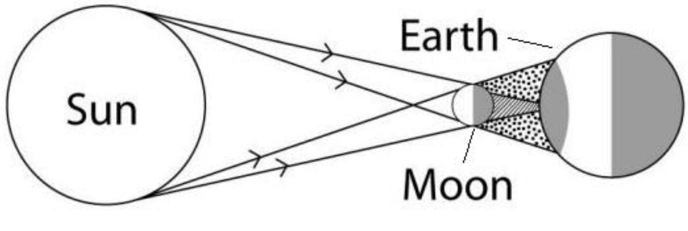
Types of Eclipse

i. Solar eclipse
ii. Lunar eclipse

Solar Eclipse

Defn: Solar eclipse is the kind of eclipse in which the moon is between sun and earth. Always occurs during the day.

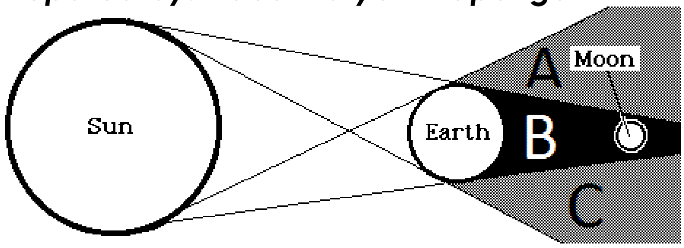
Diagram:



Lunar Eclipse

Defn: Lunar eclipse is the kind of eclipse in which the earth is between sun and moon.

Diagram:



From The Diagram Above

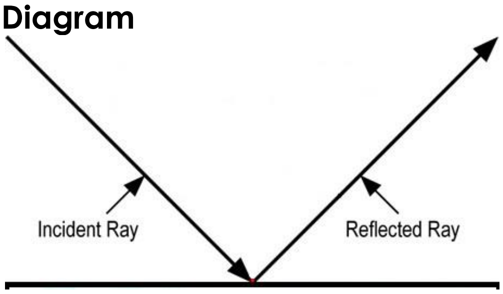
i. At point A and C: the moon is less bright but not eclipse
ii. At point B: lunar eclipse occur the moon did not light during the night

Reflection of Light

Defn: reflection of light is the throwing back of rays of light when they encounter an obstacle in their path **or** reflection of light is the is the bounce back of light

Terms Used

i. **Reflected ray** are those that are not transmitted or absorbed but bounced back when they encounter an obstacle
ii. **Incident ray** is the ray of light which strikes the shiny surface
Diagram

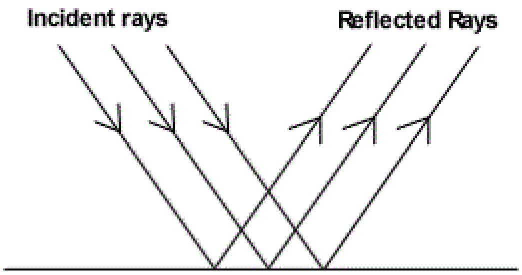


Types of Reflection

There are two types of reflection include
i. Regular reflection
ii. Diffuse reflection

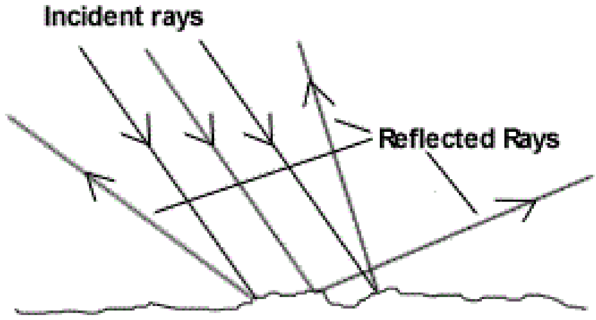
Regular Reflection

Defn: Regular reflection is the reflection where by all reflected ray reflected in one direction. The ray is in parallel to each other. Occurs at smooth surface
Diagram

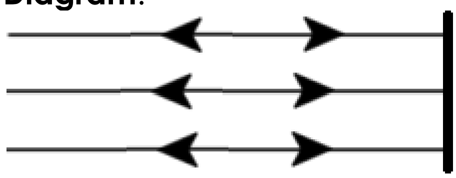


Diffuse Reflection

Defn: Diffuse reflection is the reflection where by all reflected ray reflected random or in different direction. Occurs at rough surface
Diagram



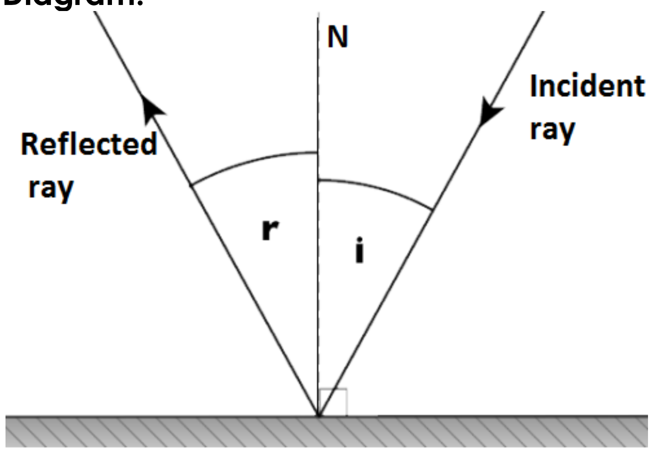
NB:
i. We see our image clear in plane mirror as a result of regular reflection.
ii. If light falls in polished surface at right angle reflect back into the air on the same pass
Diagram:



iii. Diffuse reflection also called **scattering/ irregular reflection**
iv. When sun rays inters the earth's atmosphere, it begins to be scattered by molecules of nitrogen and oxygen

Laws of Reflection

Consider the figure below
Diagram:



Where:
i = angle of incident
r = angle of reflected

N = normal line

From above diagram, the laws of reflection states that

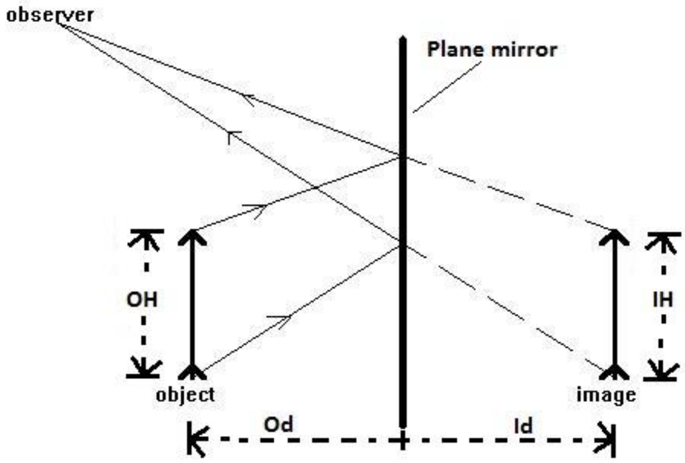
1st. "*the incident ray, the reflected ray and the normal all lie in the same plane*"

2nd."*The angle of incidence equals to the angle of reflection*"

Image Formed In a Plane Mirror

When object kept front of plane mirror the image is formed due to the reflection of light

Diagram:



Where:

M = magnification
Id = image distance
Od = object distance
IH = image height
OH = object height

Characteristics of Image Formed In Plane Mirror

i. The image is virtual (not real)
ii. The image is upright
iii. Image and object has the same size
iv. Distance of image and object from the plane mirror are the same
v. Image has a left-right reversal

Magnification

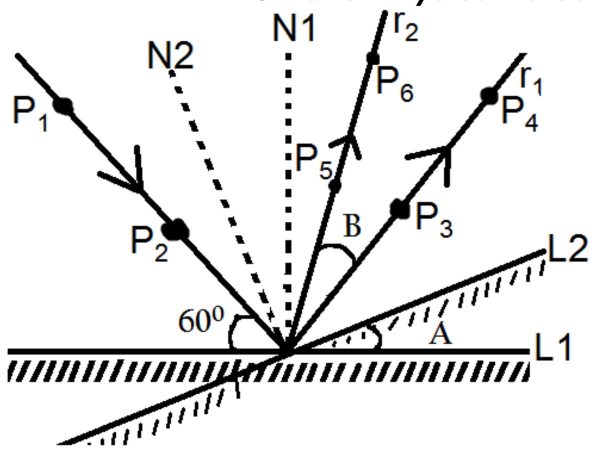
Magnification is given by the formula

M = Id/Od = IH/OH

Rotating a Mirror

If the mirror was rotated through certain angle (θ), then the angle between reflected rays after mirror rotated would be twice of certain angle (2θ)

Diagram:



Where:

θ = angle in which mirror rotates
2θ = angle former between reflected rays
2 = angular magnification
N_1 = normal along P_1 (plane mirror, θ =0^0)
N_2 = normal along P_2 (plane mirror, θ = $θ^0$)
i = incident ray
r_1 = reflected ray at P_1 (plane mirror, θ =0^0)
r_2 = reflected ray at P_2 (plane mirror, θ = $θ^0$)

Multiple Mirrors

There are systems which consist of two or more mirrors and produce several image of the same object. One such system is called a right angle mirror (two mirrors joined at 90^0)

Diagram

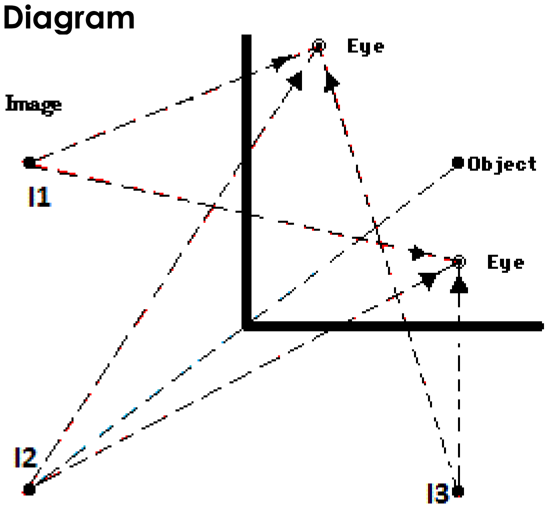


Image in parallel mirror (two mirrors joined at 0^0). The image is infinite in each mirror because there is repetition of images

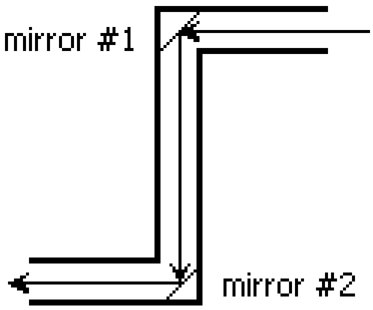
Nb:

i. The number of image increase as if the angle between mirror decreases
ii. Parallel mirrors are used commonly used in salons and barber shops
iii. The number of image can gives as

$$\mathbf{n = (\frac{360°C}{\theta°C}) -1}$$

Application of Reflection of Light
Reflection of light finds applications in a periscope

Periscope
Defn: periscope is the device for used to see over an obstacle from a concealed position. It consist of two mirrors fixed facing each other at an angle 45^0. Light is reflected by two mirrors so that an object can be seen by the observer.
Diagram:



Uses of Periscope
The periscope is used in many aspects of everyday life, include.

i. When submarine are submerged at a shallow depth, periscope are used to look for targets or threats in the surrounding sea and air
ii. Solder use periscopes to observe any potential danger while they hide in trenches
iii. Periscope form part of telescope

Telescope
Defn: telescope is the instrument containing lenses that are used to make far away object to appear larger and near. Often are used to observing stars

Static Electricity

Defn: *static electricity is the study of charge at rest*. Static electricity also called **electrostatics**

Charge

Defn: charge is the particles carry either positive particle or negative particle

Origin of Charges

When body rubbed cause the atoms to loose or gain electron which are revolve around atomic structure result causing the body to become charged. Due to that reason it tends to cause;

(a) plastic materials are rubbed on a cloth/hair attract dust and small pieces of paper
(b) Particles of wheat are attracted to amber.
(c) The moving parts of machinery, car tyres, and vehicle bodies they attract light particles
(d) Ebonite rubbed with fur/cloth attract dust and small pieces of paper
(e) Glass rubbed with silk attract dust and small pieces of paper
(f) polythene rubbed with fur/cloth attract dust and small pieces of paper
(g) polystyrene rubbed with fur/cloth attract dust and small pieces of paper
(h) Perspex rubbed with woolen cloth attract dust and small pieces of paper
(i) cellulose rubbed with woolen cloth attract dust and small pieces of paper
(j) some clothes cling to the body
(k) comb rubbed with sleeve attract piece of paper
(l) crackling noise while remove nylon cloth

Types of Electric Charges

There are two types of charge include

i. Positive charge (+)
ii. Negative charge (-)

Positive charge

Defn: Positive charge is a charge acquire when an object loose electron from its atomic structure

Negative charge

Defn: Negative charge is a charge acquire when an object gain electron from its atomic structure

Nb:

i. Electrons are revolve around the nuclear
ii. Electrons are moved from one atom to another
iii. Protons never move from one to another atom

Charge acquired after rubbed

Materials	Rubbed with	Charge acquired
Ebonite	Fur/cloth	Negative
Glass	Silk	Positive
Polythene	Cloth/fur	Negative
Polystyrene	Cloth/fur	Negative
Perspex	Woolen cloth	Positive
cellulose	Woolen cloth	Positive

Fundamental law of electrostatics

The fundamental law of electrostatics which states that

"***Like charges repel, unlike charges attract each other***"

Also is called **fundamental law of static charges** or **first law of electrostatics**

Charging

Defn: charging is the process whereby material loose or gain electrons

Methods of Charging

There are three methods as

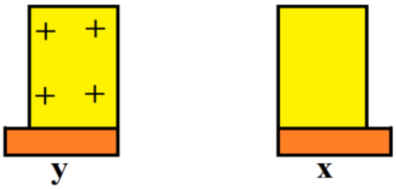
i. Rubbing or friction method
ii. Conduction or contact method
iii. induction method

Friction Method

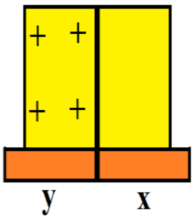
When you rub two objects the one which his outer most shell weak bound will lose and the one have sparsely electron gain the electron. Due to that electrons shift from one object to another and tend to gin one to become negative charged and lose one become positive charged

Contact Method

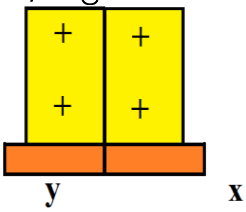
When charge and uncharged body contact the charge always move from charged body to another because like charge repel and unlike charge attract. Consider the two charge body (y) and uncharged body (x)



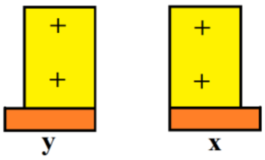
Contact two bodies



Since like charge repel each other positive charge will shift/migrate from y to x



Separate them immediately

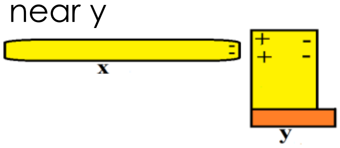


Now uncharged (x) became positive charged

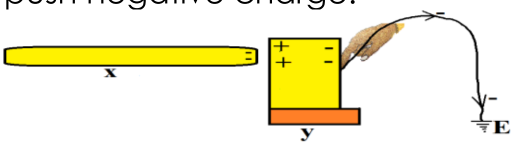
Induction Method

When two body charge and uncharged body keep near, charged body causes the other body to gain opposite charges to the one of the charging body. Consider the two charge body (x) and uncharged body (y)

Place x near y



Since like charge repel, unlike attract each other negative charge will pull positive and push negative charge.

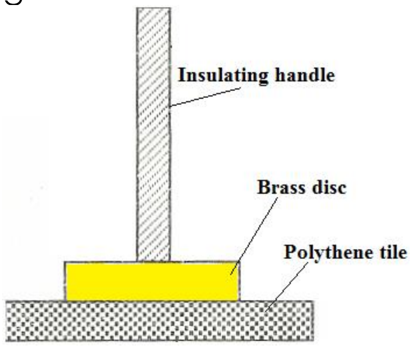


Touch y to allow movement of electrons to ground. The movement/flow of electrons to ground is called **Earthing**

Now uncharged (y) became positive charged

Electrophorus

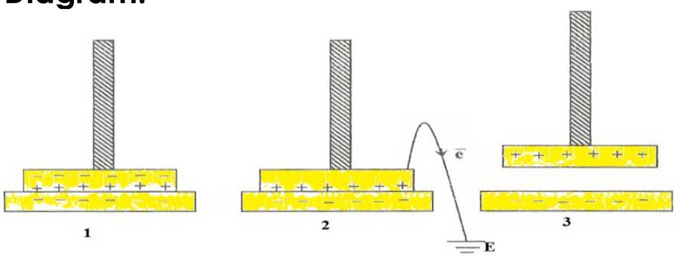
An electrophorus consists of a metal disc made of brass fitted with an insulating handle (usually an ebonite rod) resting on polythene base. It can produce numerous positive charges from a single negative charge.



Charging an Electrophorus

Electrophorus is charged by induction. The polythene is given a negative charge by rubbing it with fur causing positive charge to be induced on the upper part of the brass plate, and a negative charge on the lower part of the brass plate will leave the polythene plate charged negatively. The electrophorus is left with an excess positive charge

Diagram:

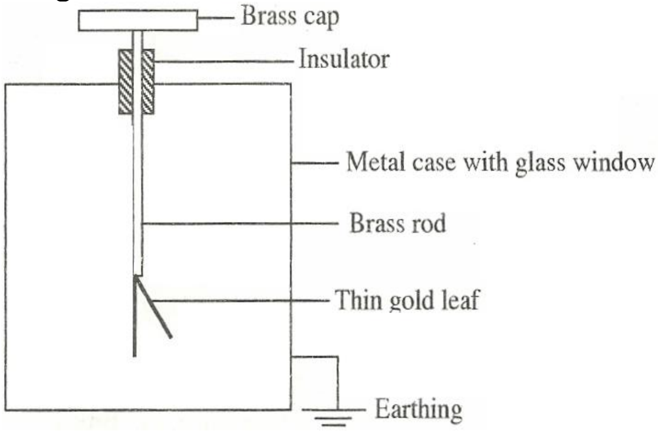


Gold Leaf Electroscope

Gold leaf electroscope is an instrument for detecting/identify the presence of an electrical charge on an object. The gold leaf electroscope consists of gold leaf and a brass rod of metal held by insulating materials

The brass cap, brass rod and the gold leaf form the conducting part of the electroscope.

Diagram:



Charging an Electroscope

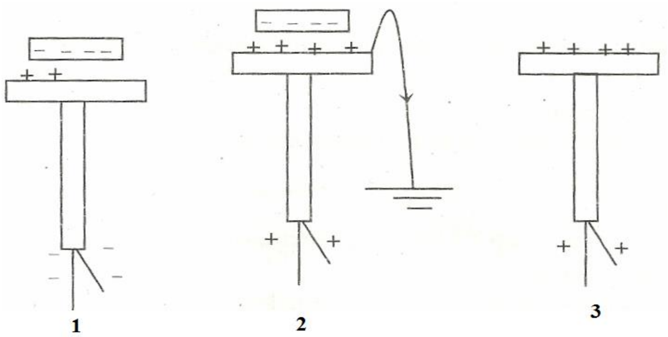
It charged by contact and Induction

Charged By Contact

When charge and uncharged body contact the charge always move from charged body to another because like charge repel and unlike charge attract. Therefore the charged one when brought to contact with metal cap result to charge metal cap and became charged

Charged By Induction

A negatively charged rod is brought near the brass cap of the gold leaf electroscope. Induced charges are formed with brass rod acting as conductor.



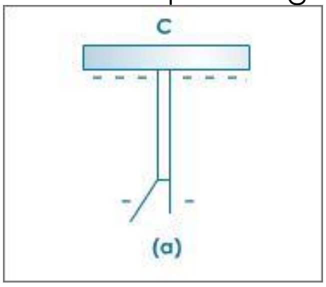
Uses of Gold Leaf Electroscope

A **gold leaf electroscope** has a number of functions the follows are some of them

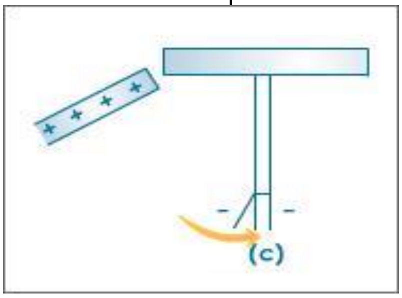
i. Test for the sign of charge on a body
ii. Identify the insulating properties of material
iii. Detect the presence of charge on a body

Test for the sign of charge on a body

i. It used to test whether charge is positive or negative. In order to identify the charge of a body we should use a charged electroscope. Let us say the electroscope is negatively charged.

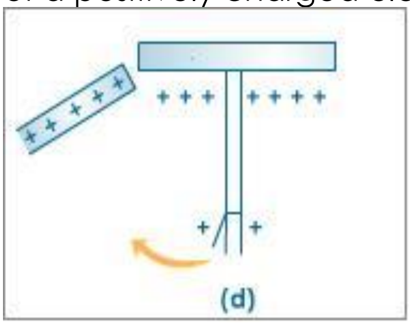


Now bring the unknown charged body 'X' near the cap of the electroscope.



ii. If the leaves diverge more the charge in 'X' must be negative. Suppose that the leaves close a little when 'X' is brought near 'C', then 'X' may have a positive charge or it may not have any charge.

iii. In order to confirm the positive charge you must bring the rod 'X' near the cap of a positively charged electroscope.



If the leaves diverge more, then 'X' has positive charge and vice versa.

Nb:

i The leave diverge/increase due to high concentration of charge
ii The leave converge/decrease due to low concentration of charge

Table of summary of charges and their effect

Charge on electroscope	Charge brought near cap	Effect on leaf divergence
+	+	Increase
-	-	Increase
+	-	Decrease
-	+	Decrease
+ or -	Uncharged body	Decrease

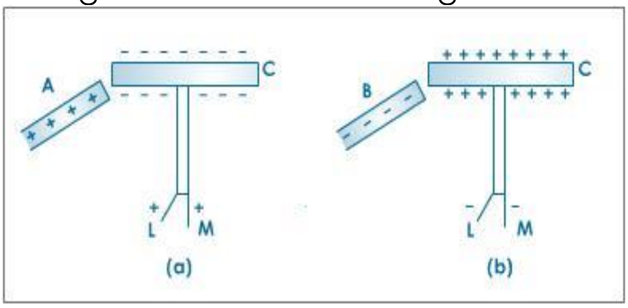
Identify the insulating properties of material

An electroscope that is positively charged can used to test for the insulating properties of material

If the material that as placed near the cap of an electroscope is a conductor, then the metal leaf will converge and a divergence will show that the material is an insulator

Detect the presence of charge on a body

To detect a charge on a rod 'A' or 'B' bring the rod near to the metallic disc or cap of the electroscope. In either case the leaf diverges as shown in the diagram.



Conductor

Defn: *conductor is substances which allow electricity to flow through them*. Example, s of conductors are metals like iron, copper etc

In conductors electrons are free to move which are conduct charge from one to another

Insulator

Defn: *insulator is a material that does not allow electricity to flow through them*. Example, s of insulators are plastic, wood, rubber, mica, ebonite and glass. In insulators there are no free electrons for conduction.

Nb: Insulators and conductors are sometimes applied together in electric power usage.

Capacitors

Defn: capacitor is device used to store electric charges.

Nb:

i The ability to store electric charges is known as **capacitance**.

ii SI unit of Capacitance is **Farad**

iii Capacitor are found in all electronic circuits, e.g. in **radios**, **television**, **alarm systems**, etc.

The potential difference (Voltage produced by cell/battery), V across the two capacitor plates of the capacitor is directly proportional to the charge, Q accumulating on its plates

$$V \propto Q$$

Remove proportionality constant

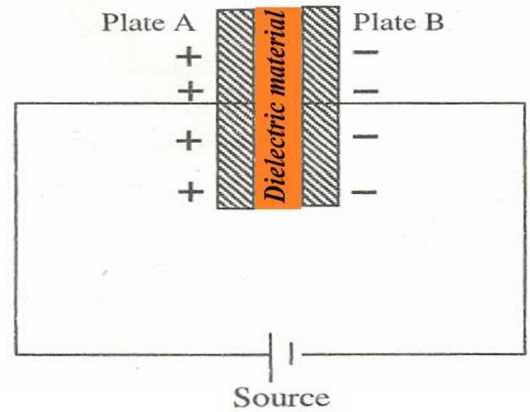
$$Q = kV$$

But: k = C = capacitance

$$\mathbf{Q = CV}$$

Charging a Capacitor

A capacitor consists of two metal plates (say plate A and plate B) arranged in parallel with a dielectric material between them. The two plates accumulate charges when a potential difference is applied across them



Defn: *potential difference is the work done needed to move a charged particle from a point to point*. Its SI unity is voltage. Also called **potential**

Discharging a Capacitor

When the two plates of a capacitor are joined, the electrons from the negatively charged plate will flow around the circuit and neutralize the positive charges on the positively charged plate. This movement of electrons will cause a current to flow for a short time and if you are using a wire to connect the two plates you can draw a spark. When the current stop flowing, the capacitor is said to be discharged

Types of Capacitors
There are different types of capacitors depending on the dielectric material used and the application.
i. Paper/plastic filled capacitor
ii. Oil filled capacitor
iii. Electrolytic capacitor
iv. Mica capacitor
v. Variable/ air filled capacitor

Paper Capacitor
It this paper/plastic/polyester material is used as dielectric material. It has metal foil strip as their conductor.

Oil Capacitor
It this oil material is used as dielectric material.

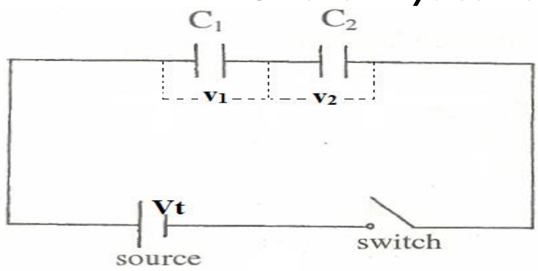
Electrolytic Capacitor
Its contain paper material soaked in a chemical as conduct and a thin aluminium oxide is formed on the positive plane. The thinner the layer higher the capacitance

Mica Capacitor
In mica a sheets of metal foil are separated by strips of mica. Mica is preferred because it is a natural mineral and splits easily into thin sheets

Variable Capacitor
Conduct are semicircular plates are separated by air ad dielectric material. One set of plate is fixed and other is rotate by means of the knobs. The rotation changes the area of the plate

Arrangement of Capacitors
Capacitors can be arranged in series or in parallel to get the desired effect:

Capacitors in Series

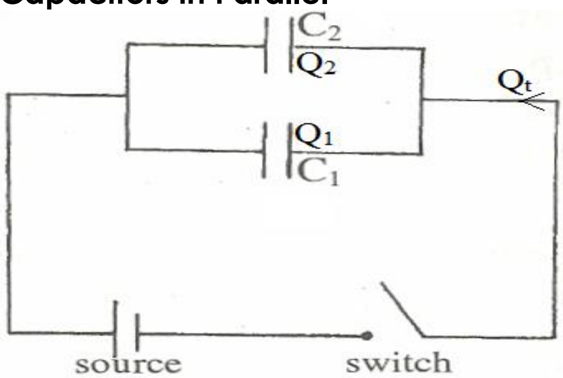


From the diagram above
$V_t = V_1 + V_2$
But: Q = CV – make v subject
V = C/Q
Therefore:
$V_t = Q_t/C_t$
$V_1 = Q_1/C_1$
$V_2 = Q_2/C_2$
But: charge store is equal but each of capacitor
$Q_t = Q_1 = Q_2 = Q$
Modify:
$V_t = Q/C_t$
$V_1 = Q/C_1$
$V_2 = Q/C_2$

Where:
First capacitance = C_1
Second capacitance = C_2
Effective capacitance = C_t
Charge from capacitance, $C_1 = Q_1$
Charge from capacitance, $C_2 = Q_2$
Total capacitance, $C_t = Q_t$
Voltage across capacitance, $C_1 = V_1$
Voltage across capacitance, $C_2 = V_2$
Total voltage across capacitance, $C_t = V_t$

From: $V_t = v_1 + v_2$ - Substitute each
$Q/C_t = Q/C_1 + Q/C_2$
$Q/C_t = Q(1/C_1 + 1/C_2)$ – divide by Q both sides
$1/C_t = 1/C_1 + 1/C_2$
Therefore for capacitor in series their total capacitance is obtained by formula;
$\mathbf{1/C_t = 1/C_1 + 1/C_2}$

Capacitors in Parallel



From the diagram above

$Q_t = Q_1 + Q_2$

But: $Q = CV$

Therefore:

$Q_t = C_tV_t$

$Q_1 = C_1V_1$

$Q_2 = C_2V_2$

But: voltage across each capacitor is equal

Modify:

$Q_t = C_tV$

$Q_1 = C_1V$

$Q_2 = C_2V$

From: $Q_t = Q_1 + Q_2$ - Substitute each

$C_tV = Q(C_1V + C_2V)$

$C_tV = V(C_1 + C_2)$ – divide by V both sides

$C_t = C_1 + C_2$

Therefore for capacitor in series their total capacitance is obtained by formula;

$$\mathbf{C_t = C_1 + C_2}$$

Example,

Two capacitors of 20 μF and 25 μF are connected in (i) series, and (ii) parallel. What is the effective capacitance for (i) and (ii)?

Data given

First capacitance, C_1 = 20 μF

Second capacitance, C_2 = 25 μF

Effective capacitance, C_{t} = ?

Solution

(i) Series

From: $1/C_t = 1/C_1 + 1/C_2$

$1/C_t = 1/20 + 1/25$

$1/C_t = (5 + 4)/100$

$1/C_t = 9/100$

$C_t/1 = 100/9$

$\underline{C_t = 11.11\ \mu F}$

(ii) Parallel

From: $C_t = C_1 + C_2$

$C_t = 20 + 25$

$\underline{C_t = 45\ \mu F}$

Example,

Determine the effective capacitance obtained when two capacitors each of 10 μF are connected first in parallel and then in series.

Data given

First capacitance, C_1 = 10 μF

Second capacitance, C_2 = 10 μF

Effective capacitance, C_{t} = ?

Solution

(i) Series

From: $1/C_t = 1/C_1 + 1/C_2$

$1/C_t = 1/10 + 1/10$

$1/C_t = (1 + 1)/10$

$1/C_t = 2/10$

$C_t/1 = 10/2$

$\underline{C_t = 5\ \mu F}$

(ii) Parallel

From: $C_t = C_1 + C_2$

$C_t = 10 + 10$

$\underline{C_t = 20\ \mu F}$

Example,

It is required to obtain effective capacitance of 3 μF, there are two capacitors; the first is 12 μF, what will be the value of the other capacitor. State the way it will be connected to the first.

Data given

First capacitance, C_1 = 20 μF

Second capacitance, C_2 = ?

Effective capacitance, C_t = 2 μF

Solution

(i) Series

From: $1/C_t = 1/C_1 + 1/C_2$

$1/3 = 1/12 + 1/C_2$

$1/C_2 = 1/3 - 1/12$

$1/C_2 = (4 - 1)/12$

$1/C_2 = 3/12$

$1/C_2 = 3/12$

$C_2/1 = 12/3 = 4$

$\underline{C_t = 4\ \mu F}$

It will be connected in series to the first one and its value will be 4 μF

Factor Affecting Capacitance

Capacitance of a parallel plate capacitor is affected by three factors, namely

i. The area of plates
ii. The dielectric material
iii. The distance between plates

Area of Plates

An increase in the area of the plate causes a decrease in potential difference between the plates, hence an increase in capacitance.

$$C \propto 1/V$$

Dielectric Material

Dielectric material will cause the capacitance to increase or decrease depending on the material. Example, capacitance increases if we use dielectric material such as glass or book or polythene between the plates rather than air

Distance between Plates

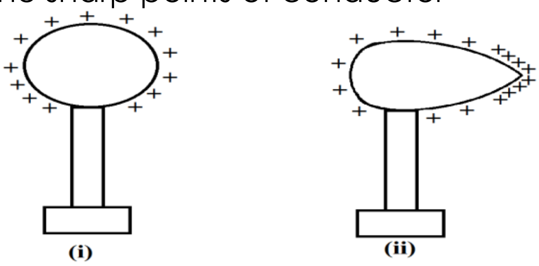
A decrease in the distance between plates causes a decrease in potential difference between the plates, hence an increase in capacitance.

$C \propto 1/d$

Charge Distribution

Scientists and engineers have developed several experiments to prove the distribution of charge as;

i. Hollow object only have charge on their outer surface
ii. Charge is normally concentrated on the sharp points of conductor



Lightning

Lightning is a giant electric spark that arises due to discharge of atmospheric electricity

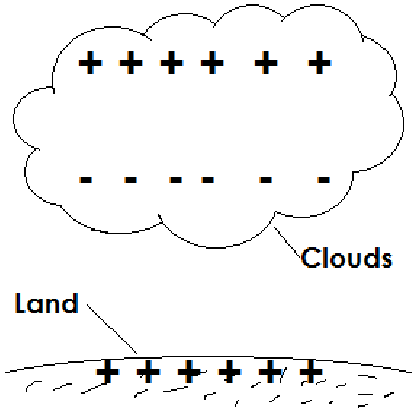
Or

Lighting is sparking on a very large scale

How Lightning Happens

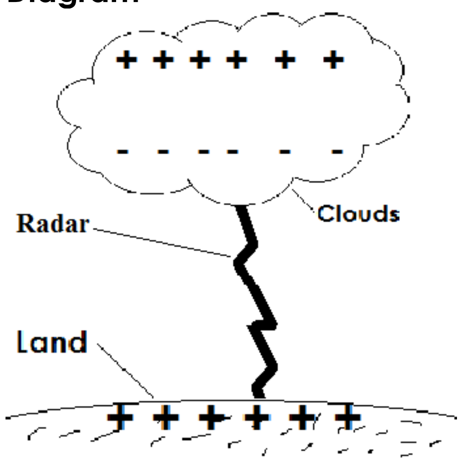
Occurs when water molecules (clouds) in the sky rubbed each other resulting the lower portion of clouds become negatively, the upper portion of clouds become positively while ground become positively after induced by lower portion

Diagram



When wind passes across clouds, a few electrons move across the air toward positive clouds but in zigzag path called **Radar**

Diagram



Thunderstorm

Air around the radar undergoes rapid expansion and contraction due to overheating causing high speed of air molecules. This produces an audible sound called **thunder**

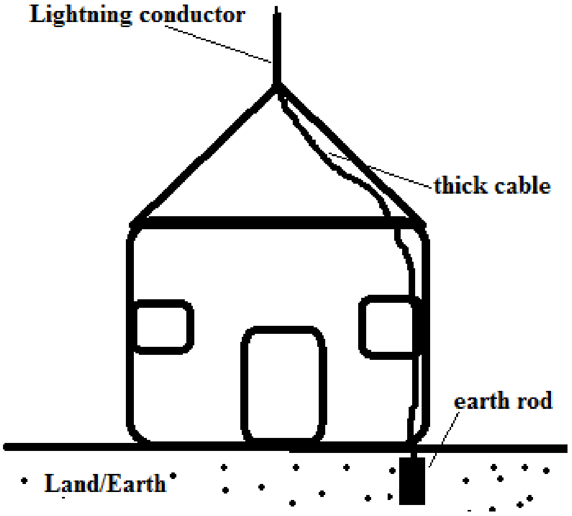
Lightning Conductor

Lightning conductor is a long pointed conductor at the top reaching high above the highest point of a building connected to earth by a thick cable to earth rod

Or

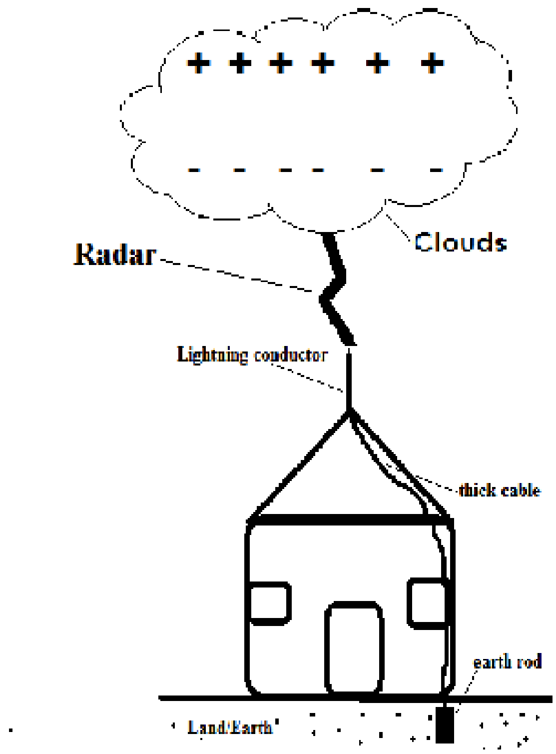
Lightning conductor is a metal rod with tip has sharp spikes attached to a build and connected to a thick copper strip that leads into the ground

Diagram



Function of Lightning Conductor
To protect buildings from being struck by a lightning

Mode of Action
With a thunder cloud forming or passing close to the house as depicted, the sharp point of the lightning conductor becomes inductively charged opposite to the thunder cloud. The resulting high electric field ionizes the air in the vicinity such that the charged air molecules move upwards earth rod to the ground. This action discharges the thunder cloud, thereby preventing a lightning flash occurrence.
Diagram



Current Electricity

Defn: Current electricity is the study of electric charge in motion or dynamic electric charge

To maintain motion of electric charge two things are required

i. Source of electric charges
ii. Closed path around the charges move and returning to the source

This closed path is called ***electric circuit***

Nb:

The size of the electric current (I) in material depends on the number of charge carries taking part and the speed at which they are moving, In a simple electric circuit the charge carries are the **electrons**

Defn: Electric current is amount of charge per time taken for the passage if the charge in a circuit

Mathematically

I = Q/t

Where:

I = electric current

Q = quantity of charge

t = time taken by charge to rotate circuit

Make subject Q

I = Q/t – multiply by t both sides

Q = It

Also electric current can be defined *as the rate of flow of charge*

From the definition the SI unit of I is

I =Q/t

I = Coulombs/Second = c/s = ampere = A

The common SI unit of I is ***ampere (A)***

The other units are Mill Amperes (mA), Kilo amperes (kA), and microamperes (μA)

Their equivalence to the ampere is as follows

1A $=10^{3}$ mA

1A $= 10^{6}$ μA

1kA =1000A

Defn: coulomb is the quantity of electric which passes a given point in 1second when steady current of 1A is flowing in circuit

The device used to measure electric current is called **Ammeter**

Uses of Current Electrics

i. Cooking
ii. Lighting
iii. Communication
iv. Heating

Source of Current Electricity

All sources of I work by converting some kind of energy into electrical energy

There are two basic sources are:

i. Batteries
ii. Generators

Batteries

It converts chemical energy into electrical energy

Generators

It converts mechanical energy into electrical energy.

E.g.; Wind energy, HEP (Hydroelectric power), solar energy, Ocean waves, Thermal energy etc

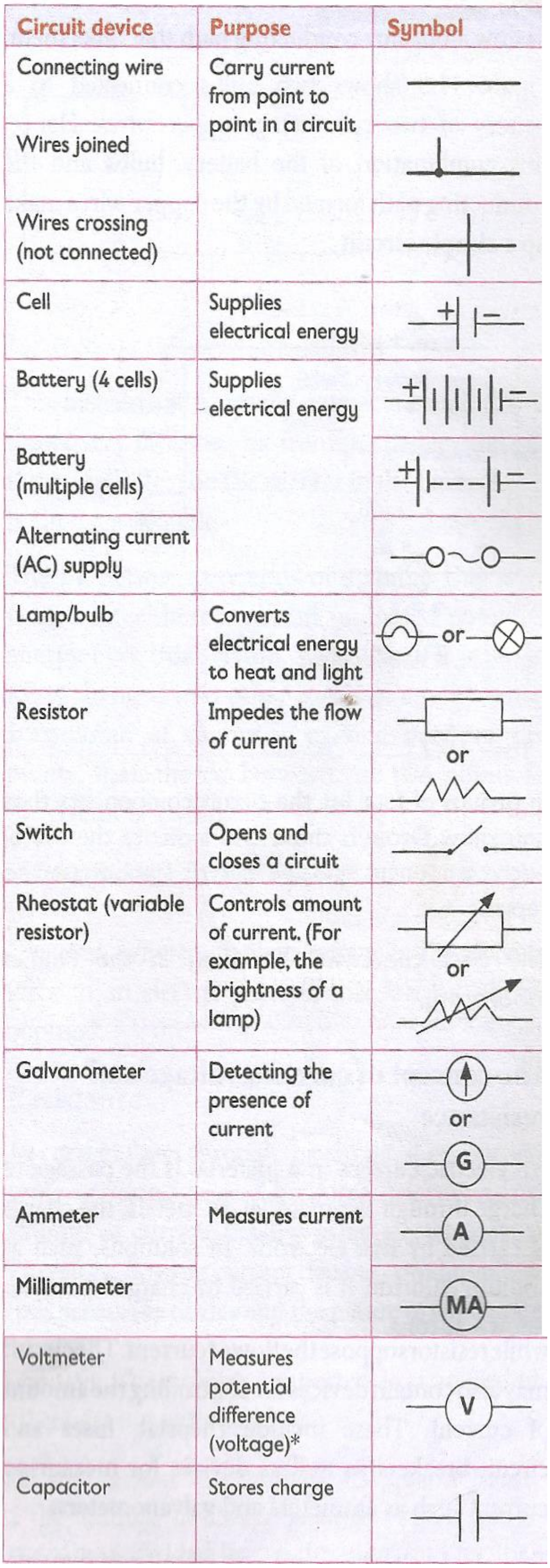
Simple Electric Circuits

As we see precious circuit contain;

a) Source of charge, it may be battery or generator
b) Closed path (connecting wires made of a conducting material)
c) Electrical device such as; Bulb, Switches, Resistors, Ammeter, Voltmeters etc

Always the electric circuit used symbols for all component, consider the symbols in the table below,

Table Shows Electric Symbols

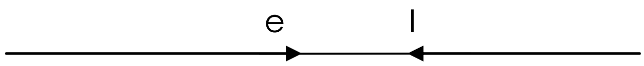


Circuit device	Purpose	Symbol
Connecting wire	Carry current from point to point in a circuit	
Wires joined		
Wires crossing (not connected)		
Cell	Supplies electrical energy	
Battery (4 cells)	Supplies electrical energy	
Battery (multiple cells)		
Alternating current (AC) supply		
Lamp/bulb	Converts electrical energy to heat and light	or
Resistor	Impedes the flow of current	or
Switch	Opens and closes a circuit	
Rheostat (variable resistor)	Controls amount of current. (For example, the brightness of a lamp)	or
Galvanometer	Detecting the presence of current	or G
Ammeter	Measures current	A
Milliammeter		MA
Voltmeter	Measures potential difference (voltage)*	V
Capacitor	Stores charge	

Circuit Device	**Purpose**	**Symbol**
Connecting Wire		
Wire Joined		
Wire Crossing(Not Connected)		
Cell		
Battery (4 Cells)		
Battery (Multiple Cells)		
Alternating Current (AC) Supply		
Lamp/Bulb		
Resistor		
Switch		
Rheostat (Variable Resistor)		
Galvanometer		
Ammeter		
Milliameter		
Voltmeter		
Capacitor		

Nb:

i. In electric circuit the electron are moving where the protons are stationary where the electric current opposes the direction of electron.



ii. The potential different between the positive and the negative terminals of a battery cause current to flow along any conducting path that links them.

iii. Potential different/voltage is a measure of electrical energy

Example,

An electric current of 0.12A passes a point B along a conducting wire. How much electric charge is flowing past this point in minute?

Data given:

Electric current, I = 0.12A

Time taken, t =1min = 60 sec

Electric charge, Q = ?

Solution:

From: Q = It

Q = It

Q = 0.12I x 60

Q = 7.2 C

Voltage

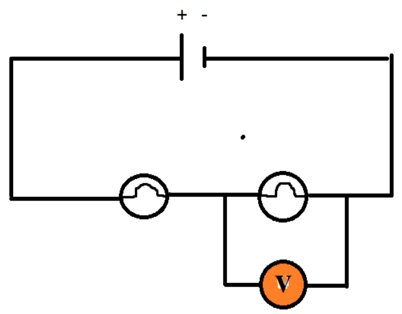
Every cell has voltage commonly referred to as **potential difference (P.d)** across its terminals.

P.d causes the electrons (charges) in a circuit to flow.

Voltage is measured by using device known as **Voltmeter**

SI unit of voltage is the **Volt.**

It is always connected parallel to the device whereby you want to measure its voltage drop across it



The overall effect on the current is almost negligible.

Since "***energy cannot be created or destroyed***"

P.d across the battery	**=**	**Sum of P.d around a conducting path**

Note:

I. Wrong connection of ammeter can damage it so the red terminal of the ammeter should connect to the positive terminal.

II. Ammeter is always connected in series in a circuitry

Resistance

Defn: resistance is the phenomena, in which the electric current flow opposed.

It is discovered by George Ohm. Its SI unit is ***Ohm (Ω)***

The device which measure the resistance is known as **Resistor**

Defn: Resistor is a device which offers resistance to the flow of an electric current.

Types of Resistance

Resistor includes;

(a) Fixed resistor

(b) Rheostat

Other units of resistance are;

Kilohm (kΩ)

Megaohm (MΩ)

Milliohms (mΩ)

Microhms (μΩ)

Ohm's Law

It's States that;

"***At constant temperature and other physical factors, a current in conductor is directly proportional to the potential different across its end***"

Mathematically

V α I

V=KI

Where:

K= constant R= resistance

Now;

V=IR

Then;

V/I = IR/I

V/I = R

R = V/I

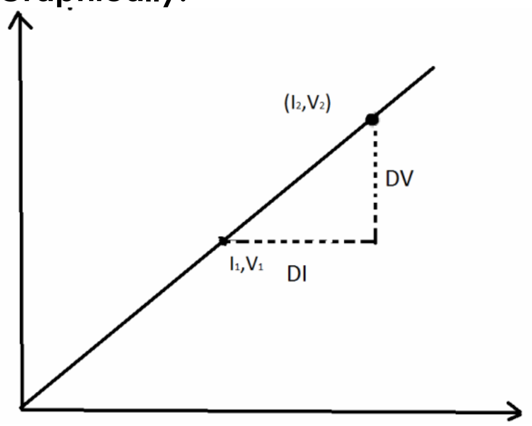
Where;

R= Resistance

V= Voltage

I= Electric current.

Graphically:



From the graph above

Slope = ΔV/ΔI = m

Where:

ΔV= (V2 - V1) = V

ΔI= (I2 - I1) = I

Now:

m = V2 - V1)/ I

m = (I2 - I1) / I

Since;

m = V/I = R

Therefore:

Slope = Resistance

Factor Affect Resistance

1. **Length of the conductor**

   The longer the wire the higher the resistance and vice versa

   R α L

   Where;

   R=Resistance

   L=Length of the conductor

2. **Temperature**

   The higher the temperature the higher the resistance and vice versa, this is important in resistance thermometer

Other metals different from other metals

a. **Constant wire. (Copper allow)**

   Changes to a very small extended thus why used in a standard resistance.

b. Connecting wire used in a circuit has a very low resistance to prevent energy wasted in form of heat to maximum.

   T α R

3. **Types of material**

   Nichrome wire has more resistance than a copper wire of a same dimension. ***That why***

   I. *Nichrome wire is used in heating element of electric fires*

   II. Copper wire is mostly used for connecting wires

4. **Cross-section area**

   A thin wire has more resistance than a thick conductor.

   R α 1/A

   But; A =πr^2

   Where : A = area of wire

Example,

A battery is 5V has a resistance wire of 20Ω connected across it. Calculate the current in the circuit.

Data given:

Voltage, V = 5V

Resistance, R = 20Ω

Current, I = ?

Solution

From ohm's law

V= IR

Make I subject

I =V/R

I = 5V/20Ω

I = 0.25A

Example,

An Ohmic conductor has a voltage drop of 9V measured across it. The current flowing in the conductor is 3 mA what is its resistance?

Data given;

Voltage drop, V = 9V

Current, I = 3 mA $=3\times10^{-3}$A

Resistance, R = ?

Solution:

From ohm's law;

V= IR

Make R subject

R = V/I

$R = 9/3\times10^{-3}$

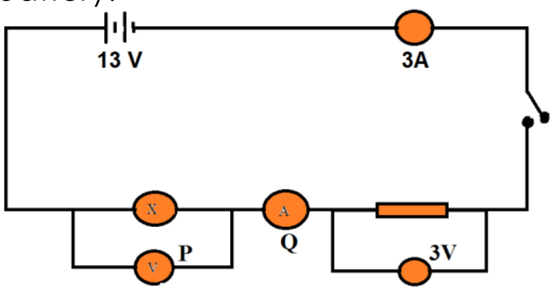
$R = 9\times10^{3}/3$

R = 9000/3

R = 3000 Ω = 3 kΩ

Example,

Calculate the reading of the voltmeter, P and the ammeter, Q in the electric circuit battery.



From:

P.d across the battery	=	Sum of P.d around a conducting path

Now:

13v = 3V+P

-P = 3V-13v

P = 13V-3v

P =10V

Combination of Resistors

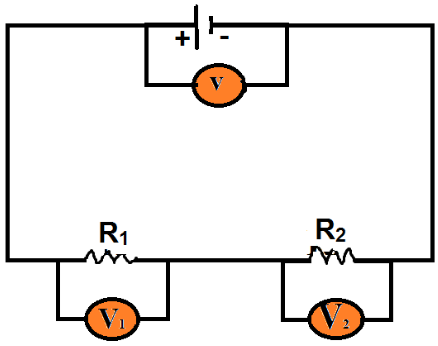
There are two main methods of connecting circuits component include:

i. Series connection

ii. Parallel connection

Series Connection

In this series arrangement the resistors are connected end to end.



From:

P.d across the battery	=	Sum of P.d around a conducting path

Therefore:

$V_t = V_1 + V_2$

But: The current is the same at all points round circuit.

From ohm's law

R = V/I

Now:

$R_t = V_t/I$

Substitute $V_t = V_1+V_2$ into equation $R_t = V_t/I$

$R_t = (V_1+V_2)/I$

$R_t = (V_1/I)+(V_2/I)$

$R_t = (V_1/I)+(V_2/I)$

But:

$R_1 = V_1/I$

$R_2 = V_2/I$

Substute into the equation $R_t = (V_1/I)+(V_2/I)$

$R_t = R_1+ R_2$

$\mathbf{R_t = R_1+ R_2}$

Therefore:

Total resistance (R_T) for resistor in series is equal to the sum of individual resistance.

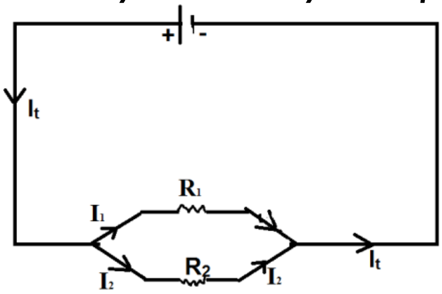
$\mathbf{R_T = R_1+R_2 + \ldots\ldots + R_n}$

Where:

Rn = the last resistor

Parallel Connection

Resistors are connected across two common points in a parallel arrangement.



NB:

→ $I_t = I_1 + I_2$

→ P.d is the same for all the branches.

From ohm's law

$R = V/I$

Therefore:

$I_t = V/R_T$ .... (i)

$I_t = V/R_1$ .... (ii)

$I_t = V/R_2$ .... (iii)

Substitute into equation $I_t = I_1 + I_2$

$V/R_T = V/R_1 + V/R_2$

Divide by V both sides we get

$\mathbf{1/R_T = 1/R_1 + 1/R_2}$

Therefore:

Total resistance (R_T) for resistor in series is equal to the sum of individual resistance.

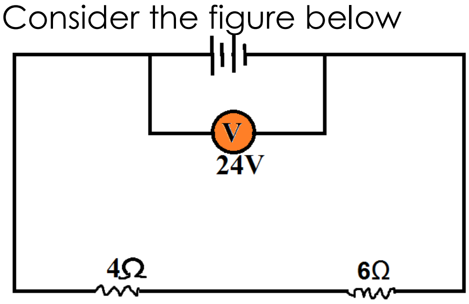
$\mathbf{1/R_T = 1/R_1 + 1/R_2 + ... + 1/R_n}$

Where:

Rn = the last resistor

Example,

Consider the figure below



Calculate P.d across:

a) 4 Ω

b) 6Ω

Data given:

Voltage, V = 24V

First Resistance, R_1 = 4Ω

Second Resistance, R_2 = 6Ω

Current across the circuit, I = ?

Voltage across 4Ω, V_1 = ?

Voltage across 6Ω, V_2 = ?

Solution

First find the current across the circuit

From ohm's law

V= IR

Make I subject

I =V/R

But:

R = 4Ω + 6Ω = 10Ω

Now:

I = 24V/10Ω

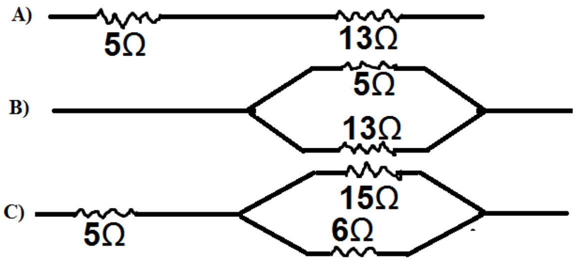
I = 2.4A

a) Voltage across 4 Ω, V_1 = ?
   From ohm's law, V= IR
   $V_1 = IR_1$
   $V_1 = 2.4 \times 4$
   $\mathbf{V_1 = 9.6\ V}$

b) Voltage across 6 Ω, V_2 = ?
   From ohm's law, V= IR
   $V_2 = IR_2$
   $V_2 = 2.4 \times 6$
   $\mathbf{V_2 = 14.4\ V}$

Example,

Calculate the combination resistance in



a) Resistance between 5 Ω and 13 Ω, in series R = ?
   Data given:
   First Resistance, R_1 = 5Ω
   Second Resistance, R_2 = 13Ω
   Solution
   From: $R = R_1 + R_2$
   R = 5 + 13
   R = 18 Ω

b) Resistance between 5 Ω and 13 Ω, in parallel R = ?
   Data given:
   First Resistance, R_1 = 5Ω
   Second Resistance, R_2 = 13Ω
   Solution
   From: $1/R = 1/R_1 + 1/R_2$
   1/R = 1/5 + 1/13
   1/R = (13 + 5)/65
   1/R = 18/65
   $(1/R)^{-1} = (18/65)^{-1}$
   R = 65/18
   R = 3.61 Ω

c) Resistance between 13 Ω and 13 Ω in parallel connected series with 5 Ω,R = ?

Data given:

First Resistance, $R_1 = 5\Omega$

Second Resistance, $R_2 = 15\Omega$

Third Resistance, $R_3 = 6\Omega$

Solution

First calculate resistance between 13 Ω and 13 Ω connected in parallel, R_P = ?

From: $1/R_P = 1/R_2 + 1/R_3$

$1/R_P = 1/15 + 1/6$

$1/R_P = (6 + 15)/ 90$

$1/R_P = 21/90$

$(1/R_P)^{-1} = (21/90)^{-1}$

$R_P = 90/21$

$\mathbf{R = 4.2\ \Omega}$

Second calculate the resistance between 13 Ω connected series with R_P, R = ?

Solution

From: $R = R_P + R_1$

$R = 4.2 + 5$

$\mathbf{R = 9.2\ \Omega}$

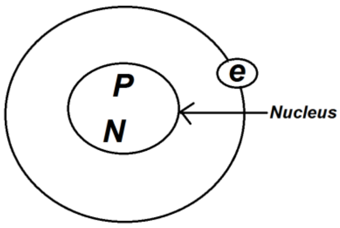
Magnetism

Defn: is the tendency in which piece of iron attracted by other mineral iron ore. The natural mineral iron ore is called **magnetite** or **tri-iron tetra-oxide**. Any material that has properties similar to those of the iron ore is called a **magnet.**

Why Magnet Attract?

Magnet is caused due to motion of electrons in two dimension/types include:

i. Motion of electrons around the nucleus of an atom



ii. Motion in electrons spin around their own axis, which is similar to the rotation of the earth about its own axis.

These motions independently impart a magnetic effect on each electron, causing each to behave like a tiny magnet

Magnetic and Non-Magnetic Materials

Defn: *Magnetic materials* are all materials that can be magnetized or attracted by magnet. E.g. **iron**, **steel**, **nickel** and **cobalt**

Defn: *Non-magnetic materials* are all materials that cannot be magnetized or attracted by magnet. E.g. **brass**, **copper**, **tin**, **zinc**, **aluminium**, **wood**, **plastic**, **clothes** etc

NB:

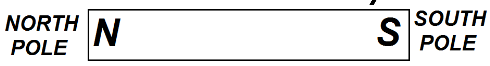
i. Materials that can be magnetized strongly (hence attracted to a magnet) are called **ferromagnetic materials**

ii. When a magnet brought near iron, it attract it due to the force that is not natural are said to possess **induced magnetism**

Properties of Magnets

i. Magnets attract magnetic materials

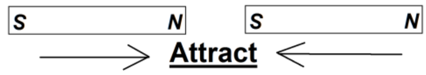
ii. The magnetic force is strongest near the poles of a magnet



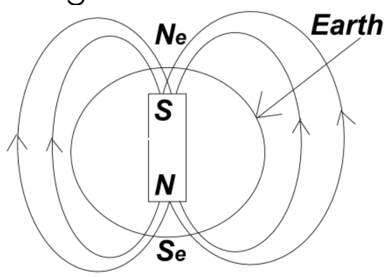
iii. Like poles repel each other and unlike poles attract

Like poles

Unlike poles



iv. Moving magnet North Pole points south and South Pole point north of the earth's magnet



Where:

Ne- earth magnet North Pole

Se- earth magnet North Pole

N- Magnet North Pole

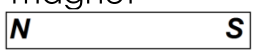
S- Magnet North Pole

v. The magnetic force is an action at a distance force

Types of Magnets

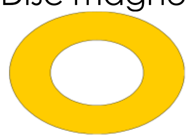
Magnets comes in different shapes include

i. Bar magnet



ii. Horse-shoe magnet

iii. Disc magnet



Magnet also vary in size include

i. Tiny discs used in speaker

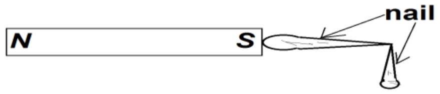
ii. Giant magnets used in power generating plant

iii. Largest magnets is perhaps the earth itself

Now: there three major types of magnetic include

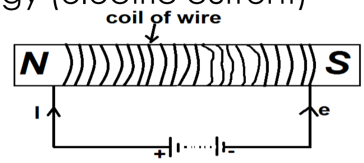
i. Temporary magnets
ii. Permanent magnets
iii. Electromagnetic

Temporary magnets
Occur when magnetic material magnetized in an external magnetic field but lose their magnetism when the field is removed



Permanent magnets
It made from alloy of aluminium, nickel and cobalt that magnetized in external magnetic field and retain/remain some of the magnetism even after the external field is withdrawn or removed.

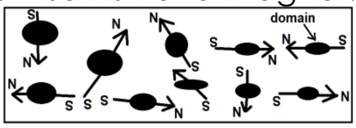
Electromagnetic
Are temporary magnets comes from electric current. It has disadvantage because they require a continuous supply of energy (electric current)



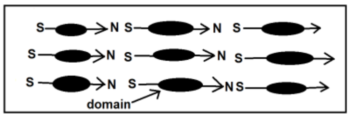
Application of Magnets
i. **Magnetic recording media:** VHS tapes, audio cassettes, floppy and hard disc recording data on a thin magnetic coating
ii. **Credit, Debit and ATM cards:** it use magnetic ink to store information to contact and individual's financial institution and connect with their account
iii. **Speaker and microphones:** it use permanent magnets and current-carrying coils to convert electric energy into sound energy
iv. **Electric generator:** It use permanent magnets convert mechanical energy to electrical energy

Magnetization
Defn: Magnetization is the process of aligning the domains of atoms in material in one direction so as to produce a net effect of attraction or repulsion
OR
Defn: Magnetization is the process of making magnet

How Magnetized?
The atoms of most materials act like tiny magnets called **magnetic dipoles** but because of their random alignment, the object itself is not a magnet.



When individual domains (magnets) became aligned in one direction, the object will behave like a magnet



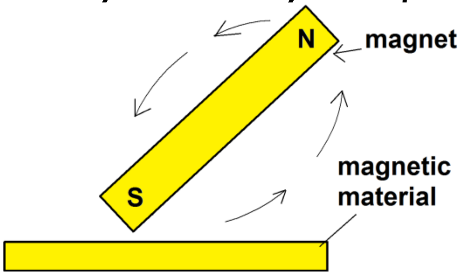
NB: materials which it is possible to cause this alignment or can be magnetized are either **ferromagnetic** or **paramagnetic**

Defn: Ferromagnetic material is the material which can from permanent magnet. E.g. steel, nickel and cobalt
Defn: Paramagnetic material which magnetized temporary. E.g. aluminium and chromium

Methods Used To Magnetized Materials
The alignment of domains in these materials can be achieved through several ways include
i. By heating or vibration method
ii. By stroking method
iii. By electric (solenoid) method

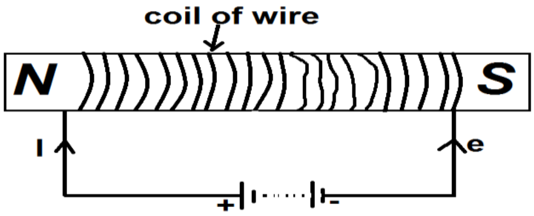
Heating or Vibration Method
When magnetic material heated in presence of external magnetic field, the dipole of magnetic material aligns, whereby in the presence of external magnetic field the atoms of magnetic materials start to move and eventually become aligned. Many natural magnetic material starts out as part of lava.

Stroking Method
When magnetic material stroked by magnetic it become magnet



Electric (Solenoid) Method

When soft iron core is wound with turns of wire and current passed through it, it produces a magnetic field. This is an industrial way of making a magnet. This magnet acts like bar magnet is called **solenoid**



Demagnetization

Defn: Demagnetization is the process of disturb the domain of an atom in magnetized material

Methods Used To Demagnetized Magnet

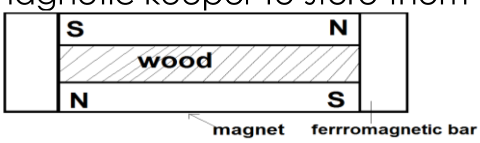
The process of disturb aligned of domains in magnet achieved through several ways include:

i. Heating or vibrate in absence of an external field
ii. Randomly stroking one magnet with another
iii. Wrapping a wire coil around magnet and connect coil to the source of current
iv. Repeat hammering/ dropping down of magnet

Storage of Magnets

In order to maintain the magnetism in magnets for a long period of time, the following practices have to be observed

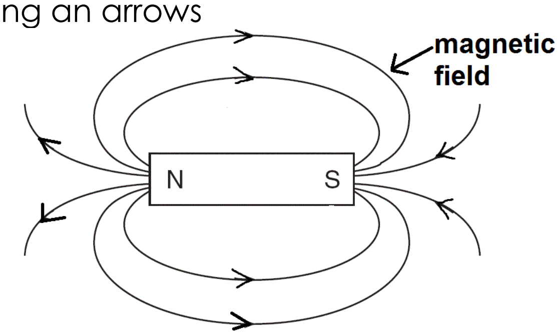
i. Store away from ferrous materials
ii. Store magnets in pairs and using magnetic keeper to store them



iii. Store away from heat
iv. Store away from strong electric and magnetic field
v. Store away from strong vibration or mechanical impacts which may brittle it

Magnetic Field of a Magnet

Defn: A magnetic field of a magnet is the region around a magnet in which magnetic materials are attracted by the magnet. A magnetic field is represented by lines of action of magnet force called **field lines**. Field lines show the direction of the magnetic force, hence are illustrated using an arrows



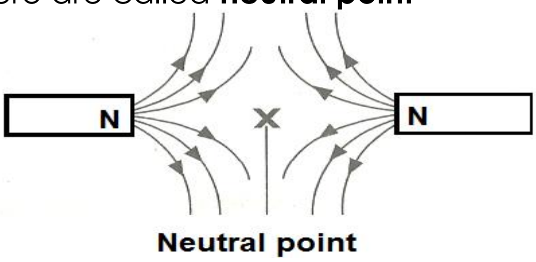
Magnetic Force Lines (Field Lines)

The lines of force point away from the North Pole of a magnet and towards the South Pole, consider the diagram above.

Properties of Magnetic Lines

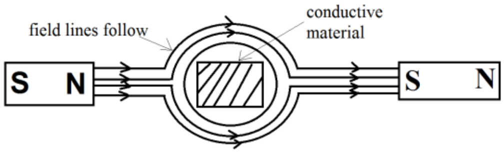
i. It always form closed loops
ii. Start at North Pole and end at the South Pole
iii. It is stronger where lines are close together and weaker where they are far apart
iv. Never cross each other
v. Parallel magnetic line of force travelling in the same direction repel each other
vi. It passes through all materials both magnetic and non-magnetic
vii. It enters or leaves a material at right angle (90^0) to the surface

NB: point where the net magnetic field is zero are called **neutral point**



Magnetic Shielding

Defn: Magnetic shielding is the process of limiting the flow of magnetic fields between two locations by separating them with a barrier made of conductive material.



Earth's Magnetism

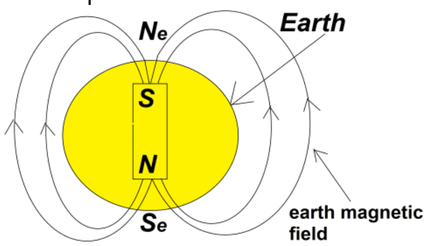
Defn: Earth's Magnetism is the behavior of the earth to act as magnet

Cause of Earth's Magnetism

It is now believed that the Earth's magnetism is due to the magnetic effect of current which is flowing in the liquid core at the center of the Earth. Thus, the Earth is a huge electromagnet.

Earth's Magnetic Field

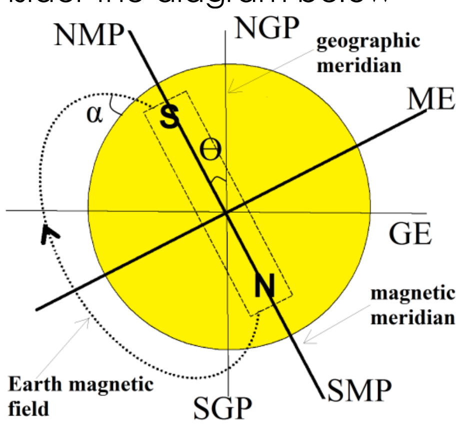
Earth behaves as if it has a short bar magnet inside it. It is inclined at a small angle to its axis of rotation, with its South Pole point to the northern hemisphere. This is inferred from the fact that the compass points towards the true north only at certain places



Where:

Ne = North hemisphere
Se = South hemisphere

Consider the diagram below



Where:

GE = Geographic Equator
ME = Magnetic Equator
Θ = Angle of declination
SMP = south magnetic pole
NMP = north magnetic pole
NGP = north geographic pole
SGP = south geographic pole
a = Angle of dip or angle of inclination

Geographic Equator

Defn: Geographic Equator is the imaginary line which cut the earth half horizontally. This line separate SGP and NGP

Magnetic Equator

Defn: Magnetic Equator is the imaginary line which cut the earth's magnetic horizontally half. This line separate SMP and NMP

Magnetic Meridian

Defn: Magnetic Meridian is the imaginary line joining the earth magnetic North Pole and South Pole

Geographic Meridian

Defn: Geographic Meridian is the imaginary line joining the earth North Pole and South Pole

South magnetic pole (SMP)

Defn: South magnetic pole is the pole near the geographic south pole of magnet

North magnetic pole (NMP)

Defn: North magnetic pole is the pole near the geographic north pole of magnet

Angle of declination (Θ)

Defn: Angle of declination is the angle formed between the magnetic meridian and geographic meridian. It vary in the word from one to another place

Angle of dip or angle of inclination

Defn: Angle of dip or angle of inclination is the between the direction of the earth's magnetic flux and the horizontal or **Angle of dip or angle of inclination** is the angle between the earth surface and the earth's magnetic field. The angle of dip varies from place to place

NB:

i. The angle of inclination is measured by using **Dip needle**, where consists magnetize on its dip of needle which is used to rotate the dip needle with horizontal component of the magnetic field and dip needle rotate vertically to align with the total field
ii. The angle of dip at the magnetic poles of Earth is 90°
iii. The angle of dip at the magnetic equator of the Earth will be 0°

Application of the Earth's Magnetic Field

i. Used by map readers for finding locations of different places
ii. Give useful information in the search for minerals
iii. Satellites transmit information through earth's magnetic field to the earth surface
iv. Magnetic compass can locate the direction of the magnetic north using the compass

Moment of a Force

Defn: moment of a force is the product of the force applied and the perpendicular distance from a fixed point or pivot

Or

Defn: moment of a force is the turning effect of the force about a point

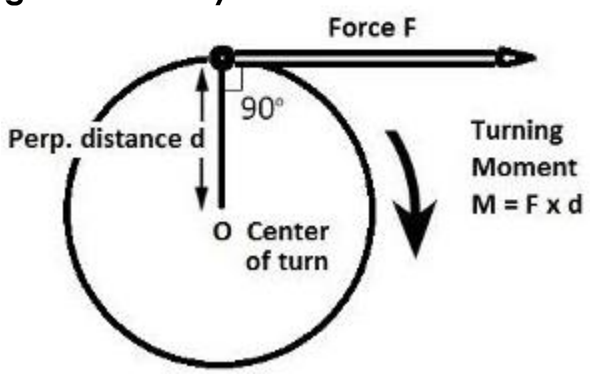
Mathematically:

M = f × d

Where:

M = moment of a force its SI unit is **Nm**
f = force applied its SI unit is **N**
d = perpendicular distance its SI unit is **m**

Diagrammatically:



NB:

i. The point where the object rotate after turning force is called **pivot** or **fulcrum**
ii. turning effect is called moment of a force
iii. Moment of force is applied in different activities such as **opening bottle caps**, **door opening** and **tightening nuts** etc
iv. The moment of a force depend on the following
   a. Size of a force
   b. Perpendicular distance

Example, s We Experience On Turning Effect

We can prove the turning effect as the following reasons

i. It is easier to open nut with a long spanner opener than with short spanner fingers due to the high moment as a result of perpendicular distance arise from the long spanner
ii. It is easier to open the cap of the bottle with a bottle opener than with your fingers due to the addition perpendicular distance arise from the opener
iii. Knob on a door is placed as far as possible from the hinges due to the addition perpendicular distance arise from the hinges to the knob

Example,

A line of action of a force of 90 N acts at a perpendicular distance of 2.5 m, from a point. Find the moment of the force

Data given

Force applied, f = 90 N
Perpendicular distance, D = 2.5 m
Moment, M = ?

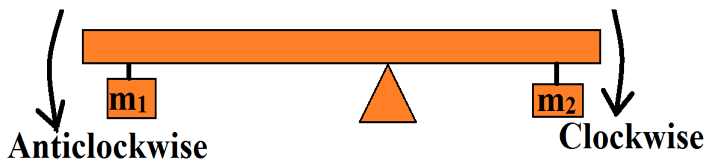
Solution

From

M = f × d
M = 90 N×2.5 m
M = 225 Nm

The Principle of Moment

Consider the ruler below



The principle of moments states that

"***When a system is in equilibrium the total sum of the anti-clockwise moments is equal to the total sum of the clockwise moments***"

Mathematically:

$m_1 = m_2$

Where:

m_1 = Anticlockwise moment
m_2 = Clockwise moment

Therefore:

$\boxed{m_1 = m_2}$

Since: m = f × d

Now:

$\boxed{f_1 \times d_1 = f_2 \times d_2}$

Example,

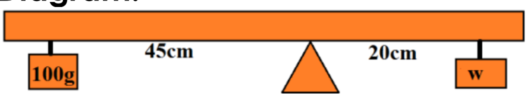
A 100 g weight is suspended 45 cm from the pivot, f of a light rod. If a weight w suspended 20 cm from the pivot balance the 100 g weight. Find weight w.

Data given

m_1 = 100 g
m_2 = w g
d_1 = 45 cm
d_2 = 20 cm
g = 10

Solution

Diagram:



From

$\boxed{m_1 = m_2}$

Since: $m = f \times d$

But: $f = m \times g$

Now:

$m_1 \times g_1 \times d_1 = m_2 \times g_2 \times d_2$

$100 \times 10 \times 45 = w \times 10 \times 20$

$\frac{100 \times \cancel{10} \times 45}{\cancel{10} \times 20} = w$

$5 \times 45 = w$

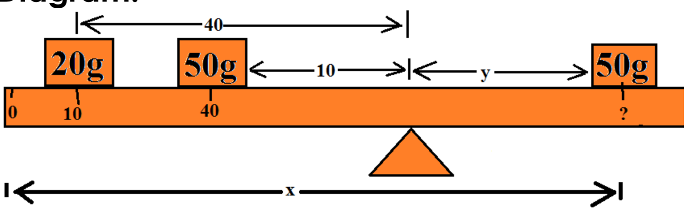
$w = 225\ Nm$

Example,

A uniform metre ruler is pivoted at its centre. A 20 g mass is placed at the 10 cm mark and a 50 g mass at the 40 cm mark. At what mark must a second 50 g mass be placed for the system to be in rotational balance?

Solution

Diagram:



From:

Total anticlockwise moment = total clockwise moment

Now:

$20 \times 40 + 50 \times 10 = y \times 50$

$\frac{20 \times 40 + 50 \times 10}{50} = y$

$\frac{800 + 500}{50} = y$

$\frac{1300}{50} = y$

$y = 26\ cm$

Then:

$x = 50 + y = 50 + 26 = 76\ cm$

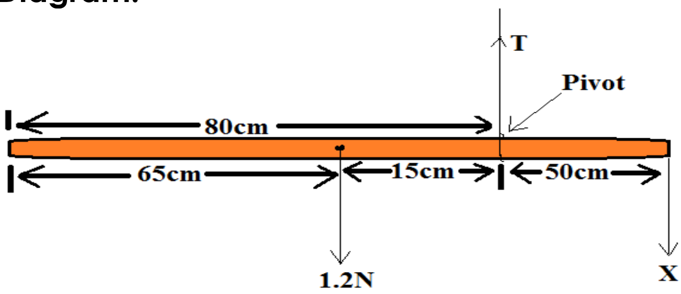
Therefore Second 50 g should place at 26 cm to the right from the pivot or placed at 76 cm mark

Example,

A uniform rod with a mass 120 g and a length of 130 cm is suspended by a wire from a point 80 cm from the rod's left end. What mass must be hang from the right end of the rod for it to be in equilibrium? What will be the tension of the wire?

Solution

Diagram:



Where:

X = mass hang for rod to be in equilibrium

W = weight of rod = $0.12\ kg \times 10 m/s^2$

W = 1.2N

T = tension of the wire

From:

Total anticlockwise moment = total clockwise moment

Now:

$1.2 \times 15 = X \times 50$

$X = \frac{1.2 \times 15}{50}$

$X = 0.36\ N$

Then:

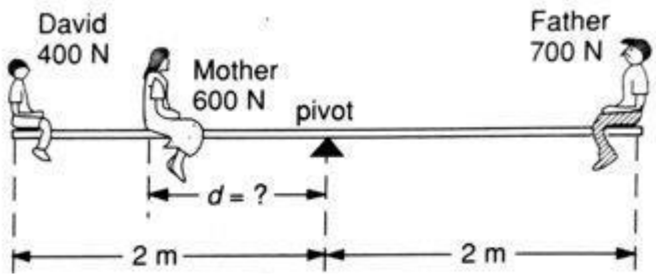
Upward force = downward force

$T = 0.36\ N + 1.2\ N$

$T = 1.56\ N$

Example,

David and his father are sitting at the end of a seesaw 2 m from the pivot while David's mother is sitting at a distance d from the pivot. The seesaw balances as shown in the figure below. Determine d.



Solution

From:

Total anticlockwise moment = total clockwise moment

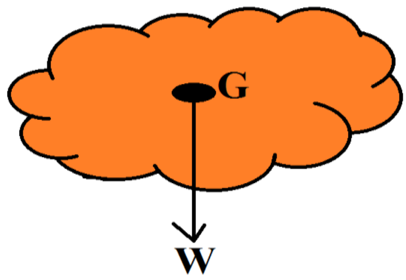
Now:

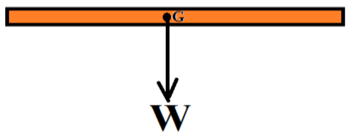
$2 \times 400 + 600 \times d = 2 \times 700$

$600 \times d = 2 \times 700 - 2 \times 400$

600d = 1400 - 800
600d = 600
d = 600/600 = 1m
Therefore, David's mother is sitting 1m from the pivot

Center Of Gravity
Defn: center of gravity is the point at which the weight of the body concentrated/ acts.
Diagram:





Where:
W = weight of the body
G = center of gravity

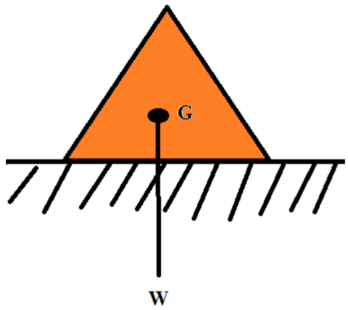
Application of Principle of Moment
i. Used to unscrew a stopper on the bottle
ii. Used to unscrew a nut on bolt
iii. Used to open a metal cap from a bottle of wine, beer etc
iv. When the door is opened, the force on the handle exerts a turning effect about the hinges
v. turning a steering wheel of a car

Equilibrium
Defn: Equilibrium is the state of balance of a body

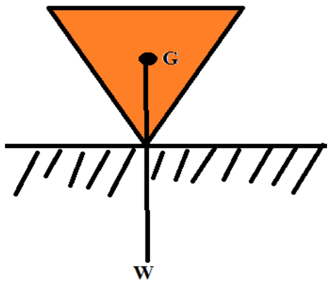
Conditions for Equilibrium
When force are in equilibrium means there is no net force to cause any movement. The following include the condition
i. **Center of gravity**: center of gravity must at lower position
ii. **Force**: Sum of upward force should be equal to the sum of downward force
iii. **Moment**: Sum of clockwise moment should be equal to the sum of anticlockwise moment

Types of Equilibrium
There are three, include
i. Stable equilibrium
ii. Unstable equilibrium
iii. Neutral equilibrium

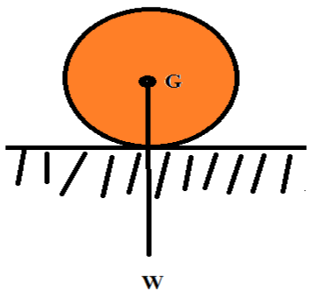
Stable Equilibrium
Stable equilibrium occurs when a body slight displaced the body returns to its original position after displacement
Diagram:



Unstable Equilibrium
Unstable equilibrium occurs when a body slight displaced the body it does not returns to its original position after displacement
Diagram:

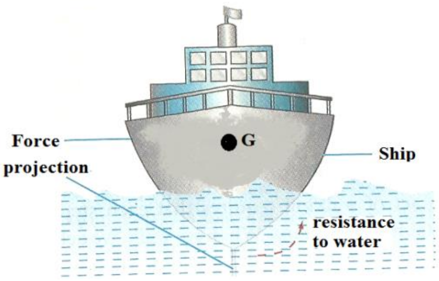


Neutral Equilibrium
Neutral equilibrium occurs when a body slight displaced the body it does not alter the position of the center of gravity
Diagram:



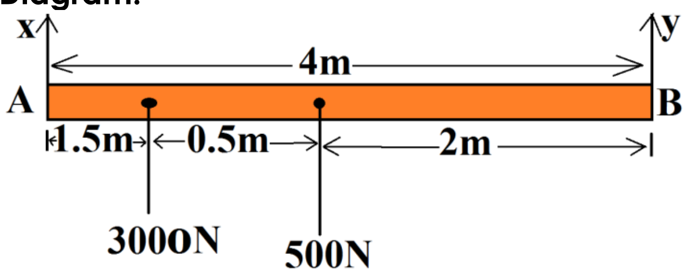
Application of Equilibrium
i. In designing of structure like bridges, aeroplane, furniture, machines, car boats, ships etc

ii. Our bodies muscles are always kind of equilibrium that is why we can walk, seat, eat, run, squat, jump etc
iii. Tall structure such as building and pylon, they are wide base and low centre of gravity so ensure stability
iv. Bus/car with seated passengers and loading the lower compartments is more stable than one with standing passengers and loaded at the top
v. Ships have long and wide projecting plates extending from their bases into the water to increase stability



vi. **Beam balance** - used for measuring masses of different objects by comparison with known masses.
vii. **Steel yard** - is a machine used for weighing heavy objects. It uses the principle of moments by balancing heavy objects with lighter objects on longer arm.
viii. **Seesaw** – is a long plank balanced at the fulcrum so that an increase in weight in one side causes it to go down while the other side goes up

Example,
A heavy uniform beam AB of weight 500N is supported at its ends. The beam carries a weight of 300N at a distance of 1.5m from the end A. if the beam is 4m long. Find the thrust/tension/reaction at A and B
Solution
Diagram:



NB: Assume pivot is at point B
Since:
Total anticlockwise moment = total clockwise moment
$4 \times Y = 3000 \times 1.5 + 500 \times 2$

$Y = \frac{3000 \times 1.5 + 500 \times 2}{4}$

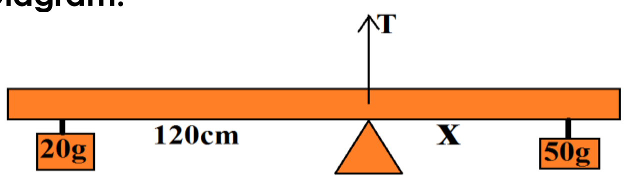
$Y = \frac{5500}{4}$

$\underline{Y = 1375N}$

Since:
Total upward force = total downward force
$Y + X = 500N + 3000N$
$Y + X = 3500N$
$X = 3500N - Y$
$X = 3500N - 1375N$
$\underline{X = 2125N}$

Example,
The diagram below shows a 150g rod balanced at its centre of gravity. A 20g mass is placed 120cm from the pivoted point
i. Find the value of x
ii. What upward force/reaction/tension does the pivot exert on the rod?

Solution
Diagram:



Since:
Total anticlockwise moment = total clockwise moment
$20 \times 120 = 50 \times X$

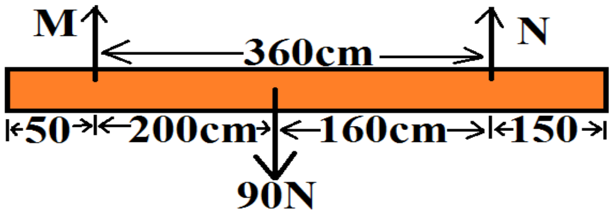
$X = \frac{20 \times 120}{50}$

$N = \frac{2400}{50}$

$\underline{N = 48cm}$

Since:
Total upward force = total downward force
$T = 0.2N + 0.5N$
$\underline{T = 0.7N}$
Upward force is exerted by pivot is 0.7N

Example, 07 (Mock 2013)
From the diagram below calculate reaction M and N



Solution

NB: Assume pivot is at point M

Since:

Total anticlockwise moment = total clockwise moment

$N \times 360 = 90 \times 200$

$N = \frac{90 \times 200}{360}$

$N = \frac{18000}{360}$

$\underline{N = 50N}$

Since:

Total upward force = total downward force

$N + M = 90N$

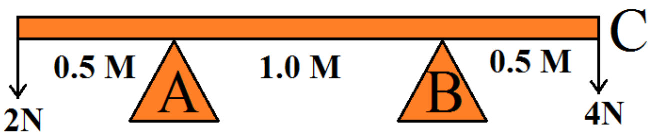
$M = 90N - 50N$

$M = 40N$

Example,

From the diagram below calculate

i. Reaction A and B
ii. Additional weight at C will just tilt the beam about B?



Solution

i. Reaction A and B

NB: Assume pivot is at point B

Since:

Total anticlockwise moment = total clockwise moment

$2 \times 1.5 = 0.5 \times 4 + A \times 1.0$

$3 = 2 + A$

$A = 3 - 2 = 1N$

A = 1 N

Since:

Total upward force = total downward force

$A + B = 6N$

$B = 6N - A$

$B = 6N - 1N$

B = 5N

ii. Additional weight at C will just tilt the beam about B?

NB: when the beam just tilts about B the reaction A becomes zero. Taking moments about the support B

Let addition weight be x

$2 \times 1.5 = 0.5 \times (4 + x) + A \times 1.0$

$3 = 0.5(4 + x)$

$3/0.5 = 4 + x$

$6 = 4 + x$

$x = 6 - 4$

$x = 6 - 4 = 2$

x = 2 N

Simple Machines

Defn: machine is any device which used to simplify work. Example, screw driver, pulley, inclined plane, bicycle, typewrite, car.

Types of Machine

They are two types of machine, include the following

i. Simple machine
ii. Complex machine

Simple Machine

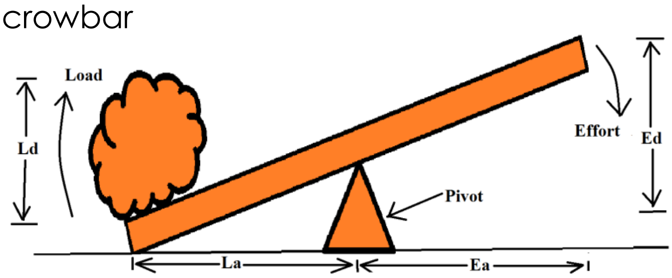
Defn: Simple machine is the machine which compose only one machine. *Example, Screw driver, Crowbar, See-saw, Pulley, Inclined plane* etc

Complex Machine

Defn: Complex machine is the machine which compose more than one machine. *Example, Bicycle, Typewrite, Car, Sewing machine* etc

Terms Used

Since in this topic we study about simple machine, consider the diagram below of crowbar



Where:

Ld = distance moved by load
Ed = distance moved by effort
La = load arm
Ea = effort arm

Therefore the following terms will be used in our topic; *Effort, Load, Mechanical advantage, Velocity ration, Work output, Work input, Efficient.*

Effort (E)

Defn: *Effort is a force applied to shift load*. Its SI unit is **Newton**

Load (L)

Defn: *Load is the weight of a body*. Its SI unit is **Newton**

Mechanical Advantage (MA)

Defn: *Mechanical advantage is the ratio of the load to the effort*. Has no SI unit. Mechanical advantage affected by friction so efficient of machine is not 100% due to friction force

MA = L/E

Example,

A man of mass 100 kg lifts a box weight 500 kg by standing on one end of a lever. How much mechanical advantage did the lever provide to the man while lifting the box?

Data given

Effort, E = 1000kg = 1000N
Load, L = 500kg = 5000N
Mechanical advantage, MA = ?

Solution

From: MA = L/E
MA = 5000N /1000N
MA = 5

Velocity Ratio (VR)

Defn: *Velocity ratio is the ratio of the distance moved by the effort to the distance moved by load*. Has no SI unit. Velocity ratio does not affected by friction

VR = Ed/Ld

Example,

When a machine pressed by effort moved down a distance of 100 cm, while the load is raised through 25 cm at the same time. Find the velocity ratio'

Data given

Distance moved by effort, Ed = 100 cm
Distance moved by load, Ld = 25 cm
Velocity ratio, VR = ?

Solution

From: VR = Ed/Ld
VR = 100 cm/25 cm
VR = 4

Work Output (WO)

Defn: Work output is the product between load and distance moved by load. Its SI unit is joule

WO = L × Ld

Work Input (WI)

Defn: Work input is the product between effort and distance moved by effort. Its SI unit is Joule

WI = E × Ed

Efficient (Eff)

Defn: Efficient is the percentage ratio of the work output to the work input

Eff = (WO/WI) × 100%

Since: WO = L × Ld
WI = E × Ed
Eff = (L × Ld / E × Ed) × 100%
Eff = (L/E) × (Ld/Ed) × 100%

But: VR = Ed/Ld - reciprocal both sides
1/VR = Ld/E
MA = L/E

Substitute:

Now: Eff = MA × (1/VR) × 100%

Eff = (MA/VR) × 100%

Example,

A machine having a velocity ratio of 5 requires 600 J of work to raise a load of 400 N if the load moved though a distance of 0.5 m. calculate the mechanical advantage and efficiency of the machine

Data given
Velocity ratio, VR = 5
Work input, WI = 600 J
Load, L = 400 N
Load distance, Ld = 0.5 m
Mechanical advantage, MA = ?
Efficient, Eff = ?

Solution

Eff = (WO/WI) × 100%
Eff = (WO/600) × 100%

Since: WO = L × Ld = 400 × 0.5 = 200
Eff = (200/ 600) × 100%
Eff = 0.3333 × 100%
Eff = 33.33%

But: Eff = (MA/VR) × 100%
33.33% = MA/5 × 100%
MA = (33.33% × 5) /100%
MA = 1.67

Example,

An athlete exerts a force of 100 N while running 100 m race, if he uses 50,000 J of food energy. Calculate his efficiency

Data given

Useful energy (work output), WO = 100 × 100 = 10000J
Total energy (work input), WI = 500000J
Efficient, Eff = ?

Solution

Eff = (WO/WI) × 100%
Eff = (10000/5000) × 100%
Eff = 0.2 × 100%
Eff = 20%

The rest energy (40000J) is wasted as heat

Types of Simple Machine

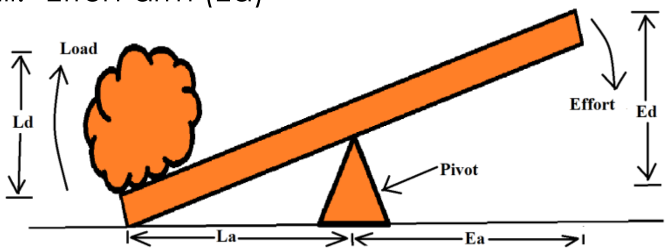
There are types of machine but will discuss about six (6) machine include

i. Levers
ii. Pulley
iii. Inclined planes
iv. Screw jack
v. Wheel and axle
vi. Hydraulic press

Levers

It consists of rigid bar that moves about fixed point called pivot. Example, *A wheel barrow, a pair of scissors, a shovel, Wire cutters* etc. A lever has three main parts include

i. Pivot/fulcrum
ii. Load arm (La)
iii. Effort arm (Ea)



It used to lift heavy weights with the small effort. The longer the bar the easier it to lift the load

Defn: fulcrum is a fixed point about which the bar moves. Lever always act as force magnifiers

Class of Levers

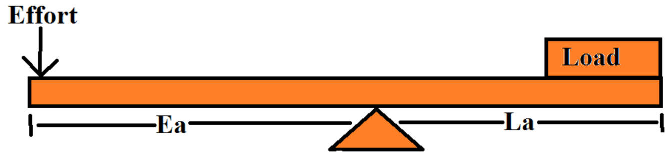
The classification of lever depends on the position of the pivot with respect to load and effort. So we have three classes of levers include

i. First class levers
ii. Second class levers
iii. Third class levers

First Class Levers

The pivot is located at the centre of load and effort. Example, *crowbars, scissors, pliers, see-saws* etc

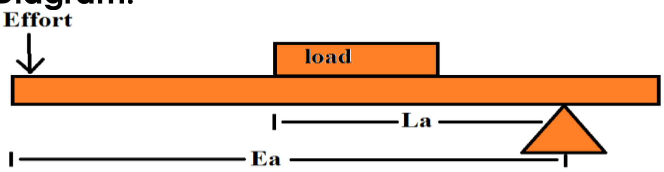
Diagram:



Second Class Levers

The load located at the centre of pivot and effort. Example, *wheelbarrows, nutcrackers, bottle openers* etc

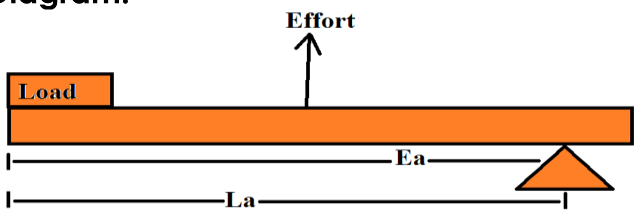
Diagram:



Third Class Levers

The effort is locate at the centre between load and pivot. Example, *shovel (spade), tweezers, fishing rod, tongs, forceps* etc

Diagram:

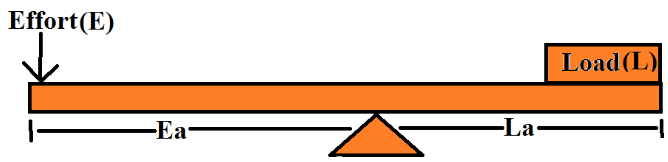


Mechanical Advantage of Lever

It expressed as we seen

MA = L/E

Also can obtained by using effort arm (Ea) and load (La), consider the diagram below



From:

Anticlockwise moment = clockwise moment

$E \times Ea = L \times La$

Divide by E both sides

$\frac{E \times Ea}{E} = \frac{L \times La}{E}$

Divide by La both sides

$\frac{Ea}{La} = \frac{L \times La}{E\ La}$

$\frac{Ea}{La} = \frac{L}{E}$

But: MA = L/E

Therefore:

MA = Ea/La

NB:

i. Effort arm (Ea) is a distance between fulcrum and effort
ii. Load arm (La) is a distance between fulcrum and load
iii. MA of second class is great than fist class lever
iv. MA of third class is less than fist class lever

Example,

A force of 30 N is applied at one end of a crowbar and adjust overcomes a resistance of 150 N at the lid of a case. Find mechanical advantage

Data given

Load, E = 30 N

Effort, E = 150 N

Mechanical advantage, MA = ?

Solution

From: MA = L/E = 150/30 = 5

MA = 5

Velocity Ratio of Lever

It obtained from the formula

VR = Ed/Ld

Where:

Ed = distance moved by effort

Ld = distance moved by load

Example,

In a certain machine , a force of 10 N moves down a distance of 5 cm in order to raise a load of 100 N through a height of 0.5 cm. calculate velocity ratio of the lever

Data given:

Effort, E = 10 N

Load, L = 100 N

Effort distance, Ed = 5 cm

Load distance, Ld = 0.5 cm

Velocity ratio, VR = ?

Solution:

VR = Ed/Ld = 5/0.5 = 10

VR = 10

Efficiency of Lever

It is obtained by using formula as usual

Example,

A machine with velocity ratio of 6 required 800J of work to raise a load of 600 N through a vertical distance of 1 m. find efficiency and mechanical advantage

Data given

Work input/ WI = 800 J

Work output. WO = 600 J

Distance moved by load, Ld = 1 m

Efficiency, Eff = ?

Mechanical advantage, MA = ?

Solution:

Eff = (WO/WI) × 100%

Eff = (600/800) × 100%

Eff = 0.75 × 100%

<u>Eff = 75%</u>

Then: Eff = (MA/VR) × 100%

<u>75%</u> = MA/6 × 100%

MA = (6× 75%) /100%

MA = 450/100

<u>MA = 4.5</u>

Example,

A certain first class lever of length 2.5 m has a velocity ratio of 12 and an efficiency of 85%. Find

a) Distance moved by effort/effort
b) Force/effort required lifting a load weighting 75N?

Data given

Distance moved by effort, Ed = ?

Distance moved by load, Ld = 2.5 m

Load, L = 75 N

Efficiency, Eff = 85%

Velocity ratio, VR = 12

Effort, E = ?

Solution:

a) VR = Ed/Ld
   12 = Ed/2.5- make Ed subject
   Ed = 12 × 2.5
   <u>Ed = 30 m</u>

b) Eff = (MA/VR) × 100% - make MA subject
   MA = (Eff × VR)/100%
   MA = (85% × 12)/100%
   MA = 1020%/100%
   MA = 10.20
   Then: MA = L/E – make E subject
   E = L/MA
   E = 57/10.2
   <u>E = 7.4 N</u>

Uses of Lever In Daily Life

i. Used in pair of scissors and tong
ii. Used in wheelbarrow to carry sand
iii. Spanner types like (wrenches) used by plumbers, electrician etc
iv. Crowbar to remove nails from piece of wood
v. Fishing rod

Pulley

Pulley is a simple machine that consists of a **wheel** that rotates around a point called **axle**

NB: the tension in the rope is the same at all points in an ideal pulley

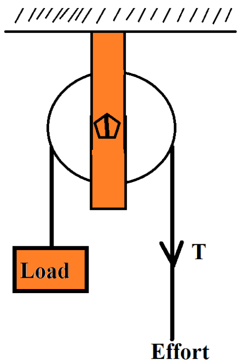
Types of Pulley

These are different types of pulley according on the number of ropes or arrangement of pulleys include;

i. Single fixed pulley
ii. Single movable pulley
iii. Combination pulley
iv. The block and tackle pulley system

Single Fixed Pulley

It consist one pulley at stationary. Consider the diagram whereby it fixed and does not move to lift the load



Where: T = tension of the rope

For single fixed pulley

MA = L/E

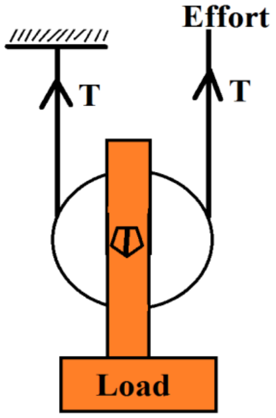
VR = Ed/Ld

But: Ed = Ld

Therefore: VR = 1(number of rope pull the road)

Single Movable Pulley

It consist one pulley at dynamic. Consider the diagram whereby its move to lift the load



For single movable pulley

MA = L/E

T = E

From the diagram above, the effort (2x) is moved twice moved by load (x)

Ed = 2x

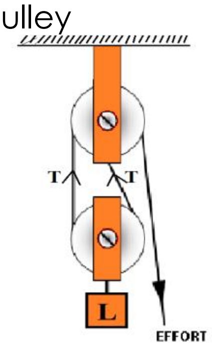
Ld = x

VR = 2x/x

Therefore: VR = 2(number of rope pull the road)

Combination Pulley

It consists of fixed and movable pulleys. Number of pulley is varies from one to another pulley



For combination pulley

MA = L/E

From the diagram above, the effort (nx) is moved twice moved by load (x)

Where:

x = distance moved by load and effort

n = number of pulley (number of rope pull the road)

Ed = nx

Ld = x

VR = nx/x

Therefore:

VR = n (number of rope pull the road)

VR = n (number of pulley)

From the diagram above

n = 2, therefore its VR = 2

The Block And Tackle Pulley

The block and tackle pulley is made of two or more pulleys. It like combination pulley system

Example,

A pulley system is made up of 8 pulleys. An effort of 200 N is applied on the pulley system, if the pulley system has an efficiency of 80%. Find the maximum load

Data given

Velocity ratio, VR = 8

Effort, E = 200 N

Efficiency, Eff = 80%

Mechanical advantage, MA = ?

Maximum load, Lmax = ?

Minimum load, Lmin = ?

Solution:

For maximum load, Lmax (normal Load, L)

Then: Eff = (MA/VR) × 100% - make MA subject

Eff = (MA/VR) × 100%

MA = (VR× Eff) /100%

MA = (8×80%) /100%

MA = 640/100

MA = 6.4

But: MA = L/E

MA = Lmax/E – make L subject

Lmax = MA × E

Lmax = 6.4 × 200

Lmax = 6.4 × 200

<u>Lmax = 1280 N</u>

Lmin is obtained by the formula

$$\frac{\text{Given Eff}}{100\%} \times \text{Lmin} = \text{Lmax}$$

$\frac{80\%}{100\%}$ x Lmin = 1280 – make Lmin subject

Lmin = (100% x 1280)/80%

Lmin = 128000%/80%

Lmin = 1600 N

Example,

A block and tackle pulley system has a VR of 4, if a load of 100 N is raised by using force of 50 N. find the mechanical advantage and Efficiency

Data given

Load, L = 100 N

Effort, E = 50 N

Velocity ratio, VR = 4

Mechanical advantage, MA = ?

Efficiency, Eff = ?

Solution

MA = 100/50

MA = 2

Then: Eff = (MA/VR) × 100%

Eff = (2/4) × 100%

Eff = 0.5 × 100%

Eff = 50%

Example,

A simple pulley system has velocity ratio of 3, if its efficiency is 90%. Find load which can raise by an effort of 100 N

Data given

Efficiency, Eff = 90%

Velocity ratio, VR = 3

Effort, E = 100 N

Load, L = ?

Solution

Eff = (MA/VR) × 100% - make MA subject

MA = (VR x Eff)/100%

MA = (3 x 90%)/100%

MA = 270%/100%

MA = 2.7

But: MA = L/E

2.7 = L/100 – make L subject

L = 2.7 x 100

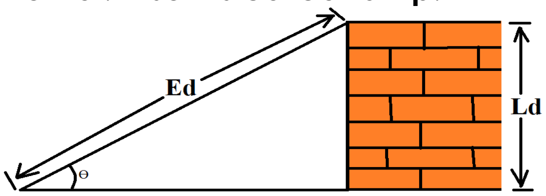
L = 270 N

Uses of Pulleys in Daily Life

i. Applicable in winches for building works
ii. Uses as transport tourist up mountain slopes
iii. Uses by fisher man to lift heavy clothes which used to move their boat as done at Mtwara coast
iv. Used in garage to lift car engine
v. Used for fetch water in the well

Inclined Planes

An inclined plane is a smooth flat rigid surface slanted at an angle to the horizontal. Also it's called **ramp**.



Where:

Distance moved by load (vertical height) = Ld

Distance moved by Effort (slanted height) = Ed

For inclined plane

MA = L/E

VR = Ed/Ld

Eff = (MA/VR) × 100%

Example,

A force of 600 N is used to move a load of 3000 N up an inclined plane. Given that the slanted height and vertical height of the plane are 18 m and 3m respectively. Find

a) Velocity ratio of the plane
b) Mechanical advantage
c) Efficiency of the plane

Data given

Effort, E = 600 N

Load, L = 3000 N

Slanted height, Ed = 18 m

Vertical height, Ld = 3 m

Velocity ratio, VR = ?

Mechanical advantage, MA = ?

Efficiency, Eff = ?

Solution

a) **From:** MA = L/E
   MA = L/E =3000/600 = 5
   MA = 5

b) **From:** VR = Ed/Ld
   VR = Ed/Ld = 18/3 = 6
   VR = 6

c) **From:** Eff = (MA/VR) × 100%
   Eff = (5/6) × 100%
   Eff = 0.8333 × 100%
   Eff = 83.33%

Example,

A loaded wheelbarrow weighting 800 N is pushed up an inclined plane by a force of 150 N parallel to the plane, if the plane rises 50 cm for every 400 cm length of the plane. Find the velocity ratio, mechanical advantage and efficiency

Data given

Load, L = 800 N

Effort, E = 150 N

Slanted height, Ed = 400 cm

Vertical height, Ld = 50 cm

Velocity ratio, VR = ?

Mechanical advantage, MA = ?

Efficiency, Eff = ?

Solution

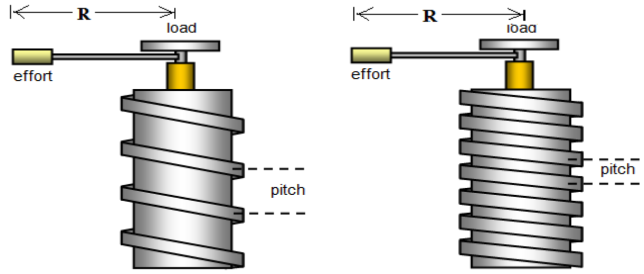
From: MA = L/E

MA = L/E =800/150 = 5.3
MA = 5

From: VR = Ed/Ld
VR = Ed/Ld = 400/50 = 8
VR = 6

From: Eff = (MA/VR) × 100%
Eff = (5.3/8) × 100%
Eff = 0.6625 × 100%
Eff = 66.25%

Screw Jack
Screw jack it consist of a rod in which there is a thread



For screw jack
MA = L/E

VR = Ed/Ld
But:
Ed = 2πR = circumference of circle of screw and jack
length of the turning = R
Ld = pitch, P
Now:
VR = 2πR /P

Eff = (MA/VR) × 100%

Example,
A screw jack has 5 threads per centimeter, if the length of the turning lever is 20 cm. find the velocity ratio (π = 3.14)
Data given:
Length of the turning, R = 20 cm
Length of the rod, x = 1 cm
Number of thread, y = 5
Pitch, P = ?
Velocity ratio, VR = ?
Solution:
Find P first where is given by the formula
P = x/y
P = 1/5
P = 0.2 cm
From: VR = 2πR /P
VR = (2 x 3.14 x 20) /0.2
VR = 125.6 /0.2
<u>VR = 628</u>

Example,
A screw jack which has a 5 thread per centimeter is used to lift a car weighting 20000 N, if the length of the turning lever is 40 cm and the efficiency of the screw jack is 90%. Find Velocity ratio, Mechanical advantage, Minimum effort and maximum effort
Data given:
Length of the turning, R = 40 cm
Length of the rod, x = 1 cm
Number of thread, y = 5
Efficiency, Eff = 90%
Load, L = 20000 N
Pitch, P = ?
Velocity ratio, VR = ?
Mechanical advantage, MA = ?
Minimum effort, Emin = ?
Maximum effort Emax = ?
Solution:
Find P first where is given by the formula
P = x/y
P = 1/5
P = 0.2 cm
From: VR = 2πR /P
VR = (2 x 3.14 x 40) /0.2
VR = 251.3 /0.2
<u>VR = 1256.5</u>

From: Eff = (MA/VR) × 100% - make MA subject
MA = (90% × 1256.5)/100%
MA = 113085%/100%
<u>MA = 1130.85</u>

From: MA = L/E – make effort, E subject
Emin = L/MA
Emin = 20000/1130.85
<u>Emin = 17.7 N</u>

Emax is obtained by the formula
$$\frac{\textbf{Given Eff}}{\textbf{100\%}} \textbf{ x Emax = Emin}$$
$\frac{90\%}{100\%}$ x Emax = 17.7 – make Emax subject
Emax = (100% x 17.7)/90%
Emax = 1770%/80%
<u>Emax = 22.125 N</u>

Example,

The handle of the screw jack is 35 cm long and the pitch of the screw is 0.5 cm. what force must be applied to the end of the handle when lifting a load of 2200 N, when efficiency of the jack is 40%

Data given

Length of the turning, R = 35 cm

Efficiency, Eff = 40%

Load, L = 2200 N

Pitch, P = 0.5 cm

Velocity ratio, VR = ?

Mechanical advantage, MA = ?

Effort, E = ?

Solution:

First find velocity ratio

From: VR = 2πR /P

VR = (2 x 3.14 x 35) /0.5

VR = 219.9 /0.5

VR = 439.8

Second find mechanical advantage

From: Eff = (MA/VR) × 100% - make MA subject

MA = (40% × 439.8)/100%

MA = 17592%/100%

MA = 175.92

Third find effort needed

From: MA = L/E – make effort, E subject

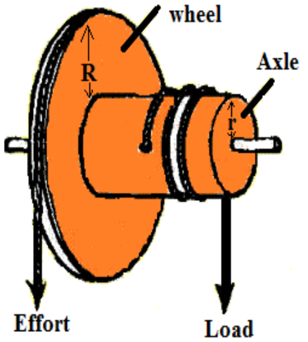
E = L/MA

E = 2200/175.92

E = 12.5 N

Wheel And Axle

Wheel and axle it consist of a wheel and an axle mounted and joined together so they have the same axis of rotation



Where:

Load distance (circumference of axle) = Ld

Effort distance (circumference of wheel) = Ed

Radius of wheel = R

Radius of axle = r

For wheel and axle

MA = L/E

VR = Ed/Ld

But: Ed = 2πR and Ld =2πr

Then: VR = 2πR /2πr

VR = R/r

Eff = (MA/VR) × 100%

Example,

A wheel and axle has a velocity ratio of 6. Determine the radius of the wheel, if the radius of the axle is (a) 5 cm (b) 8 cm (c) 12 cm

Data given

Velocity ratio, VR = 6

Radius of the wheel, R = ?

Solution:

(a) If radius of axle, r = 5 cm

But: VR = R/r

VR = R/r – make subject R

R = VR x r

R = 6 x 5

R = 30 cm

(b) If radius of axle, r = 8 cm

But: VR = R/r

VR = R/r – make subject R

R = VR x r

R = 6 x 8

R = 48 cm

(c) If radius of axle, r = 12 cm

But: VR = R/r

VR = R/r – make subject R

R = VR x r

R = 6 x 12

R = 72 cm

Example,

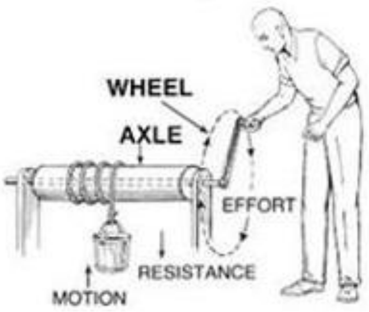
A wheel and axle with an efficiency of 90% is to be raised a load of 10000 N. the radius of the wheel is 40 cm while radius of the axle is 5 cm. find Velocity ratio, Mechanical advantage and Effort

Data given

Uses of Wheel And Axle in Daily Life

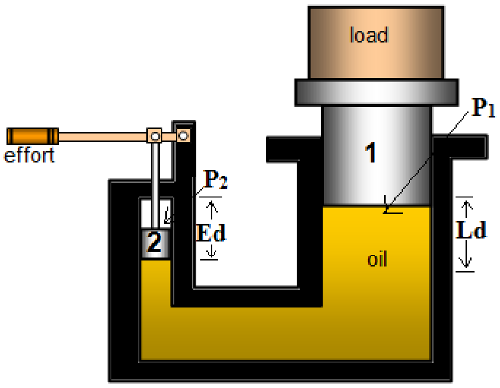
i. Riding a bicycle

ii. Used to fetch water in well



Hydraulic Press

Hydraulic press multiplies an applied effort using the pressure of a liquid or gas. This allows the lifting of a heavy load by applying little effort



Since: $P = F/A$

$P_1 = F_1/A_1$

$P_2 = F_2/A_2$

But:

$F_1 = L$

$F_2 = E$

$A_1 = \pi R^2$

$A_2 = \pi r^2$

Assume there is no friction force

But: $P_1 = P_2$

$L/\pi R^2 = E/\pi r^2$ – divide by E and πr^2 both sides

$L/E = \pi R^2/\pi r^2$

$L/E = R^2/r^2$

$L/E = (R/r)^2$ – practical is not true

But: anticlockwise moment = clockwise moment

Therefore:

L x Ld = E x Ed – divide by E and Ed both sides

L/E = Ed/Ld

L/E = Ed /Ld – practical is not true

L/E = Ed /Ld

But: L/E = Ed /Ld = VR

L/E = Ed /Ld = VR = $(R/r)^2$

Then: VR = $(R/r)^2$– practical and theoretical is true

For hydraulic press

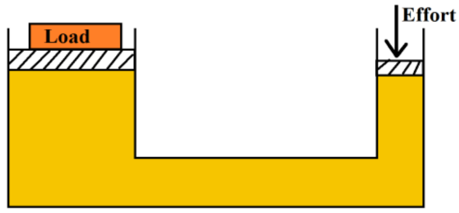
MA = L/E

VR = $(R/r)^2$

Eff = (MA/VR) × 100%

Example,

The diagram below shows a hydraulic press being used to lift a container weighting 100000 N



Radii of the effort and load piston are 20 cm and 50 m respectively, if the efficiency of the hydraulic press is 90%. Determine

a) Velocity ratio
b) Mechanical advantage
c) Minimum Effort
d) The distance the container raised through if the effort piston pushed through 1 m

Data given:

Load, L = 100000 N

Radius of Load piston, R = 5 m

Radius of effort piston, r = 20 cm = 0.2 m

Efficiency, Eff = 90%

Velocity ratio, VR = ?

Mechanical advantage, MA = ?

Minimum effort, Emin = ?

Distance moved by effort, Ed = 1m

Distance moved by load, Ld = ?

Solution

a) **From:** VR = $(R/r)^2$
   VR = $(5/0.2)^2$
   VR = (25/0.04)
   VR = 625
b) **From:** Eff=(MA/VR)×100% -make MA subject
   MA = (90% × 625)/100%
   MA = 56250%/100%
   <u>MA = 562.5</u>
c) **From:** MA = L/Emin – make Emin subject
   Emin = L/MA
   Emin = 100000/562.5
   Emin = 177.78 N
d) **From:** VR = Ed/Ld – make Ld subject
   Ld = Ed/VR
   Ld = 1/625
   Ld = 0.0016 m

Uses of Hydraulic Press in Daily Life

i. It lifts heavy loads
ii. In ginneries to compress a lump of cotton into small bales
iii. In industries to form car bodies into the required shapes

Motion in a Straight Line

Motion:

Defn: motion is the process of continuously changing in position of an object from one place to another.

Types of Motion

There are two types of motion namely:

i. Linear motion
ii. Circular motion

i. Linear Motion

Defn: linear motion is a motion of an object in a straight line.

ii. Circular Motion

Defn: circular motion is a motion of an object around the circle. Example, s of circular motion:

i. Rotation of the earth
ii. Motion of electrons around the nucleus

Kinematics

Defn: kinematics is the branch of motion deals with motion of bodies without considering the factors causing motion.

Dynamics

Defn: dynamics is the branch of motion deals with motion of bodies by considering the factor causing motion.

NB:

i. In generally the factor causing motion is **force**
ii. In kinetic the force does not put into consideration while in dynamics the force is put inconsideration.

Terms Used To Describe Motion

i. Distance
ii. Displacement
iii. Speed
iv. Velocity
v. Acceleration
vi. Retardation

Distance

Defn: Distance is the length of path taken by a particular object. The distance is represented by letter **s**

The distance is scalar quantity has magnitude but not direction.

The **SI unit** of distance is **Metre** (m). Other units are **Centimeter** (cm), and **Kilometer** (km)

Displacement

Defn: *Displacement* *is the distance moved by an object in specific direction*. The distance is represented by letter **S**

The displacement is vector quantity has both magnitude and direction.

The **SI unit** of displacement is **Metre** (m). Other units are **Centimeter** (cm), and **Kilometer** (km)

Speed

Defn: *Speed* *is the distance moved per unit time*. Or ***Speed*** *is the rate of change of distance moved with time*. The speed is represented by letter **v.** The speed is scalar quantity has magnitude only.

Speed Formula

Speed (v) = distance/Time taken

v = s/t

From: V = x/t = meter/second = m/s

Therefore: SI unit of speed is *Meter per Second* (m/s). The unit used is *kilometer per second* (km/h)

Velocity

Defn: *Velocity* *is the displacement moved per unit time*. Or ***Velocity*** *is the rate of change of displacement moved with time*. The velocity is a vector quantity. The speed is represented by letter **v**

Velocity Formula

Velocity (v) = Displacement/Time taken

v = s/t

From: V = s/t = meter/second = m/s

Therefore: SI unit of velocity is *Meter per Second* (m/s). The unit used is *kilometer per second* (km/h)

Relationship between m/s and km/h

From: 1km = 1000m ……….. (i)

Also: 1h = 3600s ……………. (ii)

Divide equation (i) to equation (ii)

$$\frac{1km}{1h} = \frac{1000m}{3600s}$$

1km/h = 1000m/3600s
1km/h = 10m/36s
1km/h = 10m/36s – multiply by 36 both sides
36km/h = 10m/s
Therefore: 36km/h = 10m/s

Types of Velocity
The following are three types of velocity
a) Initial velocity, u
b) Final velocity, v
c) Average velocity, va
d) Uniform velocity
e) Instantaneous velocity

Initial velocity
Defn: Initial velocity is the velocity of the body at starting of observation.

Final velocity
Defn: Final velocity is the velocity of the body at ending point of observation.

Average velocity
Defn: Average velocity is the mean of initial and final velocities.
Mathematically
va = (u + v)/2
Where:
Average velocity = va
Initial velocity = u
Final velocity = v

OR **Defn:** Average velocity is the ratio of the total displacement to the total time.
Mathematically
va = s/t
Where:
Average velocity = va
Total distance = s
Total time = t

Uniform velocity
Defn: *Uniform velocity is the type of velocity in which the rate of change of displacement with time does not change*.

Consider a table below:

Displacement (m)	0	2	4	8	16
Time taken, t (s)	0	1	2	4	8

The table above depicts that the body was moving with uniform velocity of 2m/s.

Instantaneous velocity
Defn: *Instantaneous velocity* ***is*** *the velocity of the body at any instant.*

Example,
An travelled 20m to the right in 4s and then 12m to the left in 3s, for its total motion, what was its average speed & its average velocity.
Data given
Distance traveled, s = 20 m + 12 m = 32 m
Time taken, t = 4s + 3 s = 7 s
Average speed, v = ?
Average velocity, va = ?
Solution
From: v = d/t
v = 32/7
<u>v = 4.57</u>
Therefore average Speed Is 4.57 m/s
From: va = s/t
Where:
Average velocity = va
Total distance = s
Total time = t
va = s/t
Assume right is wanted direction
Distance to right, s_1 = 20 m
Distance to left, s_2 = -12 m
Total distance = s = 20 + -12 m = 8 m
Then:
va = 8/7
<u>Va = 1.14 m/s</u>
Therefore Average velocity Is 1.14 m/s

Example,
A ball is dropped from a height of 20m above the ground. It hits the ground in 2s and bounces back up to a height of 12.7m in 1.6s .What are its average velocity
Data given
Assume down is wanted direction
Distance to down, s_1 = 20 m
Distance to up after bounce, s_2 = -12.7 m
Total distance = s = 20 + -12.7 m = 7.3 m
Time taken, t = 2s + 1.6 s = 3.6 s
Average velocity, va = ?
Solution
From: va = s/t
va = 7.3/3.6
<u>Va = 2.03 m/s</u>
Therefore Average velocity Is 2.03 m/s

Example,

A 100m runner finishes the race in 10s. What is her average speed?

Data given

Distance traveled, s = 100 m

Time taken, t = 10 s

Average speed, v = ?

Solution

From: v = d/t

v = 100/10

v = 10

Therefore average Speed Is 10 m/s

Acceleration

Defn: *Acceleration is the rate of change of velocity with time*. OR *Acceleration is the change in velocity per unit time*.

Mathematical:

a = (v – u)/t

Unit of acceleration

From: a = (v – u)/t

a = (v – u)/t

a = (m/s)/s

a = m/s^2

Therefore: SI unit of acceleration is *Meter per Second Square* (m/s^2). Other unit is *Kilometer per hour square* (km/h^2)

Uniform acceleration

Defn: Uniform acceleration is the type of acceleration in which the rate of change of velocity with time does not change.

Retardation/ Deceleration

Defn: *Retardation is the rate of decreasing of velocity with time*. Or *Retardation is the decreasing of velocity per unit time*. The retardation is negative acceleration.

Uniform retardation

Defn: *Uniform retardation is the one in which the rate of decreasing of velocity with time does not change*.

NB:

i. When a body starts moving from rest its initial velocity become zero, u = $0m/s^2$
ii. When a body is brought to rest by the application of brakes its final velocity, u = $0m/s^2$
iii. When a velocity of a moving object increases its acceleration become positive
iv. When the velocity of a moving object decreases its acceleration become negative
v. The negative is called *retardation*
vi. When a body is moving with a uniform velocity in acceleration becomes zero, a = 0 m/s^2

Example,

An object is moving at 15 m/s to the right after 8 sec later it is moving at 5 m/s to the right, what was the acceleration of the object?

Data given

Assume right is wanted direction

Initial velocity, u = +15 m/s

Final velocity, v = +5 m/s

Time taken, t = 8s

Acceleration, a = ?

Solution

From: a = (v – u)/t

a = (5 – 15)/8

a = -10/8

a = -2.5 m/s^2

Example,

A car brakes and slows down from 20 m/s to 5 m/s in 3 sec. find its acceleration

Data given

Initial velocity, u = 20 m/s

Final velocity, v = 5 m/s

Time taken, t = 3s

Acceleration, a = ?

Solution

From: a = (v – u)/t

a = (5 – 20)/8

a = -15/3

a = -5 m/s^2

Example,

Starting from rest, a sports car accelerate to a velocity of 96 km/h in 16 sec. find acceleration

Data given

Initial velocity, u = 0 km/h = 0 m/s

Final velocity, v = 96 km/h = 26.7 m/s

Time taken, t = 16s

Acceleration, a = ?

Solution

From: a = (v – u)/t

a = (26.7 – 0)/16

a = 26.7/16

a = 1.67 m/s^2

Example,

A car travels at 10 m/s and increase its velocity to 30 m/s in 10 sec. find acceleration of the car

Data given

Initial velocity, u = 10 m/s

Final velocity, v = 30 m/s

Time taken, t = 10s

Acceleration, a = ?

Solution

From: $a = (v – u)/t$

$a = (30 – 10)/10$

$a = 20/10$

$\underline{a = 2 \text{ m/s}^2}$

Example,

A car travels at 45 m/s and decreases its velocity uniformly to 20 m/s in 5 sec. find acceleration

Data given

Initial velocity, u = 45 m/s

Final velocity, v =2 m/s

Time taken, t = 5s

Acceleration, a = ?

Solution

From: $a = (v – u)/t$

$a = (20 – 45)/5$

$a = -15/5$

$\underline{a = -3 \text{ m/s}^2}$

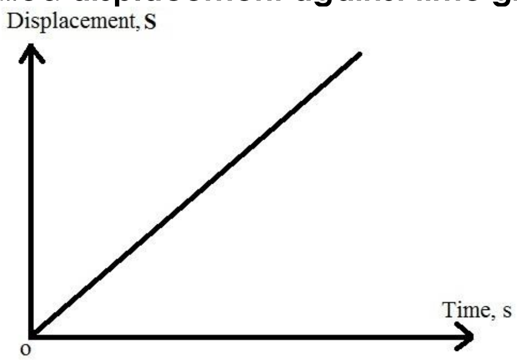
Position Time Graphs

Displacement, velocity, acceleration can be represented on a graphs.

The graph which shows the distance or displacement against or versus time is called **distance/displacement time graph**

Displacement Time Graph

Defn: displacement time graph is the graph which shows the displacement (y-axis) versus time (x-axis). It sometimes called **displacement against time graph**



Consider a body is moving with a uniform velocity i.e. Displacement rate of change.

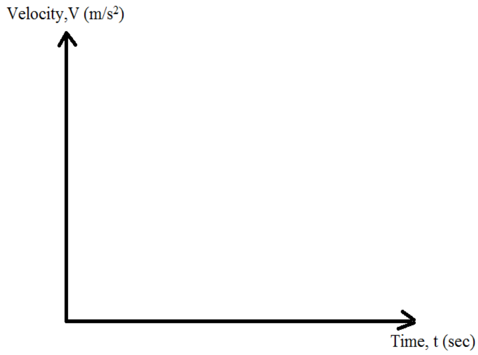
Nb:

i. The graph which shows the velocity against time is called **velocity time graph**
ii. The slope of the graph represents the speed of the object
iii. The horizontal lines show that the object is stationary or at rest for a certain period of time

Velocity Time Graph

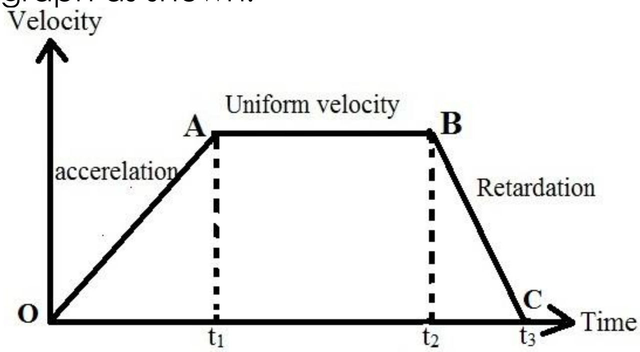
Defn: velocity time graph is the graph which shows the velocity (y-axis) versus time (x-axis). It sometimes called **velocity against time graph**

Diagram:



Consider a body starts moving from rest and accelerated uniform to a velocity, v after time, t_1. It then moved with this velocity for time, t_2 before uniformly retarded to a stop after another time, t_3.

The above information can be represented on the velocity against time graph as shown.



Deduction from velocity against time graph

a) Distance travelled (moved) can be calculated.

Generally:

S = Ta

Where:

Total distance travelled = **S**

Total Area of velocity against time = **Ta**

From the velocity against time graph above total area of velocity time graph is Area of trapezium OABC.

b) Acceleration can be calculated also

Generally:

a = Slope of velocity against time graph

But:

Slope = (change in y)/(Change in x)

Slope = $(\Delta y)/(\Delta x)$

But: $(\Delta y)/(\Delta x) = (\Delta v)/(\Delta t) = a$

Therefore: a = slope

Thus the slope of velocity against time graph represents acceleration

Nb:

i. A horizontal line represents motion at constant velocity.
ii. Displacement travelled is given by the area under the graph.
iii. Acceleration/deceleration is given by the slope of the graph.

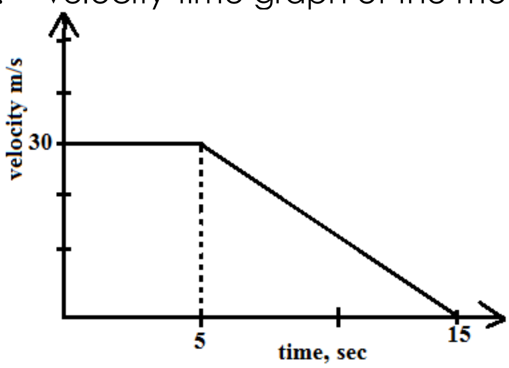
Example, : NECTA form II 2005

A car travel with uniform velocity of 30m/s for 5 second and then comes to rest 10 second with uniform deceleration.

i. Draw a velocity-time graph of the motion.
ii. Find the total distance travelled.
iii. Find the average.

Solution:

i. velocity-time graph of the motion



ii. Total distance travelled, s = ?

From: S = Ta

$S = (30 \times 5) + (30 \times 10)/2$

$S = 150 + 300/2$

$S = 150 + 150$

<u>S = 300 m</u>

iii. Find the average velocity

From velocity time graph

Total distance, s = 300 m

Total time taken, t = 15 s

Average velocity, va = ?

From: va = s/t

va = 7300/15

<u>Va = 20 m/s</u>

Therefore Average velocity Is 20 m/s

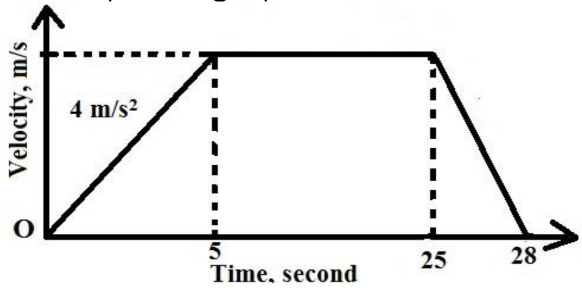
Example,

A car starts from rest and is accelerated uniformly at a rate of 4 m/s^2 for 5 sec. it maintains a constant speed for 20 sec, brakes applied and the car stops in the next 3 sec. find

a) Draw a velocity-time graph of the motion.
b) Maximum speed attained
c) Find the total distance travelled.

Solution:

a) Velocity-time graph of the motion.



b) Maximum speed attained, v = ?

From: a = slope

$a = (\Delta v)/(\Delta t)$

$\Delta v = v - u$

$\Delta t = t = 5$

Then: a = (v-u)/t – make v subject

a = (v-u)/t – multiply by t both sides

at = (v-u) = v-u

at = v-u

v-u = at – add u both sides

$v = at + u = 4 \times 5 + 0$

<u>v = 20 m/s</u>

c) Total distance travelled, s = ?

From: S = Ta = Area of trapezium

$S = (28 + 20)/2 \times 20$

$S = 48 /2 \times 20$

$S = 24 \times 20$

<u>S = 480 m</u>

Example,

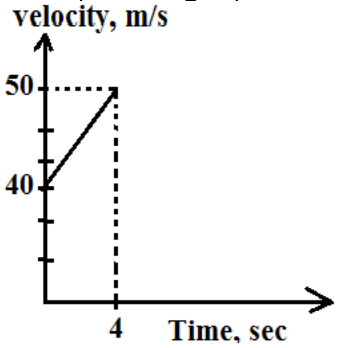
A body accelerates uniformly from velocity of 40 m/s to a velocity of 50 m/s in 4sec. find

a) Draw a velocity-time graph of the motion.

b) Acceleration of the body
c) the total distance travelled by the body in metre

Solution:

a) velocity-time graph of the motion



b) Acceleration of the body

Data given:
Initial velocity, u = 40 m/s
Final velocity, v = 50 m/s
Time taken, t = 4s
Acceleration, a = ?
Solution
From: a = (v – u)/t
a = (50 – 40)/4
a = 10/4
<u>$a = 2.5\ m/s^2$</u>

c) Total distance travelled, s= ?
From: S = Ta
S = (40 x 4) + (4 x 10)/2
S = 160 + 40/2
S = 160 + 20
<u>S = 180 m</u>

Newton's Equation of Motion

We have about three equation of linear motion introduced by sir Isaac Newton's in 1886, include the following

i. Newton's first equation of motion
ii. Newton's second equation of motion
iii. Newton's third equation of motion

Newton's first equation of motion

It is related *final velocity*, *initial velocity*, *acceleration* and *time taken*. The Newton's first equation of motion is given by:

$$V = u + at$$

Proof:

From: $a = (v - u)/t$

$a = (v - u)/t$ – multiply by t both sides

$a = (v - u)/t$

$at = v - u$ – add u both sides

$at + u = v – u + u$

$at + u = v$

$\mathbf{V = u + at}$

Hence proved

Newton's second equation of motion

It relates *distance (displacement) moved*, *initial velocity*, *time taken*, and *acceleration*. The Newton second equation is given by:

$$S = ut + ½(at^2)$$

Proof:

From: Newton's first equation of motion

$at + u = v$

But:

$va = (u + v)/2$

$va = s/t$

$va = s/t = (u + v)/2$

Then: $s/t = (u + v)/2$

$s/t = (u + v)/2$ – make s subject

$s/t = (u + v)/2$ – multiply by t both sides

$s = (u + v)t/2$

But: $v = u + at$ **–** substitute into equation above

$s = (u + v)t/2$

$s = (u + u + at)t/2$

$s = (2u + at)t/2$

$s = (2ut + at^2)/2$

$s = (2ut)/2 + (at^2)/2$

$s = ut+ (at^2)/2$

$\mathbf{S = ut + ½(at^2)}$

Hence Proved

Newton's third equation of motion

It relates to *final velocity*, *initial velocity*, *acceleration* and *distance moved*. The Newton's third equation of motion is given by

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

Proof:

From Newton first equation of motion:

$v = u + at$ - Square both side:

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

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

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

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

$v^2 = u^2 + 2a(ut+1/2at^2)$

But:

$S = ut + ½(at^2)$ **–** substitute into equation above

$v^2 = u^2 + 2a(S)$

$\mathbf{v^2 = u^2 + 2aS}$

Hence Proved

Alternative:

Newton's third equation of motion can be delivered by eliminating t from Newton's first equation of motion.

$v = u + at$ - make t subject

$v - u = at$– divide by a both sides

$at = v - u$

$t = (v – u)/a$ …………………….. (i)

From: $s/t = (u + v)/2$

$s/t = (u + v)/2$ – make s subject

$s/t = (u + v)/2$ – multiply by t both sides

$s = (u + v)t/2$ ……………………………….. (ii)

Substitute (i) into (ii) equation

$s = ((u + v) (v – u)/a)/2$

$2s = ((u + v) (v – u))/a$

$2as = (u + v) (v – u)$

$2as = (u + v) (v - u)$

From difference of two square

$(u + v) (v - u) = v^2 - u^2$

$2as = v^2 - u^2$

$\mathbf{v^2 = u^2 + 2aS}$

Hence Proved

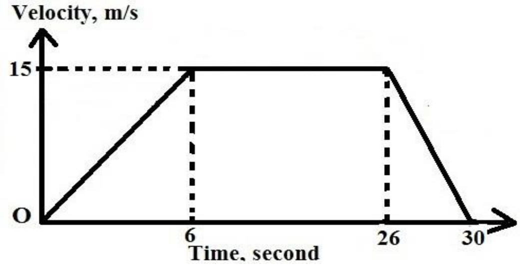
Example,

Starting from rest, a car accelerates uniformly at $2.5m/s^2$ for 6sec. 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. find

a) Draw speed time graph
b) Maximum speed in km/h
c) Displacement covered in km

Solution:

a) speed time graph



b) Maximum speed in km/h = Final velocity, v = ?

Data given:

Initial velocity, u = 0 m/s

Final velocity, v = ?

Time taken, t = 6s

Acceleration, a = 2.5 m/s^2

From: v = u + at

v = 0 + 2.5 x 6

v = 0 + 15

v = 15 m/s = 54 km/h

v = 54 km/h

c) Displacement covered in km, s = ?

From: S = Ta = Area of trapezium

S = (30 + 20)/2 x 15

S = 50/2 x 15

S = 25 x 15 = 375 m = 0.375 km

S = 0.375 km

Example, : NECTA 2010

A car accelerates uniformly from rest to a speed of 15km/h in 10s, Find:

a) The acceleration in m/s^2

b) Distance covered in meters

Data given:

Initial velocity, u = 0m/s

Final velocity, v = 15km/h = 4.2 m/s

Time taken, t = 10 sec

Solution:

a) The acceleration, a = ?

From: Newton's first equation of motion

v = u + at – make a subject

a = (v – u)/t

a = (4.2 - 0)/10

a = 4.2/10

a = 0.42 m/s^2

b) Distance covered, s = ?

From: Newton's second equation

S = ut + ½(at^2)

S = 0 x 10 + ½(0.42 x 10^2)

S = 0 + ½(0.42 x 100)

S = 0 + ½(42)

S = 0 +21

S = 21 m

Motion under Gravity

All the body fall in the same acceleration due to gravity called acceleration of a free falling body denoted by letter g. it value is 10 m/s^2 or 9.8 m/s^2. Also distance moved by object changed to height because if falling

Now: a = +g

s = h

Substitute a by g and s by h from Newton's equation of motion

V = u + at changed to **V = u + gt**

S = ut + ½(at^2) changed to **h = ut + ½(gt^2)**

v^2 = u^2 + 2as changed to **v^2 = u^2 + 2ah**

Note:

a) When the body falling down (a = g) & (s = h)

V = u + gt

h = ut + ½(gt^2)

v^2 = u^2 + 2ah

b) When the body thrown up/vertical (a = -g) & (s = h)

V = u - gt

h = ut - ½(gt^2)

v^2 = u^2 - 2ah

Example,

A stone is thrown vertically upward from the ground with a velocity of 30 m/s. find

a) Maximum height reached

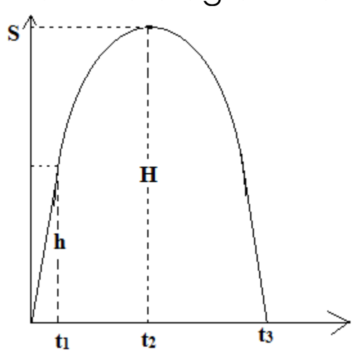
b) Time taken for maximum height

c) Time taken for reach ground again

d) The velocity reached half-way to the maximum height

Solution:

Draw the diagram first



a) Maximum height reached, s = H = ?

Data given:

Initial velocity, u = 30 m/s

Final velocity, v = 0 m/s
Acceleration, a = -g = -10 m/s^2
From: Newton's third equation of motion
$v^2 = u^2 - 2gH$ – make H subject
$2gH = u^2 - v^2$ – divide by 2g both sides
$H = (u^2 - v^2)/2g$
$H = (30^2 - 0^2)/(2 \times 10)$
$H = 900/20$
$\underline{H = 45\ m}$

b) Time taken for maximum height, t_2 = ?
From: Newton's first equation of motion
$v = u - gt_2$ – make t_2 subject
$g = (u - v)/t_2$
$t_2 = (u - v)/g$
$t_2 = (30 - 0)/10$
$t_2 = 30 /10$
$\underline{t_2 = 3\ sec}$

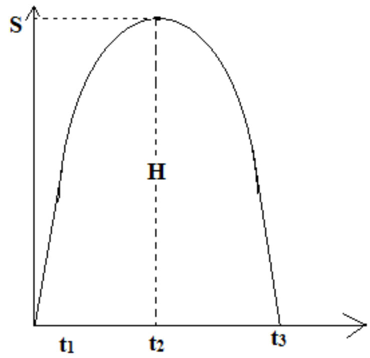
c) Time taken for reach ground again, t_3 = ?
Data given:
Initial velocity, u = 0 m/s
Final velocity, v = 30 m/s
Time from H and ground, t = ?
Acceleration, a = = g = 10 m/s^2
From: Newton's first equation of motion
$v = u + gt$ – make t_2 subject
$g = (v - u)/t$
$t = (v - u)/g$
$t = (30 - 0)/10$
$t = 30 /10$
t = 3 sec
$t_3 = t + t_2 = 3 + 3 = 6$
$\underline{t_3 = 6\ sec}$

Alternative:
$t_3 = 2t_2 = 2 \times 3 = 6$
$\underline{t_3 = 6\ sec}$

d) Velocity reached half-way to the maximum height , vh = ?
When stone is halfway to maximum height, the height attained is h = H/2 = 45/2 = 22.5 m
Data given:
Initial velocity, u = 30 m/s
Final velocity, vh = ?
Acceleration, a = -g = -10 m/s^2
From: Newton's third equation of motion
$vh^2 = u^2 - 2gh$
$vh^2 = 30^2 - (2 \times 10 \times 22.5)$
$vh^2 = 900 - (2 \times 225)$
$vh^2 = 900 - 450$
$vh^2 = 450$ – square root both sides
vh = 21.2 m/s
Therefore Velocity reached half-way to the maximum height is 21.2 m/s

Example,
An object is thrown straight up with an initial velocity of 50 m/s
a) How long will take to reach its maximum height
b) To what height will it rise?
c) What will be its velocity when it returns to its starting point?
d) How long will be in the air?

Solution
Draw the diagram first



a) Time taken for maximum height, t_2 = ?
Data given:
Initial velocity, u = 50 m/s
Final velocity, v = 0 m/s
Acceleration, a = -g = -10 m/s^2
From: Newton's first equation of motion
$v = u - gt_2$ – make t_2 subject
$g = (u - v)/t_2$
$t_2 = (u - v)/g$
$t_2 = (50 - 0)/10$
$t_2 = 50 /10$
$\underline{t_2 = 5\ sec}$

b) Height will it rise, h = ?
From: Newton's third equation of motion
$v^2 = u^2 - 2gh$ – make H subject
$2gh = u^2 - v^2$ – divide by 2g both sides
$h = (u^2 - v^2)/2g$
$h = (50^2 - 0^2)/(2 \times 10)$
$h = 2500/20$
$\underline{h = 125\ m}$

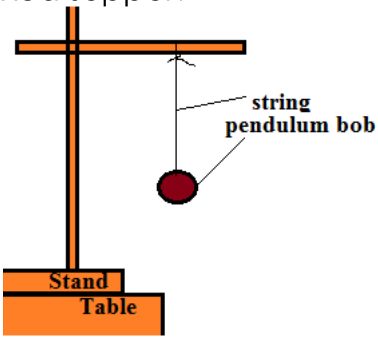
c) Velocity at starting point,, vh = ?
Data given:

Initial velocity, u = 0 m/s
Final velocity, vh = ?
Acceleration, a = g = 10 m/s^2
From: Newton's third equation of motion
$vh^2 = u^2 + 2gh$
$vh^2 = 0^2 – (2 \times 10 \times 125)$
$vh^2 = 0 + (2500)$
$vh^2 = 0 + 2500$
$vh^2 = 2500$ – square root both sides
<u>vh = 50 m/s</u>

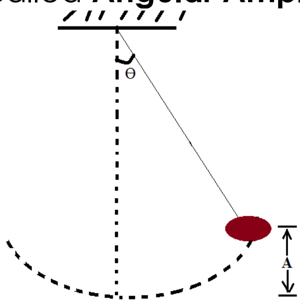
d) Long will be in the air, t_3 = ?
$t_3 = 2t_2 = 2 \times 5 = 10$
<u>t_3 = 10 sec</u>

Simple Pendulum

Simple pendulum is a small heavy body suspended by a light inextensible string from a fixed support



When pendulum bob swings it reached maximum displacement called **Amplitude** and the angle between string and vertical axis is called **Angular Amplitude**

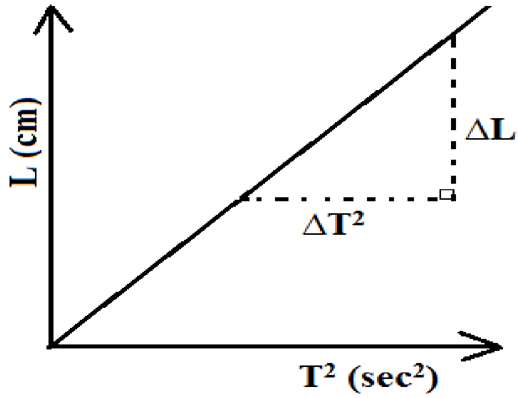


θ = Angular Amplitude
A = Amplitude
When the length of string change while the mass of pendulum bob constant, the period is always constant and that constant time is given by
$T = 2\pi(L/g)^{1/2}$

Where:
T = period for complete oscillation
L = length of string
g = acceleration due to gravity

From: $T = 2\pi(L/g)^{1/2}$ – square both
$T^2 = (4\pi^2L)/g$
$T^2 = ((4\pi^2L)/g)L$
Since:
$(4\pi^2/g) = k$ is constant keep proportionality constant
$T^2 = kL$
T^2 a L
Therefore T^2 is directly proportional to the L. it Means when T^2 Increase also L Increase and vice versa

Graph of T^2 against L



From the graph above
Slope = $\Delta L/\Delta T^2 = (4\pi^2)/g$
Therefore: Slope$^{-1} = (4\pi^2)/g$

Application of gravitational force

i. Uses to launch satellites and space vehicle into space requires overcoming the gravitational attraction forces for take off
ii. Uses to keep satellite rotating on earth's orbit
iii. It causes everybody to be attracted towards the earth's surface
iv. It uses to calculate the time taken by object to reach to ground for all objects near the earth's surface. E.g. *army aircraft when firing bombs, parachutist move under free fall,(a = g)etc*

Newton's Law of Motion

We have about three Newton's law of motion, include the following
i. Newton's first law of motion
ii. Newton's second law of motion
iii. Newton's third law of motion

Newton's First Law of Motion

In a car passenger tend to be thrown forwards when the car stops suddenly and vice versa. This law is also known as the **law**

of inertia. These phenomena known as **inertia**

Inertia

Defn: inertia is a resistance an object has to change its state of motion

OR

Defn: inertia is the ability of resting body to resist motion (moving body in a straight line) when abruptly stopped

Types of Inertia

There are three types of Inertia include

i. Inertia of rest
ii. Inertia of motion
iii. Inertia of direction

Inertia of Rest

Defn: Inertia of rest is the resistance of a body to change its state of rest

Inertia of Motion

Defn: Inertia of motion is the resistance of a body to change its state of motion

Inertia of Direction

Defn: Inertia of direction is the resistance of a body to change its direction of motion

Therefore the Newton's first law of motion state that "***A body continues in its state of rest (uniform motion) in a straight line unless external force act on it***"

Where Inertia Law Experience

i. when the "daladala" suddenly starts, the passengers sitting or standing in the bus tend to fall backwards
ii. when the "daladala" suddenly stops, the passengers sitting or standing in the bus are thrown forward

Newton's Second Law of Motion

If the body in motion it possess quantity of motion which are equal. This quantity are called **momentum**

Defn: momentum is the product of mass and velocity of a body

p = mv

Where

P = Momentum
M = mass
V = velocity

SI unity of Momentum is **Kgm/s**

Due to the same initial and final momentum, Sir Isaac Newton conclude by the law which state that

"The rate of change momentum of a body is directly proportional to the applied force and takes place to the direction of applied force"

Mathematically

$\Delta P/t$ = rate of change momentum
f = force applied
$\Delta P/t \alpha f$
Since mass is a constant
$m\Delta v/t \alpha f$
But: $\Delta v = v-u$
$m(v-u)/t \alpha f$
But: $a = (v-u)/t$
$ma \alpha f$
Remove proportionality constant
$f \alpha ma$
$f = kma$
But: $k = 1$
$\mathbf{f = ma}$
From: $m\Delta v/t \alpha f$
Multiply by t both sides
Remove proportionality constant
$ft \alpha m\Delta v$
$ft = km\Delta v$
But: $k = 1$
$\mathbf{Ft = m\Delta v}$
ft is called **Impulse**, SI unit is **Kgm/s** or **Ns**

Application of Momentum and Impulse in Our Daily Life

i. While goalkeeper catching ball extends his hands forward so that he has enough room to let his hand move backward after impact to prevent bounce of ball
ii. A person jump from a high ground to the floor bends his knees upon making contact otherwise his/she leg break
iii. Glassware is wrapped in paper before packing to avoid breaking

Example, 01

A man of mass 1000 kg is moving with a velocity of 60 km/h. find its momentum

Data given

Mass of a car, m = 1000 kg
Velocity of a car, v = 60km/h = 16.7 m/s
Momentum of a car, p = ?

Solution

From: p = mv

P = 1000 x 16.7

P = 16700 Kgm/s

Example, 02

Suppose you exert an upward force of 10 N on a 3kg object. What will be the object acceleration?

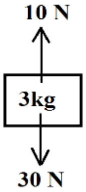
Data given

Force applied, f = 10 N

Mass of object, m = 3 kg = 30 N

Acceleration of an object, a = ?

Solution



Net force, f = force used = 30 - 10 = 20 N

From: f = ma – make a subject

a = f/m

a = 20/3

$a = 6.67\ m/s^2$

Example, 03

A tennis ball whose mass is 150 g is moving at a speed of 20 m/s. it is then brought to rest by one player in 0.05 s. find average force applied

Data given

Mass of tennis ball, m = 150 g = 0.15 kg

Initial velocity, u = 20 m/s

Final velocity = 0 m/s

Time taken, t = 0.05 s

Force applied/average, f = ?

Solution

From: f = ma

But: a = (v-u)/t

f = m(v-u)/t

f = 0.15(0-20)/0.05

f = 60 N

Conservation of Linear Momentum

Before we discuss about conservation of linear momentum let first study about collision

Collision

When two bodies collide, may loss kinetic energy or not. Example, of collision is

i. Two car collide at an intersection
ii. Player's foot strikes a soccer ball

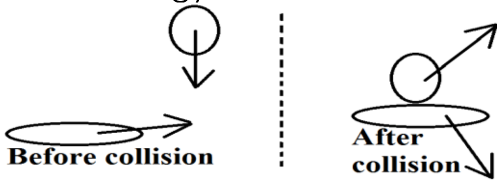
Types of Collisions

There are two types of collision include.

i. Elastic collisions
ii. Inelastic collisions

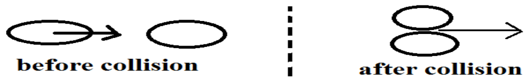
Elastic Collisions

Elastic collision is the one in which the objects exist in the same state after the collision as before it. There is no loss in kinetic energy



Inelastic Collisions

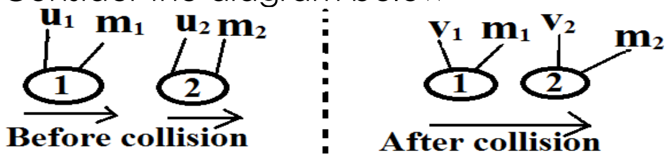
Inelastic collision is the one where the objects after the collision are not the same as before it. There is loss of kinetic energy



Principle of Conservation of Momentum

It state that ***"if there is no external force acting on a colliding system, total momentum before collision is equal to total momentum after collision body"***

Consider the diagram below



From the principle of momentum

Total momentum before = total momentum after

$$\mathbf{M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

Example, 04

A bullet of mass 10 g leaves a gun of mass 500 g with a velocity of 100 m/s. Find the velocity of the gun coil.

Data given

Mass of a gun, m_1 = 500 g

Mass of a bullet, m_2 = 10 g

Initial velocity of a gun, u_1 = 0 m/s

Initial velocity of a bullet, u_2 = 0 m/s

Final velocity of a gun, v_1 = 100 m/s

Final velocity of a bullet, v_2 = ?

Solution

From: $M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ – make v_1 subject

$M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1v_1 = (M_1u_1 + m_2u_2) - m_2v_2$ – divide by m_1 both sides
$v_1 = ((M_1u_1 + m_2u_2) - m_2v_2)/ m_1$
$v_1 = ((500 \times 0 + 10 \times 0) - 10 \times 100)/ 500$
$v_1 = ((0 + 0) - 1000)/ 500$
$v_1 = (0 - 1000)/500$
$v_1 = - 1000/500$
$\mathbf{v_1 = - 2\ m/s}$

Example, 05

A 4 kg object is moving to the right at 2 m/s when it collides elastically head on with a stationary 6 kg object as shown in the figure below after the collision, the velocity of the 6 kg object is 1.6 m/s to the right. Find

a) Velocity of 4 kg after the collision
b) Total kinetic energy before and after collision
c) Change in kinetic energy before and after collision

Data given

Mass of 4 kg, $m_1 = 4$ kg
Mass of 6 kg, $m_2 = 6$ kg
Initial velocity of 4 kg, $u_1 = 2$ m/s
Initial velocity of 6 kg, $u_2 = 0$ m/s
Final velocity of 4 kg, $v_1 = ?$
Final velocity of 6 kg, $v_2 = 1.6$ m/s

Solution

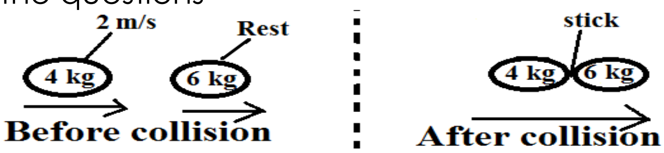
a) Velocity of 4 kg after the collision, $v_1 = ?$
From: $M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
Make v_1 subject
$M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$m_1v_1 = (M_1u_1 + m_2u_2) - m_2v_2$
Divide by m_1 both sides
$v_1 = ((M_1u_1 + m_2u_2) - m_2v_2)/ m_1$
$v_1 = ((4 \times 2 + 6 \times 0) - 6 \times 1.6)/ 4$
$v_1 = ((8 + 0) - 9.6)/ 4$
$v_1 = (8 - 9.6)/4$
$v_1 = - 1.6/4$
$\mathbf{v_1 = - 0.4\ m/s}$

b) Total kinetic energy before and after collision, $\mathbf{KE_t = KE_{tb} + KE_{ta}}$
Where:
KE_{tb} = Total kinetic energy before collision
KE_{ta} = Total kinetic energy after collision
But: $KE = (mv^2)/2$
$KE_{tb} = (m_1u_1^2)/2 + (m_2u_2^2)/2$
$KE_{tb} = (m_1v_1^2)/2 + (m_2v_2^2)/2$
$KE_{tb} = (4 \times 2^2)/2 + (6 \times 0^2)/2$
$KE_{tb} = (4 \times 4)/2 + (6 \times 0)/2$
$KE_{tb} = (16)/2 + (0)/2$
$KE_{tb} = 8 + 0$
$KE_{tb} = 8$ J
Then:
$KE_{ta} = (m_1v_1^2)/2 + (m_2v_2^2)/2$
$KE_{ta} = (m_1v_1^2)/2 + (m_2v_2^2)/2$
$KE_{ta} = (4 \times (- 0.4)^2)/2 + (6 \times 1.6^2)/2$
$KE_{ta} = (4 \times 0.16)/2 + (6 \times 2.56)/2$
$KE_{ta} = (0.64)/2 + (15.36)/2$
$KE_{ta} = 0.32 + 7.68$
$KE_{ta} = 8$ J
Therefore: $KE_t = KE_{tb} + KE_{ta}$
$KE_t = 8 + 8$
$\mathbf{KE_t = 16\ J}$

c) Change in kinetic energy before and after collision (ΔKE_t)
$\Delta KE_t = KE_{tb} - KE_{ta}$
$\Delta KE_t = 8 - 8$
$\underline{\Delta KE_t = 0\ J}$
Since change in KE = 0 J hence KE I conserved

Example, 06

Consider the diagram below and answer the questions



a) What their velocity after the collision
b) Total kinetic energy conserved

Data given

Mass of 4 kg, $m_1 = 4$ kg
Mass of 6 kg, $m_2 = 6$ kg
Initial velocity of 4 kg, $u_1 = 2$ m/s
Initial velocity of 6 kg, $u_2 = 0$ m/s
Final velocity of 4 kg, $v_1 = ?$
Final velocity of 6 kg, $v_2 = ?$
NB: Since they stick final velocity of 4 kg (v_1) and 6 kg (v_2) are equal, ($v_1 = v_2 = v = ?$)

Solution

a) Velocity after the collision, $v = ?$
From: $m_1u_1 + m_2u_2 = m_1v + m_2v$
Make v subject
$m_1u_1 + m_2u_2 = m_1v + m_2v$
$m_1u_1 + m_2u_2 = (m_1 + m_2)v$
$(m_1 + m_2)v = m_1u_1 + m_2u_2$
$(m_1 + m_2)v = m_1u_1 + m_2u_2$

Divide by ($m_1 + m_2$) both sides

$v = (m_1u_1 + m_2u_2)/ (m_1 + m_2)$

$v = (m_1u_1 + m_2u_2)/ (m_1 + m_2)$

$v = (4 \times 2 + 6 \times 0)/ (4 + 6)$

$v = (8 + 0)/ (4 + 6)$

$v = 8 / 10$

$\underline{v = 0.8 \text{ m/s}}$

b) Total kinetic energy before and after collision, KE_{tb} = Total kinetic energy before collision

KE_{ta} = Total kinetic energy after collision

But: $KE = (mv^2)/2$

$KE_{tb} = (m_1u_1^2)/2 + (m_2u_2^2)/2$

$KE_{tb} = (m_1v_1^2)/2 + (m_2v_2^2)/2$

$KE_{tb} = (4 \times 2^2)/2 + (6 \times 0^2)/2$

$KE_{tb} = (4 \times 4)/2 + (6 \times 0)/2$

$KE_{tb} = (16)/2 + (0)/2$

$KE_{tb} = 8 + 0$

$\mathbf{KE_{tb} = 8\ J}$

Then: $KE_{ta} = (m_1v_1^2)/2 + (m_2v_2^2)/2$

$KE_{ta} = (m_1v^2)/2 + (m_2v^2)/2$

$KE_{ta} = (m_1v^2)/2 + (m_2v^2)/2$

$KE_{ta} = (4 \times (0.8)^2)/2 + (6 \times 0.8^2)/2$

$KE_{ta} = (4 \times 0.64)/2 + (6 \times 0.64)/2$

$KE_{ta} = (2.56)/2 + (3.84)/2$

$KE_{ta} = 1.28 + 1.92$

$\underline{KE_{ta} = 3.2\ J}$

Therefore: $KE_t = KE_{tb} + KE_{ta}$

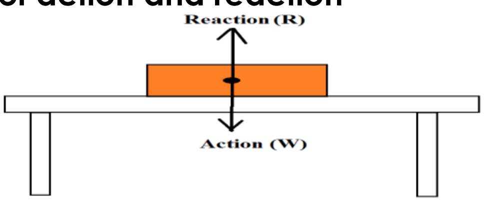
$KE_t = 8 + 3.2$

$\underline{KE_t = 11.2\ J}$

Since $KE_{tb} \neq KE_{ta}$ hence KE is not conserved

Newton's Third Law of Motion

It is always called the law of action and reaction. Consider the block when kept on a top of table it cannot move either downward or upward due to equal action (weight of block) and reaction (force pull block upward). Newton's third law is also known as the **law of reciprocal actions** or **law of action and reaction**



Since two force are equal Isaac Newton establish a law which state that

"***Every action is equal to opposite reaction***"

Application of Newton's Third Law

The following are some practical situations involving Newton's third law of motion

i. When a person throws a package out of a boat, the boat moves in opposite direction from the package. The package exerts an equal but opposite force on the person
ii. The function of rockets is based on Newton's third law of motion
iii. A falling object exerts upward force on the earth as much as the earth is exerting a downward force on the object
iv. A hammer driving a nail into block of wood
v. When the air is released from balloon it rushed out (action) tend to give reaction balloon so it acquire the motion
vi. Person standing on a platform exert normal reaction which is equal to the weight of a person
vii. An airplane pushes back on the air and the air pushes forward on the plane.
viii. The person firing the gun will feel the recoil (push back) when the bullet leaves the gun

Example, 07

A monkey has a mass of 50 kg and it climbs on a rope which can stand maximum tensional force of 600 N. when you expect the rope to break if Monkey:

a) Climb up with acceleration of 6 m/s^2
b) Climb up with uniform speed of 5 m/s
c) Fall down the rope will acceleration due to gravity
d) Fall down the rope will acceleration of 4 m/s^2

Data given:

Mass of monkey, m = 50 kg

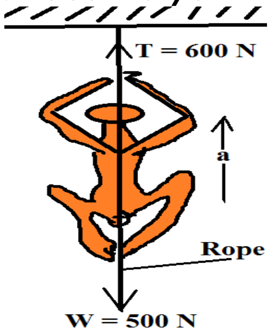
Maximum tensional of rope, T = 600 N

Weight of monkey, W = 500 N

Solution

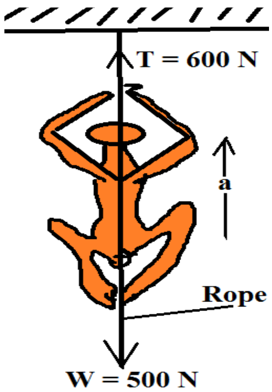
a) a = 6 m/s^2

Diagram



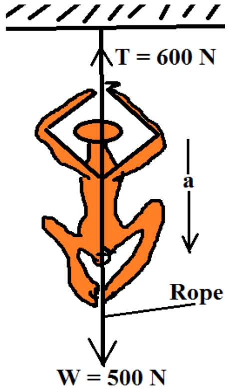
Weight due to motion, Wt = ma
Wt = 50 x 6 = 300
Reaction when monkey clip up, R = W + Wt
Therefore: From Newton third law of motion
R = W + Wt
R = 500 + 300
R = 800 N
Rope will break because R > T

b) v = 5 m/s for uniform speed a = 0 m/s^2
Diagram



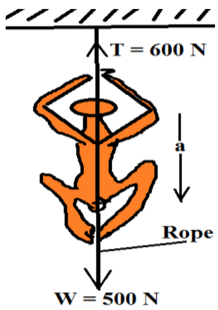
Weight due to motion, Wt = ma
Wt = 50 x 0 = 20
Reaction when monkey clip up, R = W + Wt
Therefore: From Newton third law of motion
R = W + Wt
R = 500 + 0
R = 500 N
Rope will not break because R < T

c) Fall a = -g = -10 m/s^2
Diagram



Weight due to motion, Wt = ma
Wt = 50 x -10 = -500
Reaction when monkey clip down, R = W + Wt
Therefore: From Newton third law of motion
R = W + Wt
R = 500 + -500
R = 500 - 500
R = 0 N
Rope will not break because R < T

d) a = -4 m/s^2
Diagram



Weight due to motion, Wt = ma
Wt = 50 x -4 = -200
Reaction when monkey clip down, R = W + Wt
Therefore:
From Newton third law of motion
R = W + Wt
R = 500 + -200
R = 500 - 200
R = 300 N
Rope will not break because R < T

Example, 08
A driver jumps from a plane on an air cushion. His speed is 24 m/s. the average force of the cushion on the body while he is being stopped is 9400 N. if his mass is 70 kg. Calculate the distance he will sink into the cushion
Data given
Initial velocity of driver, u = 24 m/s

Final velocity of driver, v = 0 m/s
Average force, f = 9400 N
Mass of driver, m = 70 kg
Acceleration of driver, a = ?
Distance sink into the cushion, s = ?

Solution:

First find a = ?
From: f = ma – make a subject
f = ma – divide by m both sides
ma = f
a = f/m
a = 9400/70
a = 134.3 m/s^2
Second find s = ?
From: $v^2 = u^2 + 2as$ = makes subject
$u^2 + 2as = v^2$
$2as = v^2 - u^2$ – divide by 2a both sides
$2as = (v^2 - u^2)$
$s = (v^2 - u^2)/2a$
$s = (0^2 - 24^2)/(2 \times 134.3)$
s = (0 - 576)/268.6
s = - 576/268.6
<u>s = - 2.15 m</u>

Example, 09

A man stand in a lift holds a spring balance with load of 5 kg suspended from it. What is the reading on the spring if the lift is descending with an acceleration of 3.8 m/s^2?

Data given

Mass of load in spring balance, m = 5 kg
Acceleration due to gravity, g = 10 m/s^2
Acceleration of the load, a = -3.8 m/s^2
Weight of the load, w = m x g = 5 x 10 = 50 N
Weight due to motion, Wt = ma = 5 x -3.8 = -200

Solution:

Reading on spring balance when descending, f = ?

Therefore:

From Newton third law of motion
f = W + Wt
f = 50 + -19
f = 50 - 19
<u>f = 31 N</u>

Example, 10

A 3 kg hammer is used to drive a nail into a piece of wood. If at the time of impact the hammer's speed is 5 m/s and it drive the nail 1 cm into the wood. Calculate

a) The acceleration
b) Force exerted on the nail by hammer
c) Time of impact
d) The impulse

Data given

Mass of hammer, m = 3 kg
Initial velocity (speed), u = 5 m/s
Final velocity (speed), v = o m/s
Distance covered by nail, s = 1 cm = 0.1 m

a) The acceleration, a = ?
   From: $v^2 = u^2 + 2as$ - make a subject
   $u^2 + 2as = v^2$
   $2as = v^2 - u^2$ – divide by 2s both sides
   $2as = (v^2 - u^2)$
   $a = (v^2 - u^2)/2s$
   $a = (0^2 - 5^2)/(2 \times 0.1)$
   a = (0 - 25)/0.2
   a = - 25/0.2
   <u>a = - 125 m</u>

b) Force exerted, f = ?
   From: f = ma
   f = 3 x -125
   f = 3 x -125
   <u>f = -375 N</u>

c) Time of impact, t = ?
   From: at = v – u
   at = v - u – make t subject
   at = v - u – divide by a both sides
   at = (v - u)
   t = (v - u)/a
   t = (0- 5)/-125
   t = - 5/-125
   t = 5/125
   t = 1/25
   <u>t = 0.04</u>

d) The impulse, I = ft = ?
   From: ft = mΔv
   But: mΔv =I = mv – mu = ft
   I = mv - mu
   I = m(v – u)
   I = 3(0 – 5)
   I = 3 x -5
   <u>I = -15 N</u>

Negative sign means the nail exert equal force but in opposite to hammer

Temperature

Defn: temperature is the degree of coldness or hotness of a body at a particular time

The device used to measure temperature is called **thermometer**

The SI unit of temperature is **Kelvin, K**. Other unit is **Celsius**, **°C** or **Fahrenheit**, **°F**

Equivalent:

i. K = 273 + θ°C
ii. F =($^9/_5$)θ°C + 32°C

NB:
Kelvin scale is called **absolute or thermodynamic scale.**

Measurement of Temperature

Temperature is measured by thermometer on physical properties that change linearly with temperature to give temperature readings. Physical properties of a thermometer include;

i. Expansion of liquid(mercury or alcohol) when heated
ii. Expansion of a compound strip of two metals
iii. Thermoelectric property change in which when junction of two different metals is heated an electric current is generated
iv. Change of resistance of a wire e.g. platinum resistance thermometer

NB:

i. The liquid used in thermometer is called **thermometric liquid**
ii. Temperature of the body is measured in degree centigrade, °C

Thermometric Scales

There are two scales of thermometer include;

i. Celsius or Centigrade Scale
ii. Fahrenheit Scale

Celsius or Centigrade Scale

This scale has 100 divisions between the upper and lower standard points.
This scale was introduced by a Swedish astronomer **Celsius** and is known after his name. Each division on this scale is called **one degree centigrade or one degree Celsius** and is written as 1°C.
More sensitive thermometers have 200 divisions between standard points and each division is equal to 1/2 °C. Sometimes these thermometers are called **half °C thermometers**.

Fahrenheit Scale

This scale was introduced by **Fahrenheit**. On this scale 32°F represents the melting point of ice and 212°F the steam point. Zero is marked 32°F below the ice point. The length in between the standard points is divided to 180 equal parts. Each division on this scale is called **1°F**. This scale is widely used for **meteorological** and **clinical purposes**.

Diagram

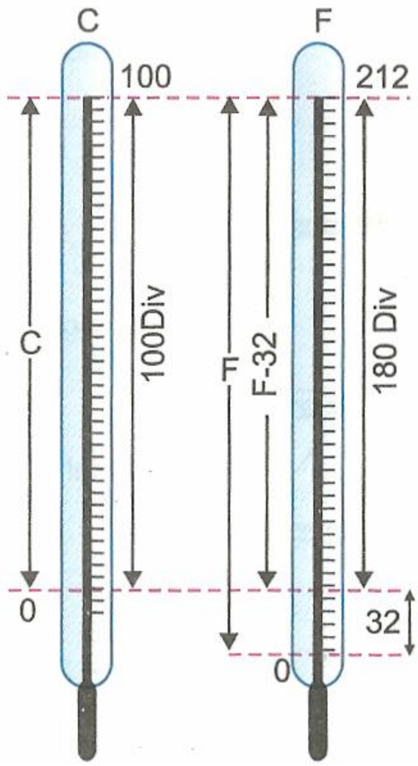


Diagram show the thermometric scale

Choice of Thermometric Liquid

A thermometric liquid must have the following properties

i. It should have low specific heat capacity, so that it rapidly attains the temperature of a given substance, without absorbing any appreciable amount of heat energy from it.
ii. It should have a uniform rate of expansion, such that a linear scale can be easy marked.

iii. It should have large expansion for a unit degree rise in temperature, so that its expansion is visible to the unaided eye.
iv. It should have a high boiling point and low freezing point, so that a wide range of temperature changes could be recorded by a single thermometer.
v. It should be shiny and opaque so that it is clearly visible in glass.
vi. It should not stick to the sides of the glass tube.
vii. It should exert low vapour pressure.
viii. It should be a good conductor of heat.
ix. It should be easily available in pure state.

Why Mercury Used In Thermometer

i. It has low specific heat capacity.
ii. Its expansion is uniform.
iii. It has a high boiling point (357°C) and low melting point (-39°C).
iv. It is opaque and shining.
v. It does not stick to the sides of the glass.
vi. It exerts very low vapour pressure.
vii. It is a good conductor of heat.
viii. It is easily available in pure state.

Disadvantages of Mercury as Thermometric Liquid

i. Its expansion is not very large for 1°C rise in temperature and hence, very small changes in temperature cannot be measured.
ii. It freezes below -39°C and hence, it cannot be used in very cold regions like Antarctic or Arctic.

Why Alcohol Used In Thermometer

i. Its freezing point is below -100°C and hence, can record very low temperatures.
ii. Its expansion per degree centigrade rise in temperature is very large and hence, very sensitive thermometers can be made with it.
iii. It can be coloured brightly and hence, is easily visible.

Disadvantages of Alcohol as Thermometric Liquid

i. It cannot be used for measuring high temperatures as alcohol boils at 78°C.
ii. It has high specific heat capacity.
iii. It sticks to the sides of glass.
iv. It has a high vapour pressure.
v. It is not a good conductor of heat.
vi. It is difficult to obtain pure alcohol.

Disadvantages of Water as Thermometric Liquid

i. It has the highest specific heat capacity (4.2 J/gK).
ii. Its expansion is not uniform.
iii. Its expansion per degree rise in temperature is very small
iv. Its melting point is 0°C and boiling point 100°C. Thus, the temperatures less than 0°C and more than 100°C cannot t measured.
v. It is transparent/colourless
vi. It sticks to the sides of glass.
vii. It evaporates under vacuum conditions.
viii. It is a bad conductor of heat.
ix. It cannot be obtained in cent per cent pure form easily.

Thermometer Fundamental Interval

Defn: Fundamental interval of a thermometer is the different between the upper fixed point and the lower fixed point of the thermometer.

Example,

The upper fixed point of water is 100 °C
The lower fixed point of water is 0 °C

Types of Thermometer

i. Mercury in glass thermometer
ii. Alcohol in glass thermometer
iii. maximum and minimum thermometer
iv. thermocouple thermometer
v. Thermistor thermometer

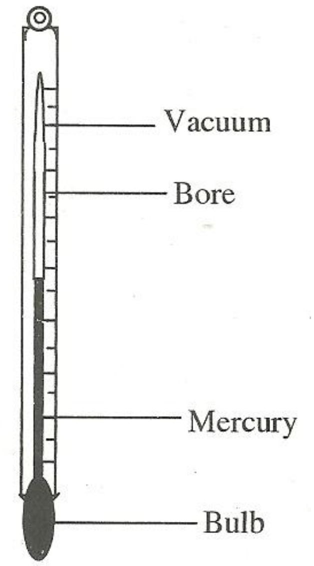
Liquid in Glass Thermometer

The working of this kind of thermometer is contraction and expansion of the liquid inside the thermometer. Always mercury and alcohol used as liquid inside thermometer so we have two types of liquid in glass thermometer

i. Mercury in glass thermometer
ii. Alcohol in glass thermometer

Mode of Action

Consider the diagram below



The thermometric liquid expands with increase of temperature and tends to raise the height of the thermometric liquid through the bore and vice versa

NB:

i. The liquid used in thermometer is called **thermometric liquid**
ii. Mercury in glass also called **clinical thermometer**
iii. Clinical thermometer it consists **Constriction** near the reservoir to kept mercury stationary/rest after the thermometer is removed

Limitation of Clinical Thermometer

i. They do not reflect the core temperature of the body
ii. May spread infection if not properly sterilized
iii. They are delicate so can easily breaks

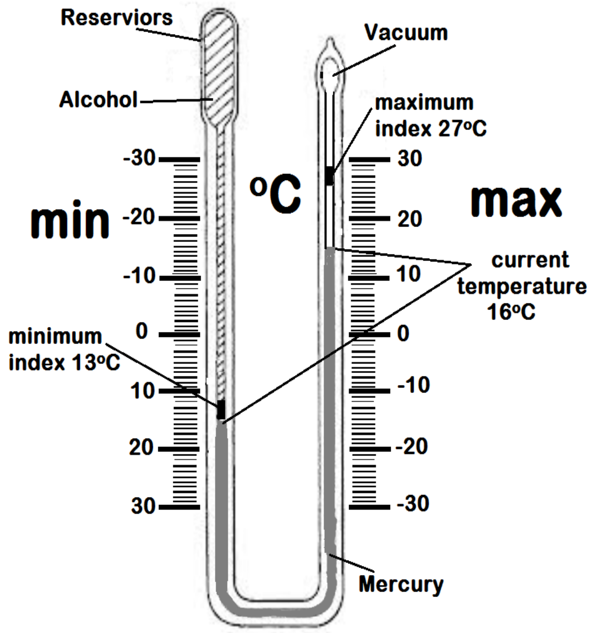
Precautions Taken When Clinical Thermometer Used

i. Don't drop or subject it to heavy shock
ii. Don't bend/bite the thermometer
iii. Damage/broken thermometer can cause injury
iv. Keep it away from unsupervised children
v. Sterilized after use to avoid contamination

Maximum and Minimum Thermometer

Maximum and minimum thermometer is also called **six's thermometer.**

Diagram:



It is used to record the highest and lowest temperatures over a period of time. It consist two thermometric liquids/fluids which is alcohol and mercury. It consist a small piece of steel called an i**ndex** (**marker**)

When mercury/alcohol expand index remain in position, to reset index on mercury (maximum thermometer) magnetic is used.

Sustainable Energy Source

Defn: sustainable energy source is the natural resource that used in the production of electricity without destroying the environment.

Types of Sources of Energy

There are two types of sources of energy namely:

i. Renewable sources
ii. Non- renewable sources

Renewable Sources

These are the energy sources, which can be turned into use again after being used. For Example, **sun**, **water**, **wind** and **fossils**

Non- Renewable Sources

These are the energy sources, which cannot be turned into use again. For Example, s: **oil**, **natural gas** and **charcoal**

Sustainable Sources of Energy

This source occurs naturally and readily available, these include the following;

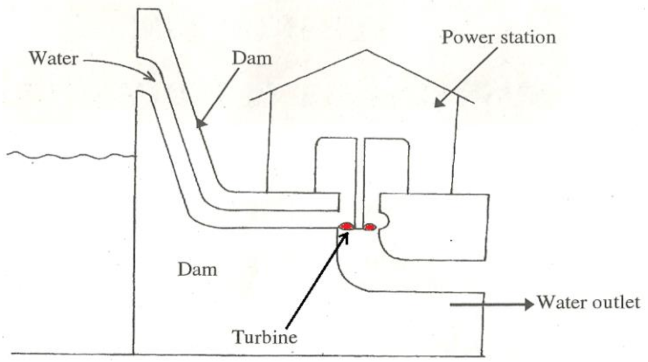
i. Hydroelectric energy
ii. Solar energy
iii. Wind energy
iv. Sea wave energy
v. Geothermal energy
vi. Tidal energy

Hydroelectric Energy

Hydroelectric energy is the generation of electricity using flowing water to drive a turbine which powers a generator. Also is called water energy

How Generated Water Energy

Consider the diagram below;



When the water comes from dam which constructed to hold water at a higher ground used to drive the turbine in order to generate electricity

Characteristics of Water Energy

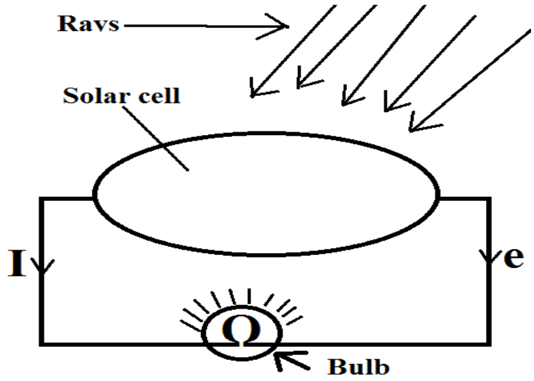
i. reliable
ii. readily available in many places
iii. environmental friendly
iv. Can be constantly generated

Advantage of Using Water Energy

i. A industrial work
ii. lighting
iii. heating and cooking
iv. Running hospital equipment.

Solar Energy

Solar energy is the radiant energy emitted by the sun. Solar energy converted by solar cells (photovoltaic or photoelectric cells). Solar cell is made of silicon; calcium and other element where solar radiation falls on it cause it to generate electricity



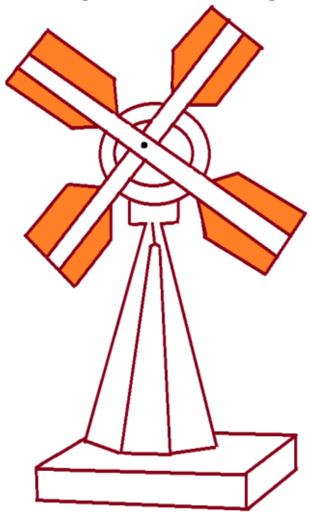
The main surface of a solar panel (several thousand cells) is dull black to enhances the absorption rate of the radiant energy from the sun

NB:

The energy from the sun is the sources of all energy on the earth

Wind Energy

Wind energy can be converted into electricity by building a tall tower with a large propeller on top called **windmill.**



Country like Denmark, Spain and German use wind energy to produce electricity

Characteristics of Wind Energy

i. is not reliable
ii. is harnessed using noisy turbines
iii. Requires large wind sites to put up the turbines.

Advantage of Using Wind Energy

i. Wind energy is used in moving ships, boats, pumping water and grinding corn.
ii. It can also be used to drive generators to produce electricity
iii. It is used to cool land
iv. It used to cool sea
v. It is used by mechanical to remove dust in car parties

Sea Wave Energy

Sea water is the form of energy in which caused by disturbing water particles resulting progress propagation from one to another point

Causes of Sea Wave Energy

Sea wave energy is as a result of wind blowing across the sea

Harvest of Sea Wave Energy

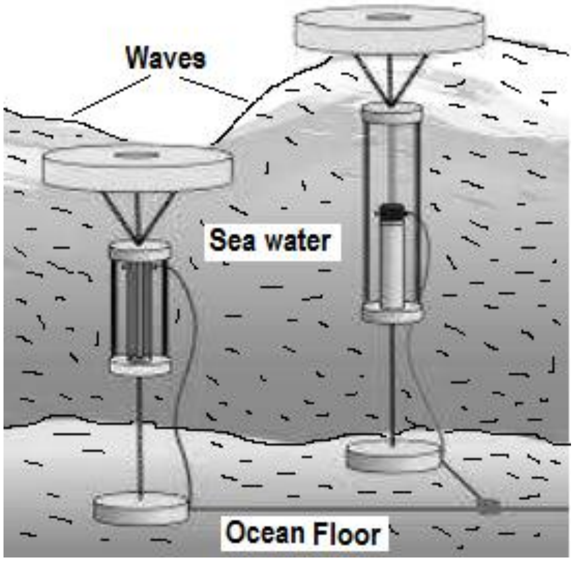
It can harvested by the following methods, includes

i. Point absorber buoys
ii. Surface attenuators
iii. Overtopping devices

Point Absorber Buoys

Point absorber buoys is the device which floats on sea water

Diagram:



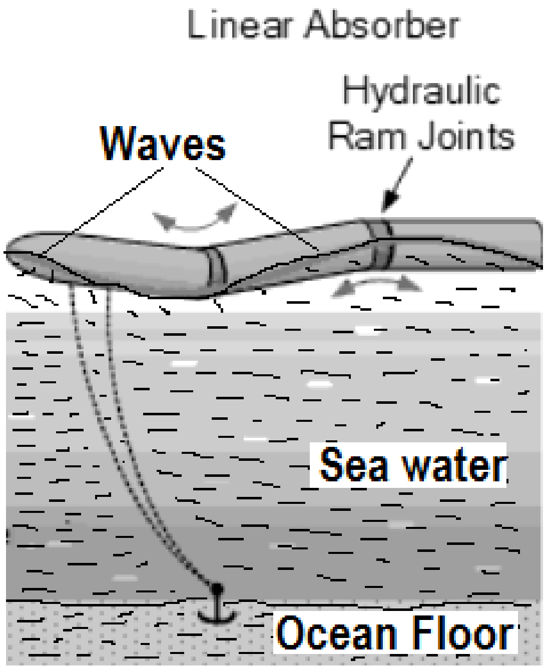
Mechanism

A buoy is a device that floats on the surface of water. Buoys use the rise and fall of swells (waves) to drive hydraulic pumps and generate electricity

Surface Attenuators

Surface attenuators is the device which floats on sea water

Diagram:



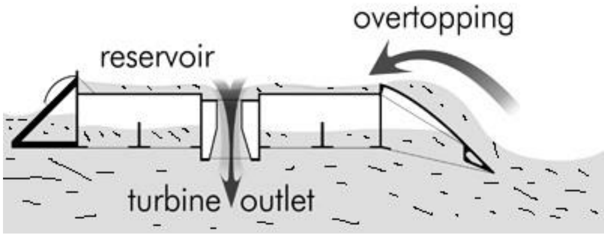
Mechanism

This consists of multiple floating segments connected to one another and is oriented perpendicular to incoming waves. A flexing motion is created by swells that drive hydraulic pumps to generate electricity

Overtopping Devices

Overtopping devices is the device which floats on sea water

Diagram:



Mechanism

During waves the sea water overtopping on reservoir which drop down through turbine outlet results rotation of turbine which generates electricity

Challenge of Harvesting Sea Wave Energy

i. It is very expensive
ii. Device can wear due to rusting
iii. Device can damage due to storm created by waves or tides

Tides

Defn: Tides energy is the rising and falling of the ocean level

Causes of Tides

It causes by the gravitational pull of the moon and to some extent the sun

Tides Energy

Defn: Tides energy is the energy results from the rising and falling of the ocean level. The change of water levels that the tides produce can be used as an energy source.

Harvest of Tides Energy

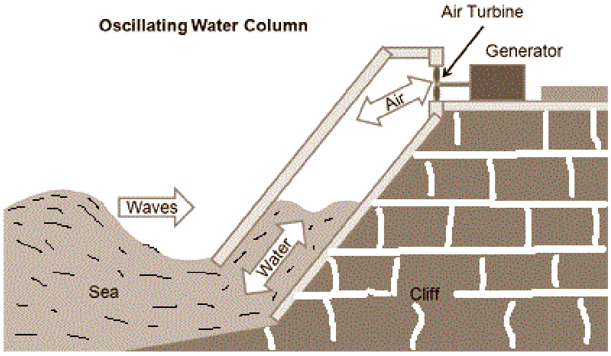
It can harvested by the following methods, includes

i. Oscillating water columns
ii. Bay dam

Oscillating Water Columns

The tidal power plants are constructed along a costal where rise and fall of water can enter and leave a column

Diagram:



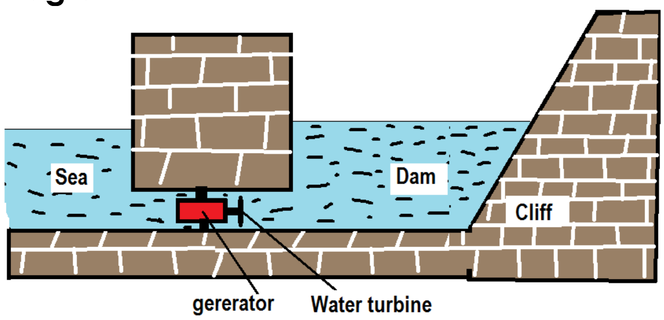
Mechanism

i. During high tides water compress/push air molecules in the column which creates high pressure than atmosphere pressure results air particles blowing away from the column therefore rotates generator in which generates electricity
ii. During low tides water pull air molecules in the column which creates low pressure than atmosphere pressure results air particles blowing inside the column therefore rotates generator in which generates electricity

Bay Dam

The tidal power plants are constructed near the narrow bays, where the water level rises up and then falls down appreciably during the tides

Diagram:



Mechanism

i. During the high tide, the sea water is allowed to pass through the dam walls by opening the gates, therefore the sea water moves from the sea to the dam through turbine which rotates the turbine in which generates electricity
ii. When the level of water tends to fall during low tide by opening the gates, therefore the sea water moves from the dam to the sea through turbine which rotates the turbine in which generates electricity

Challenge of Harvesting Tides Energy

i. It is very expensive
ii. Device can wear due to rusting
iii. Device can damage due to storm created by tides

Geothermal Energy

Geothermal comes from two words

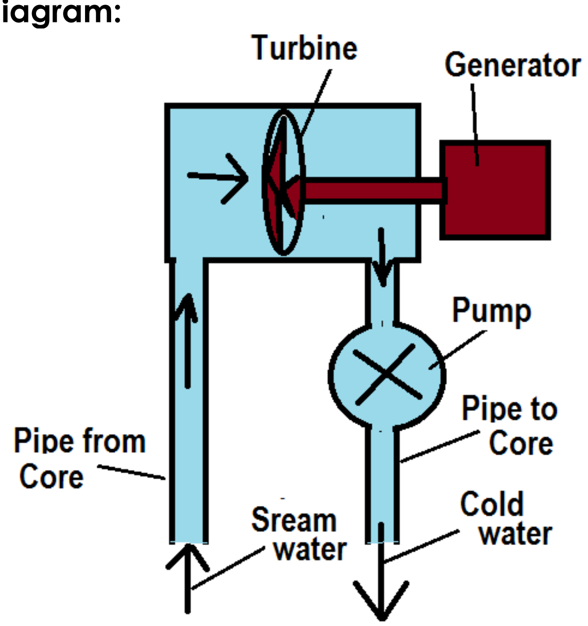
i. Geo means earth
ii. Thermal means Heat

Defn: geothermal energy is the energy generated by the flow of heat from the earth core

Harvest Of Geothermal Energy

The heat energy from the earth can be converted to electrical. Consider the diagram that follows

Diagram:



Mechanism

By pumping water to the hotter rocks, steam drawn back to generate electricity by rotates a turbine which rotates a turbine which rotates a generator to produce electricity

NB:

The turbine and propeller where are inform of mechanical energy rotate dynamo or generator which produce electricity

Energy Cycle

i. All energy comes from the sun.
ii. For instance, the solar cell generates electricity using light energy which has just arrived from the sun.
iii. energy from the sun also makes the water cycle work It evaporates water from the sea and this water later falls as rain which fills up rivers and lakes in which hydroelectric power stations capture energy.
iv. Wind is caused by the unequal heating of the earth by the sun. Wind energy therefore is a derivative of solar energy.
v. All green plants use the energy from the sun during the process of photosynthesis. They store chemical energy in form of starch. So the energy obtain from a wood fire originally comes from the sun.
vi. This is similar to the fossil fuels formed hundreds of millions of years ago. Plants died and became compressed to form coal.

Application of Vectors

Scalar Quantities

Defn: scalar quantity is the any physical quantity that has magnitude only. Example, **time**, **distance**, **temperature**, **energy**, **speed**, **mass**, **area**, **volume**, **density**, **electric current**, **specific heat capacity** etc

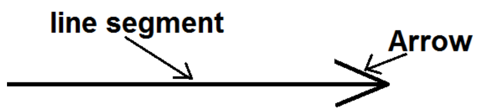
Vector Quantities

Defn: vector quantity is the any physical quantity that has both magnitude and direction. Example, **force**, **displacement**, **velocity**, **momentum**, **acceleration**, etc

Vector Arithmetic

Scalar quantity can be added, multiplied, divided or subtracted. Example, if you have two liquid in different measuring cylinder let say fist one contain 10 cm^3 and second contain $20cm^3$ if you asked to find total volume you must add to obtain total volume

Vector quantity can be represented on a diagram by a directed line segment, consider the diagram below



The length of line segment represents the magnitude and the arrow represents the direction

NB:

i. The direction can be represented by using compass direction
ii. Two vector are equal if the magnitude and direction the same.
iii. The triangle method and parallelogram method are used to adding two vectors.
iv. The vector we get after the adding of two or more vectors is called **resultant vector**
v. Resultant vector can be added by mathematical or graphical/drawing
vi. Resultant vector is measured as an anticlockwise angle of rotation from due east

Adding By Mathematical Method

When adding two or more vectors by mathematical method mathematical formula used to sum up vectors. Example, Pythagoras' theorem, trigonometrically etc

Adding By Graphical Method

The following are the steps followed when adding two or more vectors by graphical method

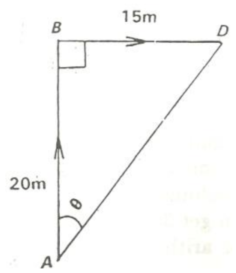
i. Choose a suitable scale and write it down on a graph paper
ii. Pick starting and draw the first vector to scale direction stated (indicate the magnitude and direction)
iii. Starting from the head of the first vector, draw the second vector to scale in the started direction until all given vectors finished
iv. Draw the line to connect tail of the first drawn vector and the head of the last vector. This is called resultant vector
v. Measure the length of the resultant vector and convert to actual unit
vi. Determine the direction of vector

Example,

Suppose a man walks starting from point A, a distance of 20m due north and then walks 15m due east. Find his new position from A

Solution

i. Using a scale of 1cm to represent 5 m
ii. Draw a vector AB 4cm due north.
iii. From B draw BD 3cm due east.
iv. Join A and D point
   The resultant diagram is a triangle as shown below



v. Measure the length of AD
   AD = 5 cm
   Change to actual unit
   1cm = 5 m
   5 cm = ?
   Cross multiplication you get 25 m
vi. Determine the direction of vector
   $\tan\theta = 15/20 = 2/4 = 0.75$
   $\Theta = 36^0\ 51'$

Therefore position of D is represented by vector AD of magnitude 25 m at an angle of 36^0 51' east of north

The Triangle Method/Triangle Law

The triangle law is appropriate when adding two vector quantities. The law state that

"If three forces are in equilibrium and that two of the forces are represented in magnitude and direction by two sides of a triangle, then the third side of the triangle represents the resultant of the two forces"

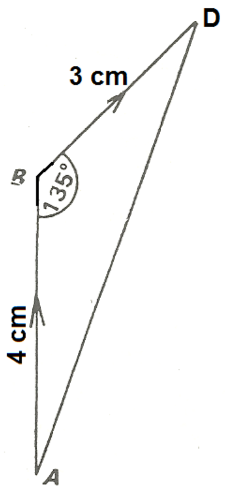
Example,

A brick is pulled by a force of 4N acting northward and another force of 3N acting north-east. Find the resultant of these two forces.

Solution

I/ Using a scale of 1cm to represent 1 N
II/ Draw a vector AB 4cm due north.
III/ From B draw BD 3cm at 45^0
IV/ Join A and D point

The resultant diagram is a triangle as shown below



V/ Measure the length of AD
AD = 6.5 cm
Change to actual unit
1cm = 1 N
6.5 cm = ?

Cross multiplication you get 6.5 N

Therefore the resultant of these two forces 6.5 N

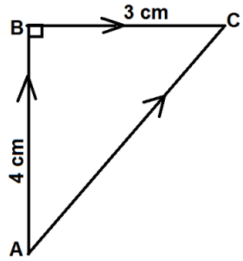
Example,

Two forces, one 8 N and the other 6 N, are acting on a body. Given that the two forces are acting perpendicularly to each other, find the magnitude of the third force which would just counter the two forces.

Solution

I/ Using a scale of 1cm to represent 2 N
II/ Draw a vector AB 4cm due north.
III/ From B draw BC 3cm at 90^0
IV/ Join A and C point

The resultant diagram is a triangle as shown below



V/ Measure the length of AC
AD = 5 cm
Change to actual unit
1cm = 2 N
5 cm = ?

Cross multiplication you get 10 N

Therefore magnitude of third force is 10 N

Parallelogram Method

The parallelogram law of vector is applicable when adding two vector quantities. The law state that

"If two forces/vectors are represented by the two sides given and they include angle between them, then resultant of the two forces/vectors will be represented by the diagonal from their common point of a parallelogram formed by the two forces/vectors"

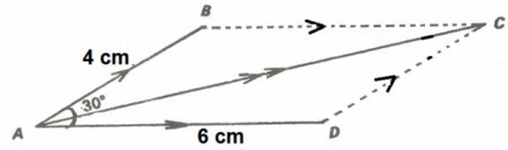
Example,

Two forces AB and AD of magnitude 40 N and 60 N respective are pulling a body on horizontal table. If the two forces makes an angle 30^0 between them, find the resultant force on the, body.

Solution

I/ Using a scale of 1cm to represent 10 N
II/ Draw a vector AD 6 cm horizontal from point A
III/ From point A draw AB 3 cm at 30^0 from vector AD
IV/ Complete the parallelogram ABCD
V/ Join A and c point

The resultant diagram is a triangle as shown below



VI/ Measure the length of Ac

Ac = 9.7 cm

Change to actual unit

1cm = 10 N

9.7 cm = ?

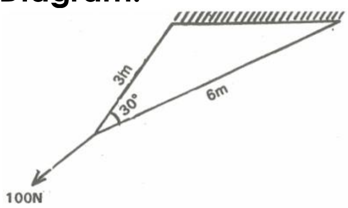
Cross multiplication you get 97 N

Therefore the resultant of these two forces 6.5 N

Example,

Two ropes of 3 m and 6 m long are tied to a ceiling and their free ends are pulled by a force of 100 N as shown in the figure below. Find the tensions in each rope if they make angle 30° between them.

Diagram:



Solution

I/ Using a scale of 1cm to represent 1 m

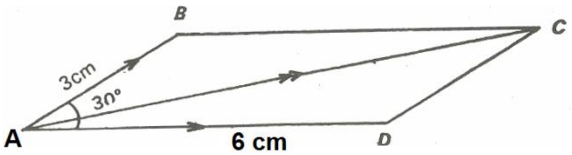
II/ Draw a vector AD 6 cm horizontal from point A

III/ From point A draw AB 3 cm at 30^0 from vector AD

IV/ Complete the parallelogram ABCD

V/ Join A and c point

The resultant diagram is a triangle as shown below



VI/ Measure the length of Ac

Ac = 8.7 cm

AC is the equal to 100 N because action is equal to opposite reaction, Ac = 8.7 cm =100 N

Now:

Tension at 3 cm calculated by:

8.7 cm = 100 N

3 cm = ?

Cross multiplication you get 34.5 N

Therefore the Tension at 3 cm is 34.50N

Then:

Tension at 6 cm calculated by:

8.7 cm = 100 N

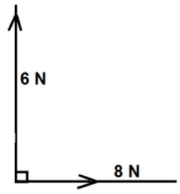
6 cm = ?

Cross multiplication you get 69 N

Therefore the Tension at 6 cm is 69 N

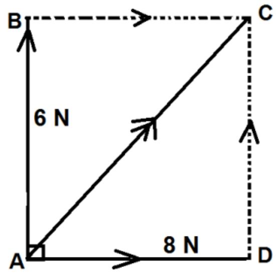
Example,

Find the resultant force when two forces act as shown in the figure below.



Solution

Joining to line to get resultant force



I/ Using a scale of 1cm to represent 1 N

II/ Draw a vector AD 8 cm horizontal from point A

III/ From point A draw AB 6 cm at 90^0 from vector AD

IV/ Complete the parallelogram ABCD

V/ Measure the length of Ac

Ac = 10 cm

Change to actual unit

1cm = 1 N

10 cm = ?

Cross multiplication you get 10 N

Therefore the resultant of these two forces 10 N

Example,

Find the resultant force, F, when two forces,

9 N and 15 N, act on an object with an angle of 60^0 between them.

Solution

I/ Using a scale of 1cm to represent 3 N

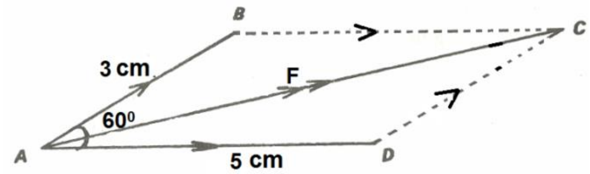
II/ Draw a vector AD 5 cm horizontal from point A

III/ From point A draw AB 3 cm at 60^0 from vector AD

IV/ Complete the parallelogram ABCD

V/ Join A and c point

The resultant diagram is a triangle as shown below



VI/ Measure the length of Ac

Ac = 7 cm

Change to actual unit

1cm = 3 N

7 cm = ?

Cross multiplication you get 21 N

Therefore the resultant force, F is 21 N

Relative Velocity

Defn: Relative velocity is the velocity of a body with respective to another moving or stationary body.

Or

Defn: Relative velocity is the velocity of a body with relative to the moving observer.

Nb:

→ Velocity of one object let say V_A respect another object let say V_B is denoted by symbol V_{AB}.

→ if all object moving to the same direction, it seems to observe low speed, therefore we minus two velocity of moving body, $(-V_B)$

$V_{AB} = V_A + (-V_B)$

$\mathbf{V_{AB} = V_A - V_B}$

→ if all object moving to the opposite direction, it seems to observe high speed, therefore we plus two velocity of moving body, $(+V_B)$

$V_{AB} = V_A + (+V_B)$

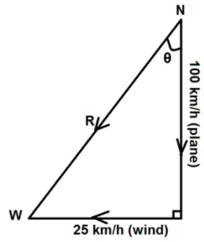
$\mathbf{V_{AB} = V_A + V_B}$

→ relative velocity also can be calculated by triangle method and by parallelogram methods

Example,

A plane travelling at a velocity of 100 km/h to the South encounters a side wind blowing at 25 km/h to the West. What is its velocity relative to an observer on the ground?

Solution:



By using Pythagoras' theorem,

$R^2 = 25^2 + 100^2$

$R^2 = 625 + 10000$

$R^2 = 10625$

$\sqrt{R^2} = \sqrt{10625}$

R = 103.1km/h

Direction of resultant

Cos θ = Adj/Hyp

Cos θ = 100/103.1

Cos θ = 0.9699

θ = 14^0 – clockwise to the east with the southward direction.

Since: Resultant vector is measured as an anticlockwise angle of rotation from due east

θ = 270^0 - 14^0 – anticlockwise to the east

θ = 256^0

Example,

Car A is moving with a velocity of 20 m/s while car B is moving with a velocity of 30 m/s.

Calculate the velocity of car B relative to car A if:

{a} they are moving in the same direction

{b} They are moving in the opposite directions.

Data given

Velocity of Car A, V_A = 20 m/s

Velocity of Car B, V_B = 30 m/s

Relative velocity, V_{BA} = ?

Solution:

{a} they are moving in the same direction

From: $V_{BA} = V_B - V_A$

$V_{BA} = 30 - 20$

V_{BA} = 10 m/s

{b} They are moving in the opposite directions.

From: $V_{BA} = V_B + V_A$

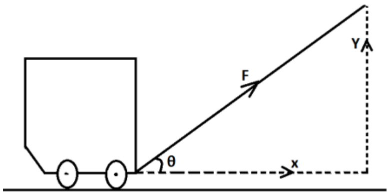
$V_{BA} = 30 + 20$

V_{BA} = 50 m/s

Resolution of the Vector

As we study at trigonometrically ration when we have values of hypotenuse and angle formed with horizontal we can calculate **vertical component** and **horizontal component.**

Consider the diagram below where the toy car pulls at a certain angle but it seems to move horizontally due to horizontal force/vector, not only that but vertical force/vector are formed

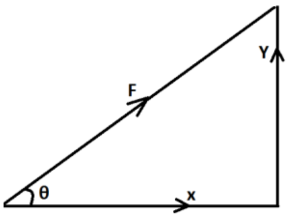


From the diagram:

Horizontal force/vector = x

Vertical force/vector = y

Extract the triangle from the above diagram



Horizontal force/vector is given by the formula

From:

Cos θ = X/F – multiply for F both sides you get

X = FCos θ

Vertical force/vector is given by the formula

From:

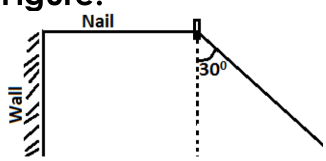
Sin θ = Y/F – multiply for F both sides you get

Y = FSin θ

Example,

A nail is being pulled using a string from a wall. The string forms an angle of 30° with the normal. If the force being used is 10 N, part of the force will tend to bend the nail while the other part will try to pull it out.

Figure:



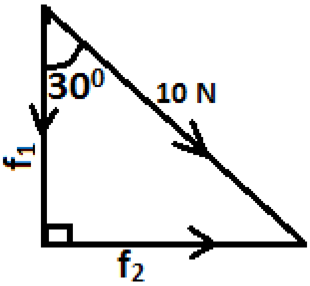
What the magnitude of the force:

{a} Tend to bend the nails?

{b} Tend to pull the nails out?

Solution:

Kept the information above into vector form



{a} Force tends to bend the nails, f_1 = ?

$f_1 = 10 \times \cos 30^0$

$f_1 = 10 \times 0.866$

$f_1 = 8.66$ N

{b} Force tends to pull the nails out, f_2 = ?

$F_2 = 10 \times \sin 30^0$

$F_2 = 10 \times 0.5$

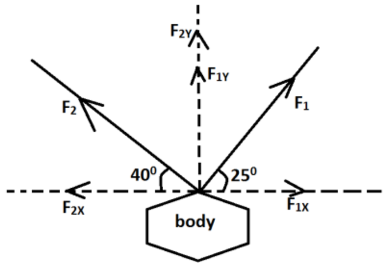
$F_2 = 5.0$ N

Example,

A body is being acted on by two forces: F_1 = 18 N acting at an angle of 25° and F_2 = 30 N acting at 140° from due East. Find the resultant of the two forces, F, by separating the forces into x- and y-components.

Solution:

Draw the diagram first



First find F_{1X} and F_{2X}

Where:

$F_1 = 18$ N

$F_2 = 30$ N

From: X = F. Cos θ

$F_{1X} = F_1$. Cos 25

$F_{1X} = 18 \times \text{Cos } 25$

$F_{1X} = 18 \times 0.9063$

$F_{1X} = 16.31$ N - toward east

Then:

$F_{2X} = F_1$. Cos 40

$F_{2X} = 30 \times \text{Cos } 40$

$F_{2X} = 30 \times 0.7660$

F_{2X} = 22.98 N - toward west

Assume the wanted direction is east so the direction of force to west will be negative. Find their net force, F_X = ?

$F_X = F_{1X} + F_{2X}$

$F_X = 16.31 + (-22.98)$

$F_X = 16.31 - 22.98$

F_X = - 6.67 N - toward west

Second find F_{1y} and F_{2y}

Where:

F_1 = 18 N

F_2 = 30 N

From: Y = F. Sin θ

$F_{1Y} = F_1$. Sin 25

F_{1Y} = 18 x Sin 25

F_{1Y} = 18 x 0.4226

F_{1Y} = 7.6 N - toward north

Then:

$F_{2Y} = F_1$. Sin 40

F_{2Y} = 30 x Sin 40

F_{2Y} = 30 x 0.6428

F_{2Y} = 19.28 N - toward north

Assume the wanted direction is north. Find their net force, F_Y = ?

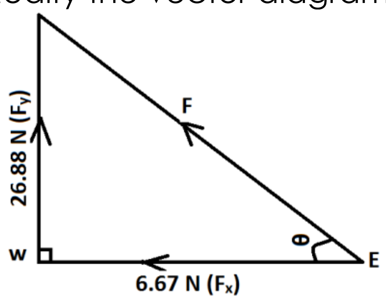
$F_Y = F_{1Y} + F_{2Y}$

$F_Y = 7.6 + 19.28$

$F_Y = 7.6 + 19.28$

F_Y = 26.88 N - toward north

Modify the vector diagram



Lastly find the resultant of the two forces, F = ?

By using Pythagoras' theorem,

$R^2 = 26.88^2 + (-6.67^2)$

R = 27.70 N

Get the direction

Tan θ = Fy/Fx

Tan θ = 26.88/6.67

Tan θ = 4.03

θ = 76.06⁰ – to the west or θ = 103.94⁰– to the east

Therefore resultant force is 27.70 N at an angle of 103.94⁰ to west

Friction

Defn: friction is the force which resists a body from motion. Friction force which occurs in fluids is known as **viscosity**

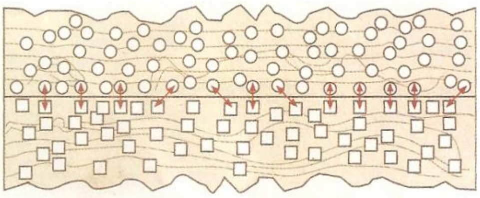
How Friction Happens

The friction force occurs due to the following

a. Adhesive bond
b. Mechanical bond
c. Deformation

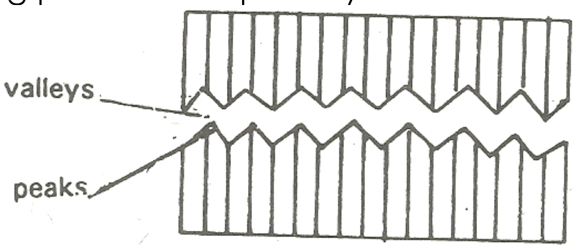
Adhesive Bond

The attraction force between two bodies can raise friction where particle from that object tend to bind each other so it is difficult to break that bond.



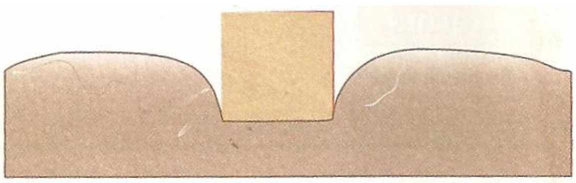
Mechanical Bond

Mechanical bond it raised due to peaks and valleys that tend to bind each other so it is difficult to break that bond. When a body becomes rough means it possesses long peaks and dip valleys.



Deformation

Sometimes deformation causes the friction, when the body deform create valley and the one which inter in that valley is peak.



Advantage of Friction

i. It aids in walking and movement
ii. Help moving body to stop
iii. Used to wear unneeded layers of some material
iv. Cause lighting match stick
v. Cause nail to stick on the wood
vi. Help bottle stopper to stick on the bottle neck

Disadvantage of Friction

i. cause wear and tear
ii. loss of heat energy
iii. slow down motion of the body
iv. heat can cause appliance to burn
v. it cause wounding, when skin wearing

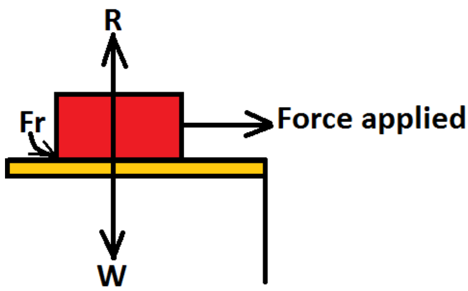
Methods of Increasing Friction

1. Increase normal force by increase the weight of the body
2. Changing/increase roughness of the surface
3. Use material of high coefficient. Example, rubber band

Methods of Reducing Friction

1. Place roller between the two rough surfaces
2. Use ball bearing
3. Use lubrication e.g. oil, water
4. Speedy material which have low coefficient of friction and thus slide easily.
5. Make surface soft

Normal Force and Limiting Friction



Defn: Normal force is the equal and opposite to the weight of the body. Always it's perpendicular to the surface on which it rests

Defn: limiting friction is the minimum force required to move a body over one another

NB:

i. From above diagram: $R = mg$
ii. when body at rest $Fr = F$
iii. when body at motion $Fr \neq F$ so we have to find net force, F
iv. when body start to move static friction force is equal to limiting friction

minimum force applied tend to start motion

v. when body start to move kinetic friction force is not equal to minimum force applied tend to start motion
vi. if limiting friction less than force applied the body move
vii. if limiting friction greater than force applied the body cannot move

Laws of Friction Forces

The following are the laws of friction:

1. Frictional force is directly proportional to the normal force between the two surfaces in contact.
   Fr α R – remove proportionality constant
   Fr = KR
   K = is the coefficient of frictional force, μ
   Now:
   Fr = μR

Fr = μR – make μ subject
μ = Fr/R
Therefore:
Defn: Coefficient of friction is the ratio friction force to the normal reaction. Since it involve ratio of the same unit it has no SI unity

2. Friction depends on the nature of surface in contacts.
3. Friction does not depend on the surface areas in contact.
4. The ration of limiting friction over normal reaction is constant for two surfaces in contact.

Types of Friction

There two main types of friction includes

i. Static friction force
ii. Dynamic friction force

Static Friction Force

Defn: static friction force is the friction at rest. This force cause some materials to be stationary Example, book can kept in the top of desk without drops down
From:
Fr = μR
Where:
Fr = static friction force
R = normal reaction
μ = coefficient of static friction force
Therefore:
Defn: Coefficient of static friction is the ratio limiting friction force to the normal reaction.

Dynamic Friction Force

Defn: dynamic friction force is the friction occurs when object moving relative to each other. Dynamic friction force also called **kinetic friction force**.
From:
Fr = μR
Where:
Fr = kinetic friction force
R = normal reaction
μ = coefficient of kinetic friction force
Therefore:
Defn: Coefficient of kinetic friction is the ratio kinetic friction force to the normal reaction.

Example, 01

A block of mass 270kg is pulled along a horizontal surface. If the coefficient of kinetic friction between the block and the surface is 0.4, what is the friction force acting on the block as it slides?
Data given:
Mass of block, m = 270kg
Acceleration due to gravity, g = 10 m/s^2
Norma reaction, R = mg = 2700 N
Coefficient of kinetic friction, μ = 0.4
Kinetic Friction force, Fr = ?
Solution:
From: Fr = μR
Fr = 0.4 x 2700
Fr = 1, 080N

Example, 02

A box of mass 2kg rest on a horizontal surface, a force of 4.4 N is required to just start the box moving. What is the coefficient of static friction between the block and the surface?
Data given:
Mass of block, m = 2kg
Acceleration due to gravity, g = 10 m/s^2
Norma reaction, R = mg = 20 N
Static Friction force, Fr = 4.4 N
Coefficient of kinetic friction, μ = ?
Solution:
From: Fr = μR – make μ subject
μ = Fr/R

$\mu = 4.4/20$
$\mu = 0.22$

Example, 03
An aluminium block of mass 2.1kg rests on a steel platform. A horizontal force of 15N is applied to the block
(a) Given that coefficient of limiting friction 0.6, will the block move?
(b) If will moves, what will be its acceleration where Given that coefficient of kinetic friction is 0.47

Data given:
Mass of block, m = 2.1kg
Acceleration due to gravity, $g = 10\ m/s^2$
Norma reaction, R = mg = 21 N
Force applied, F = 15 N
Static Friction force, Fr = 4.4 N
Coefficient of limiting friction, $\mu_s = 0.6$
Coefficient of kinetic friction, $\mu_k = 0.47$

Solution:
(a) Find the static friction force, Fs = ?
From: $F = \mu R$
Then: $Fs = \mu_s \times R$
$Fs = 0.6 \times 21$
$Fs = 12.81N$
Since: F > Fs, hence the car will move

(b) Acceleration acquired, a = ?
First find the kinetic friction force, Fk = ?
From: $F = \mu R$
Then: $Fk = \mu_k \times R$
$Fk = 0.47 \times 21$
$Fk = 9.87N$
Fk it opposes the direction of F so the force which causes motion (net force) is given;
$F_{net} = F - Fk$
$F_{net} = 15 – 9.87$
$F_{net} = 5.13\ N$
From: Newton's second law; F = ma
Then: F_{net} = ma = make a subject
$a = F_{net}/m$
$a = 5.13/2.1$
$a = 2.44\ m/s^2$

Example, 04
A brick is start sliding with 6m/s across a concrete horizontal surface floor and the coefficient of friction between the two surfaces is 0.4. How far will it travel before coming to rest?

Data given:
Initial velocity, u = 6m/s
Final velocity, v = 0m/s
Acceleration due to gravity, $g = 10\ m/s^2$
Norma reaction, R = mg = W
Weight of the brick, W = mg = friction force, F
Coefficient of kinetic friction, $\mu = 0.4$
Distance travel by brick, s = ?

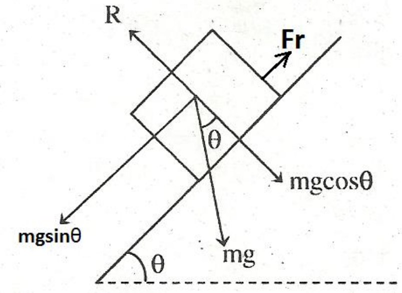
Solution:
From:
F = ma - - - - - -(i)
R = mg - - - - - -(ii)
Divide eqn (i) to eqn (ii)
F/R = ma/mg
F/R = a/g
But: $F/R = \mu = 0.4$
Now: $\mu = a/g$
0.4 = a/10
$a = 4\ m/s^2$
From third Newton's law of motion
$V^2 = u^2 + 2as$ – make s subject
$V^2 = u^2 + 2as$
$s = (v^2 - u^2)/2a$
$s = (6^2 - 0^2)/2 \times 4$
s = 36/8
s = 4.5 m

Example, 05
Find the static friction between a block of wood of mass 10kg placed on a table. A minimum force of 50N is required to make the block just move on the top.

Data given:
Mass of block, m = 10kg
Acceleration due to gravity, $g = 10\ m/s^2$
Norma reaction, R = mg = 100 N
Static Friction force, Fr = 50N
Coefficient of static friction, μ = ?

Solution:
From: $Fr = \mu R$ – make μ subject
$\mu = Fr/R$
$\mu = 20/100$
$\mu = 0.5$

Friction Force at Inclined Plane
Consider the diagram below, a mass of body sliding down the incline plane



At constant speed

$a = 0m/s^2$

$F_k = mg\sin\theta$

$R = mg\cos\theta$

But: $F_k = \mu_k R$ – make μ_k subject

$\mu_k = F_k/R$

$\mu_k = mg\sin\theta/mg\cos\theta$

$\mu_k = \sin\theta/\cos\theta$

$\mu_k = \tan\theta$

$\boldsymbol{\mu_k = \tan\theta}$

Therefore at constant speed coefficient of kinetic friction is given by the formula above

At rest

$a = 0m/s^2$

$F_s = mg\sin\theta$

$R = mg\cos\theta$

But: $F_s = \mu_s R$ – make μ_s subject

$\mu_s = F_s/R$

$\mu_s = mg\sin\theta/mg\cos\theta$

$\mu_s = \sin\theta/\cos\theta$

$\mu_s = \tan\theta$

$\boldsymbol{\mu_s = \tan\theta}$

Therefore at rest coefficient of static friction is given by the formula above

Example, 06

A mass is placed on an inclined plane such that it can move at constant speed, when slightly tapped. If the angle of the plane makes with the horizontal plane is 30^0. Find the coefficient of kinetic friction.

Data given:

Angle of the plane, $\theta = 30^0$

Coefficient of dynamic friction, μ = ?

Solution:

From: $\mu_s = \tan\theta$

$\mu_s = \tan 30^0$

$\mu = 0.56$

Example, 07

A block of wood of mass 5kg is placed on a rough plane inclined at 60^0. Calculate its acceleration down the plane if coefficient of friction between the block and the plane

Data given:

Angle of the plane, $\theta = 60^0$

Mass of the wood, m = 5kg

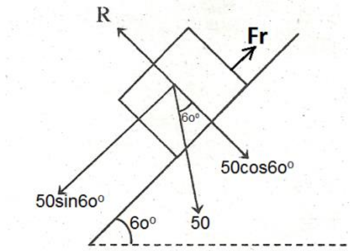
Normal reaction, $R = 50\cos 60^0$

Acceleration due to gravity, $g = 10m/s^2$

Coefficient of dynamic friction, $\mu = \tan 60^0$

Friction force, Fr = ?

Diagram:



Solution:

Net force, F = ?

$F = 50\sin 60^o - Fr$

But: $Fr = \mu_k \times mg\cos\theta$

$Fr = \mu_k \times 50\cos\theta$

$Fr = 0.3 \times 50\cos 60^o$

Now:

$F = 50\sin 60^o - 0.3 \times 50\cos 60^o$

F = 35.8N

But:

F = ma – make a subject

a = F/m

a = 35.8/5

$a = 7.1m/s^2$

Reflection of Light from Curved Mirror

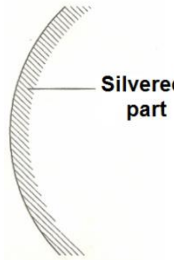
In this sub topic we will study two types of curved mirror include:

i. Convex /diverging mirror
ii. Concave/converging mirror

Convex Mirror

Defn: Convex mirror is the curved mirror which curved inward.

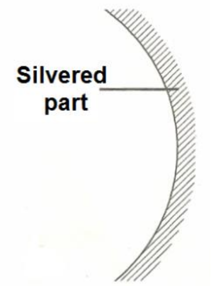
Diagram:



CONCAVE MIRROR

Defn: Concave mirror is the curved mirror which curved outward.

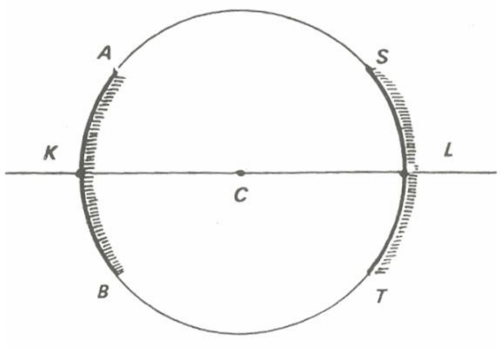
Diagram:



Terms Used In This Topic

Consider the diagram below when two curved mirror joined

Diagram:



Where:

AB = Convex mirror
ST = Concave mirror
C = centre of curvature
L = pole of the Concave mirror
K = pole of the Convex mirror
CL = radius of curvature of the Concave mirror Ck = radius of curvature of the Convex mirror
CL = principal axis of the Concave mirror
Ck = principal axis of the Convex mirror

Centre of Curvature

Defn: centre of curvature is the centre of the sphere in which the mirror is a part.

Radius of Curvature of the Curved Mirror

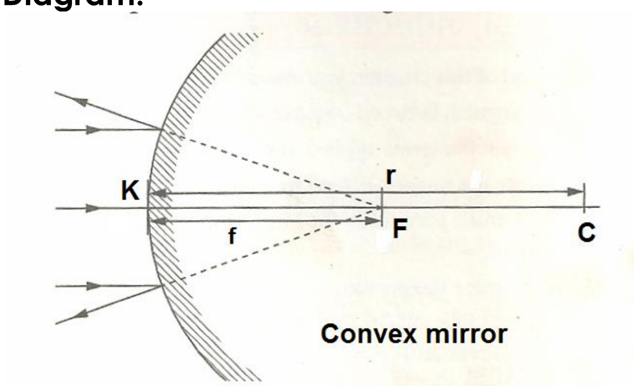
Defn: radius of curvature of the curved mirror is the distance/length between the pole of the curved mirror and the centre of curvature.

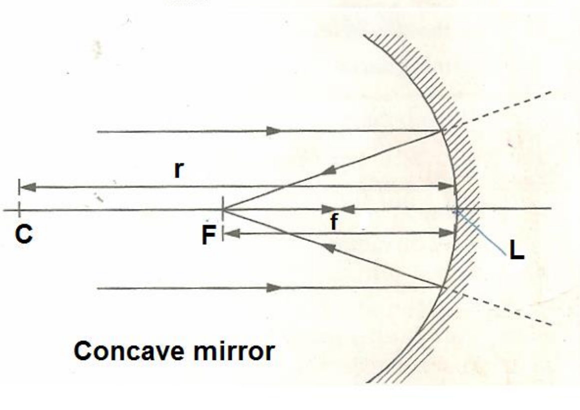
Principal Axis of the Curved Mirror

Defn: principal axis of the curved mirror is the line joining the pole of the curved mirror and the centre of curvature.

Consider when the light reflected in the curved mirror as shown in the diagram below.

Diagram:





Principle Focus, F

Defn: Principle focus is the point in which the light is reflected in curved mirror

Focal Length, f

Defn: focal length is the length/distance between poles of curved mirror to the principal focus.

NB: it was proved that focal length is equal to half of radius of curvature. **f =** $r/_2$

Location of Image Using Ray Diagrams
The following is the rules used to locate image in the curved mirror.

i. A ray of light travelling to the mirror parallel to the principal axis a ray is reflected through the principal focus
ii. A ray of light travelling to the mirror through the centre of curvature is reflected along its own path
iii. A ray of light travelling to the mirror through the principal focus is reflected parallel to the principal axis

Note: any two of these rays are sufficient to locate the image.

Procedure to Draw Ray Diagram
The following procedure is used to draw accurate ray diagrams to locate the image.

i. Choose an appropriate scale so that the ray diagram fits on the available space.
ii. Draw a horizontal line to represent the principal axis of the mirror. Mark the focal point of the mirror.
iii. Using the chosen scale, draw the object in position along the principal axis. The object is drawn as a vertical line from the principal axis.
iv. Locate the position of the image by drawing rays from the object to the mirror. Use the rules for drawing ray diagrams to draw the reflected rays.
v. At the point of intersection of the reflected rays, draw the image in position

Example, 01
An object 20cm high is placed 40cm from a concave mirror of focal length 15 cm. determine the position, nature and size of the image formed by drawing a ray diagram.
Solution:

Image Formed In Curved Mirror
Terms used to describe images formed by curved mirrors:

Position

i. **Real image** is on the same side of the mirror as the object.
ii. **Virtual image** is on the opposite side of the mirror compared to the object.

Nature

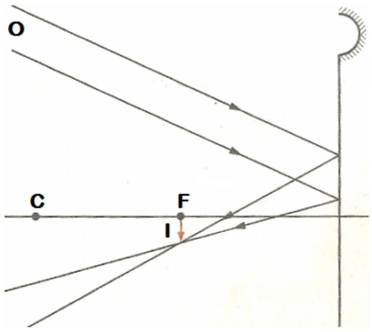
iii. **Upright image** has the same orientation as the object.
iv. **Inverted image** is oriented in an upside down position compared to the object.

Size

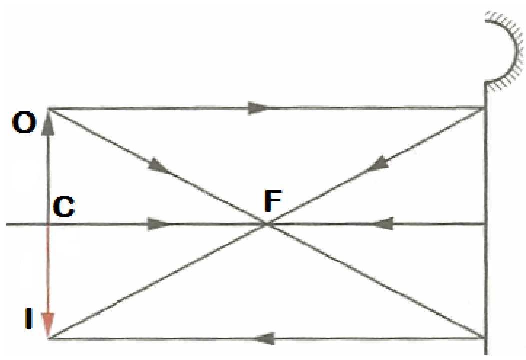
v. **Enlarged image** is bigger than the object.
vi. **Diminished image** is smaller than the object

Images Formed By Concave Mirrors
The following are the characteristics of images formed by concave mirrors:

Object at Infinity (Very Far).
The image is formed at the focal point, F, of the mirror. It is inverted, diminished and real.
Diagram:

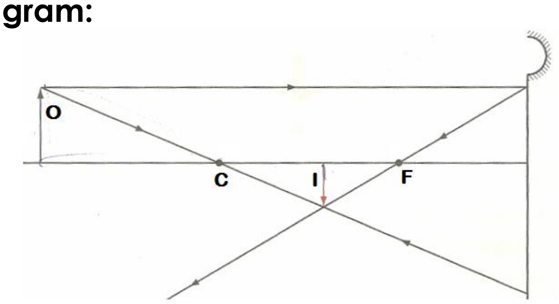


Object at the Centre of Curvature, C
The image is formed at C. It is real, inverted and the same size as the object.
Diagram:



Object beyond the Centre of Curvature, C
The image is formed between C and F. It is real, inverted and diminished.

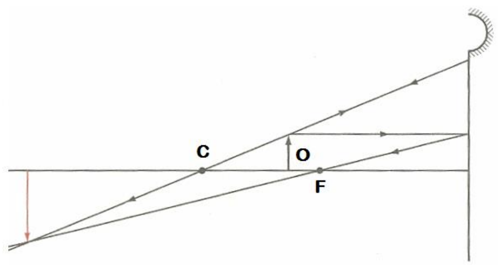
Diagram:



Objects between F and C

The image is formed beyond C. It is real, inverted and magnified.

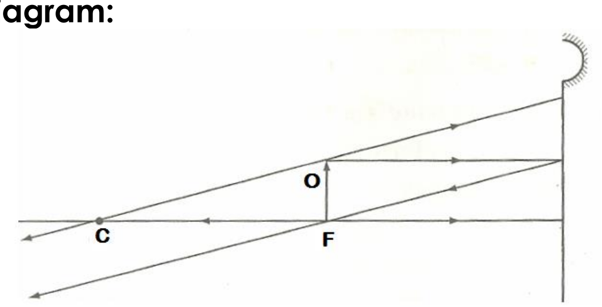
Diagram:



Object at F

The image is formed at infinity.

Diagram:



Object between F and P

The image is formed behind the mirror and is virtual, erect and magnified

Diagram:

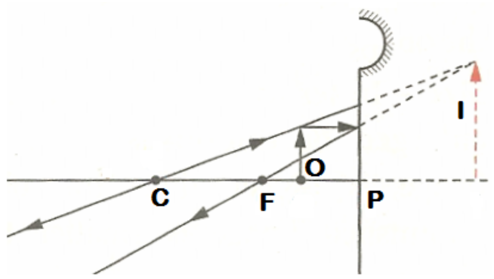
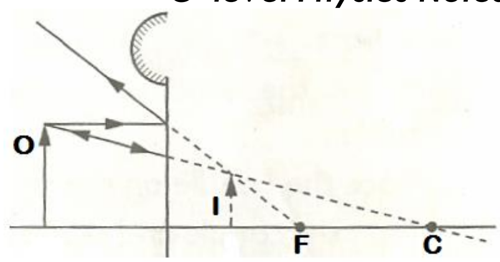


Image Formed In Convex Mirror

The images formed are always virtual, erect and diminished for all object positions.

Diagram:



The Mirror Formula

The mirror formula is expressed as follows:

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

NB:

i. Focal length, (f) for a concave mirror is positive (+)
ii. Focal length (f) for a convex mirror it is negative (-)
iii. the image distance, (v) is negative (-) For a virtual image
iv. The image distance, (v) is positive (+) for real images

Magnification of an Image

Defn: Magnification (M) is the ratio of the image size/ height (IH) to the object size/height (OH)

Formula:

$$M = \frac{IH}{OH}$$

Defn: Magnification is the ratio of the image distance (v) from the mirror to the object distance (u) from the mirror

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

NB:

i. Magnification has no units
ii. The image formed by a curved mirror can be larger, smaller or the same size as the object.
iii. When the ratio is greater than one, the image is enlarged
iv. When the ratio is less than one, the image is diminished

Example, 02

An object 3 cm high is placed 30 cm away from a concave mirror of focal length 12 cm. using the mirror formula, find the position, the height and the nature of the image formed.

Data given:

Focal length, f =l2cm

Image distance, v = ?

Object height, OH = 3cm
Object distance, u = 30 cm
Solution:
1st find distance of object
From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make v subject
V = (uf)/u-f
V = (30x12)/ (30-12)
V = 360/18
V = 20 cm
The image is real

2nd find the image height, IH
From: $M = \frac{IH}{OH}$
But: $M = \frac{v}{u}$
Therefore: $\frac{IH}{OH} = \frac{v}{u}$ - make IH subject
IH = (OH x v)/u
IH = (3 x 20)/30
IH = 60/30
IH = 2 cm
The image is diminished.

Example, 03
A concave mirror with a radius of curvature of 30 cm produces an inverted image 4 times the size of an object placed on its principal axis.
Determine the position of the object and that of the image.
Data given:
Radius of curvature, r = 30
Focal length, f = r/2 = l2cm
Magnification, M = 4
Image distance, v = ?
Object distance, u = ?
Solution:
1st find distance of object
Form: $M = \frac{v}{u}$
$4 = \frac{v}{u}$ - make v subject
v = 4u
Then: From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make u subject
u = (vf)/v-f
Substitute v by putting 4u
u = (4ux f)/(4u-f)
u = (4ux 15)/(4u-15)
u = 60u/(4u-15) – multiply by (4u-15) both sides
u(4u-15) = 60u
$4u^2$ -15u = 60u
$4u^2$ = 60u + 15u
$4u^2$ = 75u
4u = 75
u = 18.75 cm

2nd find image distance, v
From: 4u = 75 cm
But: 4u= v
Therefore v= 75 cm
v = 75 cm

Example, 04
An object 30 cm high is placed 20 cm away from a convex mirror of focal length 25 cm. Describe the image formed.
Data given:
Focal length, f = -25cm
Object height, OH = 30cm
Object distance, u = 20 cm
Image distance, v = ?
Image height, IH = ?
Solution:
1st find distance of object
From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make v subject
V = (uf)/u-f
V = (20x-25)/ (20--25)
V = (20x-25)/ (20+25)
V = -500/45
V = -11. cm
The image is virtual

2nd find the image height, IH
From: $M = \frac{IH}{OH}$
But: $M = \frac{v}{u}$
Therefore: $\frac{IH}{OH} = \frac{v}{u}$ - make IH subject
IH = (30 x -11.1)/20
IH = -333/30
IH = -16.8 - always is positive
IH = 16.8 cm
The image is diminished.

NB:
i. Convex mirrors produce diminished images but have a very wide field of view compared to plane mirrors
ii. Concave mirrors magnify images

Uses of Convex Mirrors
The following are some of the areas where convex mirrors are used:
i. Used in driving due to Wide field of view

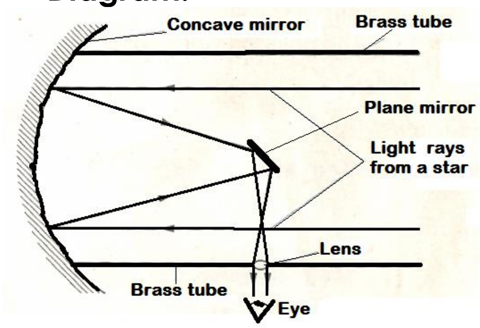
ii. Seeing around corners to avoid the crashing of vehicles or supermarket trolleys at the corners
iii. Supermarket surveillance for surveillance in business establishments and security installations

Uses of Concave Mirrors

The following are some of the areas where concave mirrors are used:

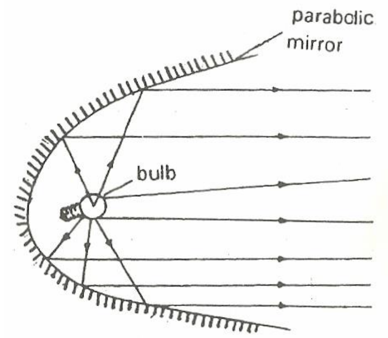
1. Shaving mirrors due to magnification and erect image
2. Reflecting telescopes

   Diagram:



3. Used in solar cookers.
4. It is used to making car headlamp and torch by concave mirror called parabolic mirror

   Diagram:

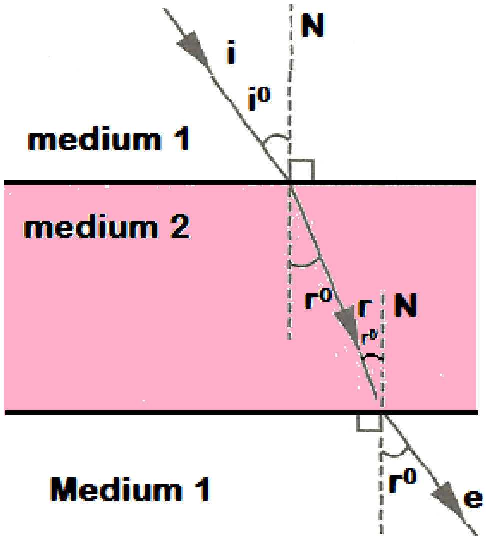


Refraction of Light through Plane Media

When The Light travels in a straight line in constant speed/velocity unless there is change in medium e.g. glass, water or oil, result change light speed/velocity because different media have different optical densities, this phenomenon is called **refractive**

Defn: Refraction is the process by which the direction of a ray of light changes when passes from one medium to another of different optical density

Diagram:



Where:

i = incident ray
i^0 = incidence angle
r = refracted ray
r^0 = refraction angle
e = emergent ray

Laws of Refraction

We have about three law of refraction of light which are stated as follows:

i. First law of refraction of light
ii. second law of refraction of light

First law of refraction of light

States that

"***Incident ray, the normal and the refracted ray all lie in the same plane***"

Second law of refraction of light / Snell's Law

States that

"***For a particular material, the ratio*** $\frac{\sin i^0}{\sin r^0}$ ***is constant value called refractive index***"

Refractive Index

Refractive index can be obtained according to the angle of light formed or velocity of light from one to another medium.

Suppose light travels from air medium to glass

Let the angle of incidence be i^0 and the angle of refraction r^0. Refractive index between air and glass is given by formula

$${}_a\mu_g = \frac{\sin i^0}{\sin r^0}$$

Defn: The refractive index is the ratio of angle of incidence to the angle of refraction.

Alternative:

Also alternative definition of refractive index may be given in terms of the velocity of light in air medium and glass medium as follows;

$${}_a\mu_g = V_a/V_g$$

Defn: The refractive index is the ratio of the speed of light in medium to the speed of another medium

NB:

i. Refractive index between vacuum/air to any other materials is called **absolute refractive index or refractive index**

$${}_a\mu_g = \mu_g$$

ii. Refractive index between medium to medium except vacuum/air is called **relative refractive index.** For instance if light passes from water to glass.

$${}_w\mu_g = V_w/V_g$$

iii. Any material has its own refractive index due to fact that each has optical density individual

Refractive Index of Different Medium

Medium	Refractive Index
Diamond	2.417
Ethyl alcohol	1.360
Glass/crown	1.520
Quartz	1.553
Water(20^0C)	1.333
Air (at stp)	1.00029
Benzene	1.50
Glycerin	1.47

Paraffin	1.44
Crown(flint)	1.65
Ice	1.31
Mica	1.56

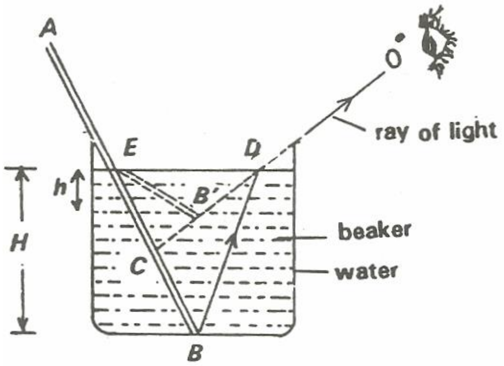
1. Derivation
Given: The refractive index of light from water to grass given as:
$_w\mu_g = v_w/v_g$ ---------1
Given: The refractive index of light from glass to water given as:
$_g\mu_w = v_g/v_w$ --------- 2
Then: find Reciprocal equation (2)
$(_g\mu_w)^{-1} = (v_g/v_w)^{-1}$
$1/_g\mu_w = v_{gw}/v_g$
But: $_w\mu_g = v_w/v_g$ substute into equation above
Then: $1/_g\mu_w = {_w\mu_g}$
$$\mathbf{1/_g\mu_w = {_w\mu_g}}$$

2. Derivation
Given: The absolute refractive index of water to given as:
$\mu_w = v_a/v_w$
Then: make va subject
$v_a = \mu_w \times v_w$ ---------1
Given: The absolute refractive index of glass given as:
$\mu_g = v_a/v_g$
Then: make va subject
$v_a = \mu_g \times v_g$ --------- 2
Since: va is equal, so equation (1) = equation(2)
Then: $\mu_w \times v_w = \mu_g \times v_g$
Divide by v_w and μ_w both sides
$$\mathbf{v_w/v_g = \mu_g/\mu_w}$$
Where:
v_w = velocity of light in the water medium
μ_w= absolute refractive index of water
v_g = velocity of light in the glass medium
μ_g = absolute refractive index of glass
Since: $_w\mu_g = v_w/v_g$
Finally: $_w\mu_g = \mu_g/\mu_w$
$$\mathbf{_w\mu_g = \mu_g/\mu_w}$$

3. Derivation
$$_a\mu_g = \frac{\sin i^0}{\sin r^0} = \frac{1}{_g\mu_a} = \frac{\sin r^0}{\sin i^0}$$

Alternative:
Another way of determining the refractive index of a material is by **real-and-apparent depth method**.

Diagram:



When one looks at a stick placed inside a beaker of water, the stick immersed in water point raised from its real position due to refractive index of water
Where:
H = real depth/height
h = apparent depth/height
Now:
$$\mathbf{_a\mu_w = H/h}$$

Defn: The refractive index is the ratio of the real/actual depth/height to the apparent depth/height of water/liquid

Example, 05
When a ray of light is travel from one air to glass, the angle of is 30^0. If the refractive index of the glass is 1.5. Determine the angle of incidence, i.
Data given:
Angle of incidence, I = ?
Angle of refracted = 30^0
Refractive index of the glass, $_a\mu_g$ = 1.5
Solution:
From: $_a\mu_g = \frac{\sin i^0}{\sin r^0}$ - make $\sin i^0$ subject
$\sin i^0 = {_a\mu_g} \times \sin r^0$
$\sin i^0 = 1.5 \times \sin 30^0$
$\sin i^0 = 1.5 \times 0.5$
$\sin i^0 = 0.75$
$i^0 = \sin^{-1}(0.75)$
$\underline{i^0 = 48.6^0}$

Example, 06
A coin at the bottom of a jar of glycerin appears to be 13.2 cm below the surface of the glycerin. Calculate the height of the column of glycerin in the jar given that the refractive index of glycerin is 1.47.
Data given:
Real depth, H = ?
Apparent depth, h = 13.2 cm
Refractive index of the glass, $_a\mu_g$ = 1.47

Solution:

From: ${}_a\mu_g = \frac{H}{h}$ - make H subject

$H = {}_a\mu_g \times h$

$H = 1.47 \times 13.2$

$\underline{H = 19.4\text{ cm}}$

Example, 07

Water is poured into a beaker to a depth of 24 cm. To an eye looking vertically down through the water, the bottom of the beaker appears to be raised 6 cm from the bottom of the beaker. Determine the refractive index of the water.

Data given:

Real depth, H = 24 cm

Apparent depth, h = (24 - 6) cm = 18 cm

Refractive index of the glass, ${}_a\mu_g$ = ?

Solution:

From: ${}_a\mu_g = \frac{H}{h}$ - make H subject

${}_a\mu_g = \frac{24}{18}$

$\mathbf{{}_a\mu_g = 1.33}$

Applications of Refractive Index

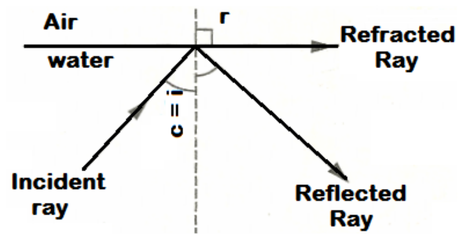
i. The refractive index of a material is very important in optical systems. It is used to calculate the focusing power of lenses

ii. Refractive index is also used to identify a substance or confirm its purity. This is because pure substances have definite refractive indices

Critical Angle

Defn: Critical angle is a unique angle of incidence for which the angle of refraction is 90^0.

Diagram:



Where:

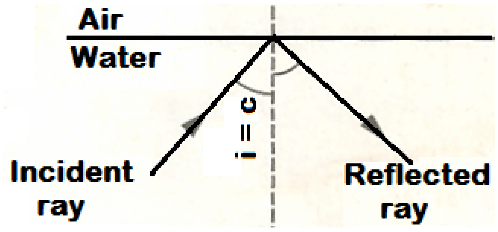
c = critical angle

r = refracted angle = 90^0

Total Internal Reflection

Defn: total internal reflection is the angle of incidence in which the angle of incidence exceeding the critical angle

Diagram:



c = total internal reflection

r = refracted angle = θ > 90^0

NB:

i. The reflected ray goes back to the more dense medium

ii. Total internal reflection only occurs when light travels from a more dense medium to a less dense medium

iii. When Total internal reflection occurs, there is no refraction at all

Relation between Critical Angle and Refractive Index

Consider the equation below;

$${}_w\mu_a = \frac{\sin i^0}{\sin r^0}$$

But: $r^0 = 90^0$ and $i^0 = c$

$${}_w\mu_a = \frac{\sin c}{\sin 90^0}$$

But: $\sin 90^0 = 1$

$${}_w\mu_a = \frac{\sin c}{1}$$

Then: $\sin c = 1 \times {}_w\mu_a$

But: ${}_w\mu_a = 1/\mu_w = 1/1.5 = 2/3$

Then: $1/\mu_w = \sin c$

Therefore: $\mu_w = \frac{1}{\sin c}$

$$\mu_w = \frac{1}{\sin c}$$

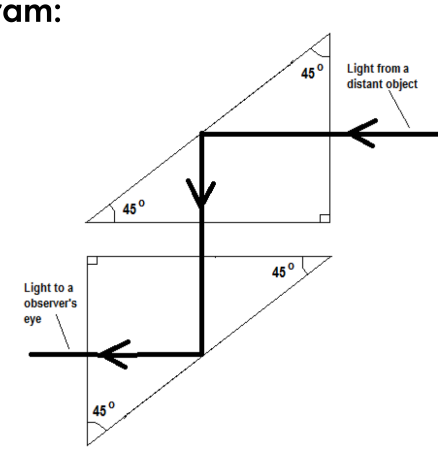
This is true for all material media where, water, w represent material media

Applications of Total Internal Reflection

1. **Prism periscope**

A prism periscope consists of two 45° - 90°

Diagram:

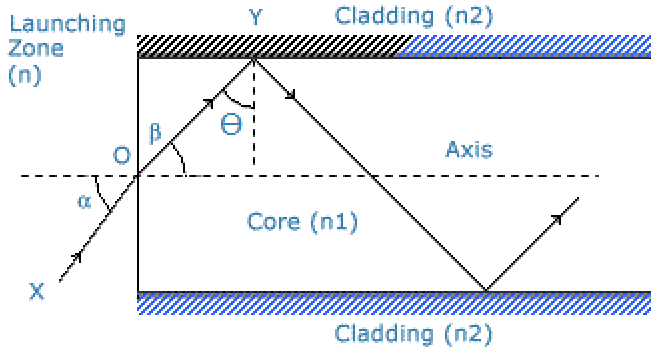


2. **Optical fibres**

An optical fibre is a thin rod of high-quality glass designed to guide light along its length by total internal reflection.

Light inside these fibres hits the sides at an angle greater than the critical angle and is transmitted by being repeatedly totally internally reflected.

Diagram:



Some uses of optical fibres

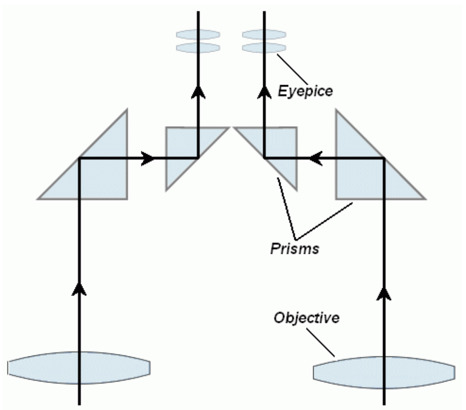
i. Used as a medium for telecommunications and networking.
ii. They are also used as light guides in medical and other applications
iii. Optical fibres are also used in imaging optics. A bundle of fibres along with lenses are used to make a long imaging device called an **endoscope**.

NB:

i. Medical endoscopes are used in minimally invasive surgical procedures.
ii. Industrial endoscopes are used for inspecting machine parts

3. **Binoculars and telescopes**

Diagram:



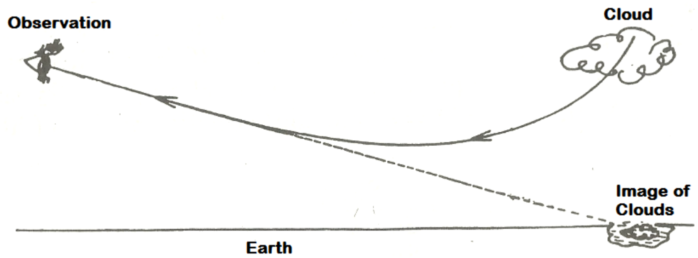
Mirages

Defn: A mirage is an optical phenomenon in the atmosphere that makes an object appears to be displaced from its true position.

When light pass from cold air layer (optical dense) to earth surface of hot air layer (optical less dense) continuous light bending (refraction), where incidence exceeds the critical angle.

All the light is reflected upwards (total internal reflection). This looks like the reflection produced by a **pool of water**

Diagram:



Refraction of Light by Lenses

Defn: lens is a transparent or a translucent medium that alters the direction of light passing through it

Types of Lenses

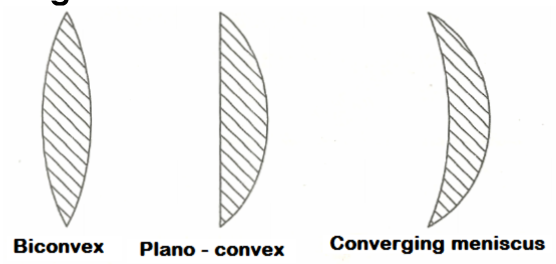
There are two main types of lenses based on their shape.

i. Convex lenses
ii. Concave lenses

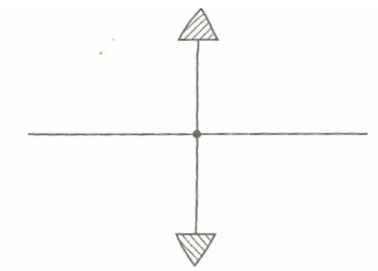
Convex/Converging Lenses

A convex lens is thicker at its centre than at its edges. Convex lenses converge light. Convex lenses can be biconvex, piano-convex or converging meniscus

Diagram:



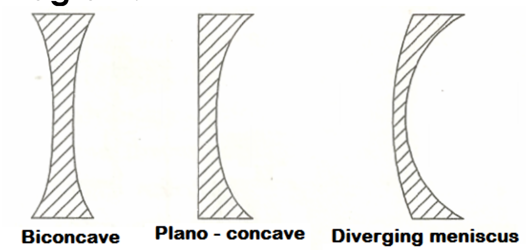
Symbol for convex lens



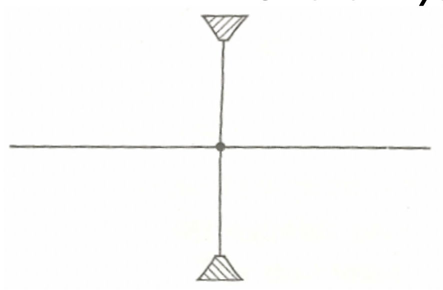
Concave/Diverging Lenses

A concave lens is thicker at its edges than at its centre. Concave lenses diverge light. Concave lenses include biconcave, plan-concave and diverging meniscus lenses.

Diagram:



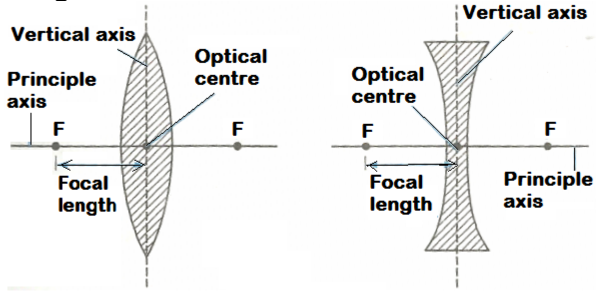
Symbol for concave lens



Terms Used On Thin Lenses

Consider the diagram below

Diagram:

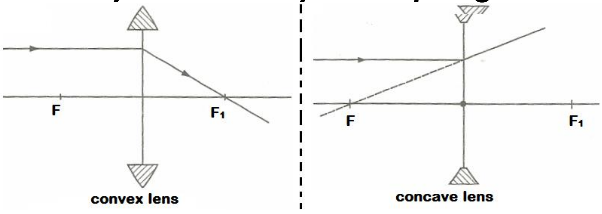


i. **Optical centre**: This is the geometric centre of a lens.
ii. **Centre of curvature, C/2F**: This is the geometric centre of the sphere of which the lens surface is a part of.
iii. **Principal axis:** This is an imaginary line which passes through the optical centre of the lens at a right angle to the lens.
iv. **Radius of curvature, R**: is the distance between optical centre and the centre of curvature.
v. **Principal focus/focal point, F:** This is a point through which all rays travelling close and parallel to the principal axis pass through the lens.
vi. **Aperture**: is the width of the lens, from one edge to another
vii. **Focal length, f**: This is the distance between the optical centre and the principal focus

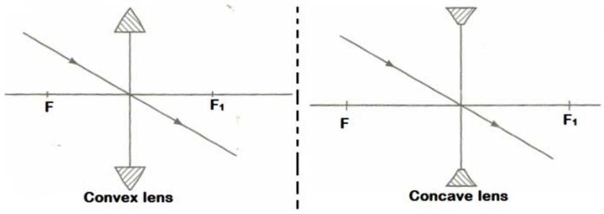
Construction of Ray Diagrams

The following is the rules used to locate image in the lenses.

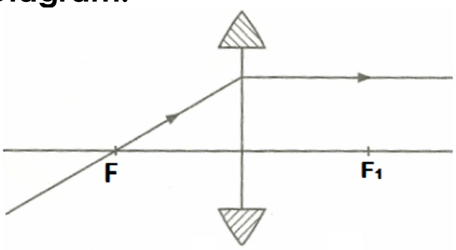
i. Choose a suitable scale
ii. Draw a principle axis and the lens
iii. Draw object in the position
iv. A ray of light travelling parallel to the principal axis passes through the principal focus
   Diagram:



v. A ray of light travelling through the optical centre goes undeviated (not refracted) along the same path.
Diagram:

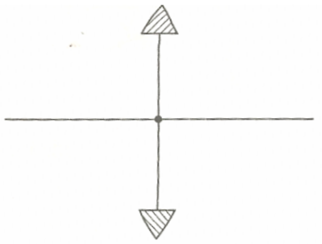


vi. A ray of light travelling through the principal focus is refracted parallel to the principal axis
Diagram:

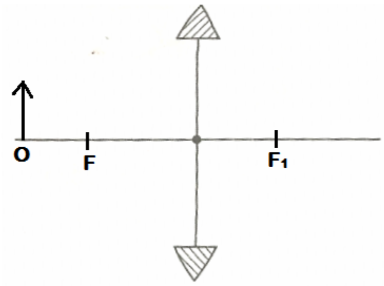


vii. Measure the height and the distance of the image
viii. Convert the measurements into actual units using the chosen scale

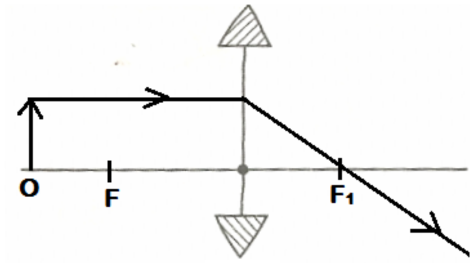
Example, 08
An object 0.05 m high is placed 0.15 m in front of a convex lens of focal length 0.1 m. Find, by construction, the nature, the position and the size of the image.
Solution:
i. Choose a suitable scale
ii. Let us choose 1cm ≡ 5cm
iii. Draw a principle axis and the lens



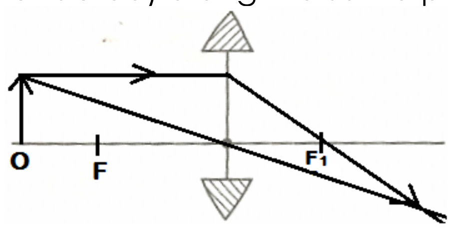
iv. Draw object in the position



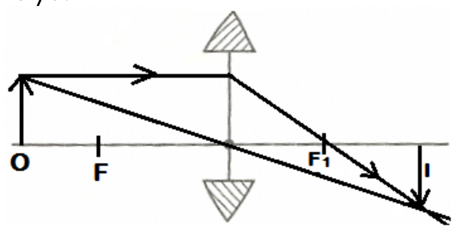
v. A ray of light travelling parallel to the principal axis passes through the principal focus



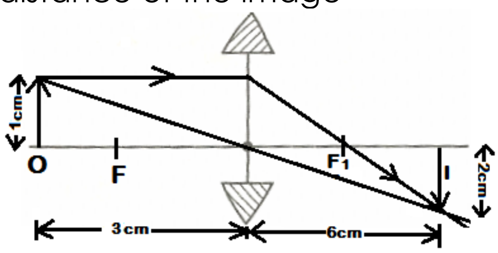
vi. A ray of light travelling through the optical centre goes undeviated (not refracted) along the same path.



vii. Draw the image of the object at the point of intersection of the refracted rays.



viii. Measure the height and the distance of the image



ix. Convert the measurements into actual units using the chosen scale
From the graph:
Image height, IH = 2cm x 5 = 10 cm = 0.1 m IH **from:** 1cm ≡ 5cm
2cm ≡ x?
X = 2cm x 5 = 10 cm = 0.1 m

Image distance, v = 6cm x 5 = 30 cm = 0.3 m

From: 1cm ≡ 5cm

6cm ≡ x?

X = 6cm x 5 = 30 cm = 0.3 m

Therefore: The image is 0.1 m high and 0.3 m from the lens.

Linear Magnification

Defn: Magnification is a measure of the extent to which an optical system enlarges or reduces an image in relation to the object.

$$\mathbf{M} = \frac{IH}{OH}$$

Where:

IH = image height

OH = object height

M = magnification

Also can be given by

$$\mathbf{M} = \frac{v}{u}$$

Where:

v = distance of the image from the lens

u = distance of the object from the lens

M = magnification

The Lens Formula

It given by formula;

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

Real-Is-Positive Convention

To calculate the values of u and v a sign rule or convention is adopted. The rule is referred to as the **real-is-positive convention**.

Sign For object and image

v = +

u = +

Sign For virtual object and image

v = -

u = -

NB:

i. Sign of **virtual object and image is negative** Because the principal focus of a concave lens is virtual
ii. Convex lenses have positive values of focal length, F = +
iii. Concave lenses have negative values of focal length, F = -

Example, 09

An object is placed 12 cm from a convex lens of focal length 18 cm. using the lens formula. Find the position of the image.

Data given:

Focal length, f =+18 cm

Distance of object, u = +12 cm

Distance of image, v = ?

Solution:

From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make v subject

v = fu/(u-f)

v = (18x12)/(12-18)

v = 216/-6

<u>v = -36</u>

The image is virtual and erect

Example, 10

An object is placed 10 cm from a concave lens of focal length 15 cm. using the lens formula, determine the nature and the position of the image.

Data given:

Focal length, f =-15 cm

Distance of object, u = +10 cm

Distance of image, v = ?

Solution:

From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make v subject

v = fu/(u-f)

v = (-15x10)/(10 +15)

v = -150/15

<u>v = -6</u>

The image is virtual and erect

Example, 11

An object 2 cm high is placed 24 cm from a converging lens. An erect image which is 6 cm high is formed. Find focal length of the lens.

Data given:

Distance of object, u = +24 cm

Distance of image, v = ?

Image height, IH = -6cm

Object height, OH = 2cm

Focal length, f = ?

Solution:

First: find v

From: M = $\frac{v}{u} = \frac{IH}{OH}$

Therefore: $\frac{v}{u} = \frac{IH}{OH}$ make v subject

v = (uxIH)/(OH)
v = (24 x-6)/(2)
v = - 144/2
v = - 144/2
v = - 72 cm

then: find f

From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ make f subject.

f = vu/(u+v)
f = (-72x24)/(24-72)
f = -1728/-48
<u>f = 36 cm</u>

Example, 12

The focal length of a converging lens is 10 cm. How far should the lens be placed from an illuminated object to obtain an image which is five times the size of the object on a screen?

Data given:
Distance of object, u = ?
Distance of image, v = ?
Focal length, f = +10
Magnification, M = 5

Solution:

First: find v and u

From: M = $\frac{v}{u}$ make v subject

v = Mu
v = 5xu
v = 5u

From: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ substitute v by 5u.

$\frac{1}{f} = \frac{1}{u} + \frac{1}{5u}$ make u subject

u = 6f/5
u = (6x10)/5
u = 60/5
<u>u = 12 cm</u>

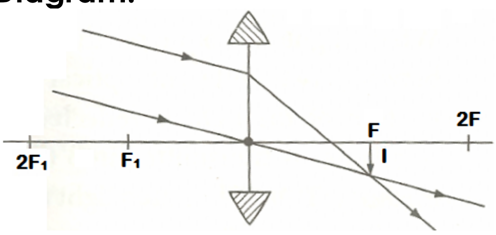
Images Formed By Thin Lenses

Let us look image formed by convex lens and concave lens

Images Formed By Convex Lens

Object at Infinity (Very Far).

Diagram:

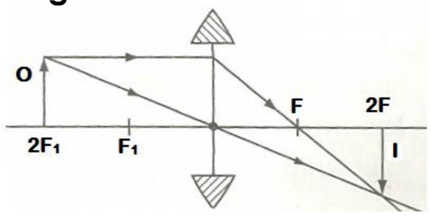


Properties of image formed

i. It real
ii. Formed at F
iii. Inverted (upside down)
iv. Diminished (smaller in size than object)

Object at C/2F

Diagram:

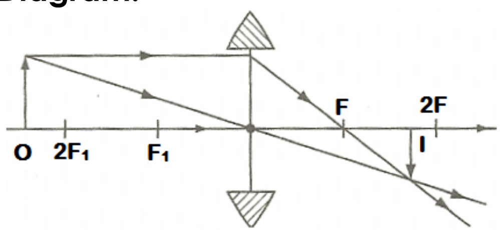


Properties of image formed

i. It real
ii. Formed at F
iii. Inverted (upside down)
iv. same in size as the object)

Object Beyond C/2F

Diagram:

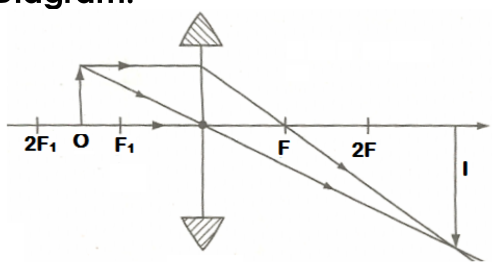


Properties of image formed

i. It real
ii. Formed between F and c/2F
iii. Inverted (upside down)
iv. diminished

Objects between F and C/2F

Diagram:

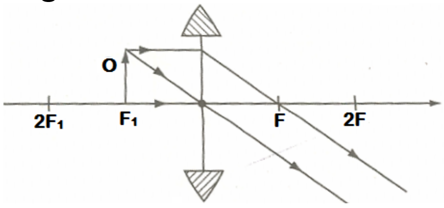


Properties of image formed

i. It real
ii. Formed behind C/2F
iii. Inverted (upside down)
iv. magnified (larger in size than object)

Object at F

Diagram:

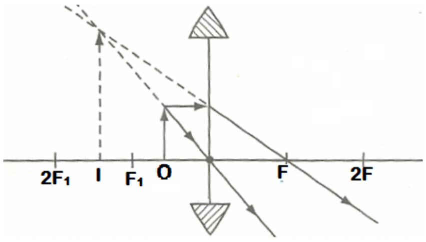


Properties of image formed

i. real
ii. Formed at infinity
iii. Inverted (upside down)
iv. magnified (larger in size than object)

Object between F and Lens

Diagram:



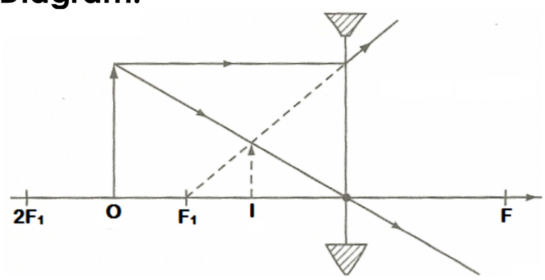
Properties of image formed

i. virtual
ii. behind the object
iii. erect
iv. magnified (larger in size than object)

Image Formed In Concave Lens

The images formed are always virtual, erect and diminished for all object positions.

Diagram:



Properties of image formed

i. virtual
ii. formed between the object and the lens
iii. erect
iv. diminished
v. as U increase to infinity also V increase to F

Refraction through Prism

Defn: prism is a solid piece of glass or transparent material that has a least two planes inclined toward each other through which light is refracted.

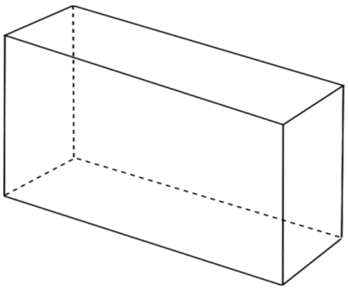
Types of prism

i. Rectangular prism
ii. Triangular prism

Rectangular prism

Rectangular prisms are commonly called glass blocks, which already discussed in previous topic

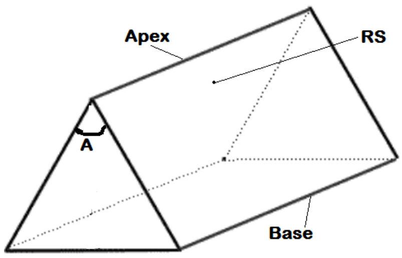
Diagram:



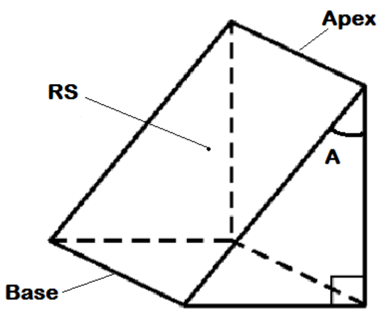
Triangular prism

Triangular prism is a wedge-shaped piece of glass material or any other transparent material..

Diagram:



Equilateral prisms (60°-60°-60°)



Right angle prisms (45°-90°-45°)

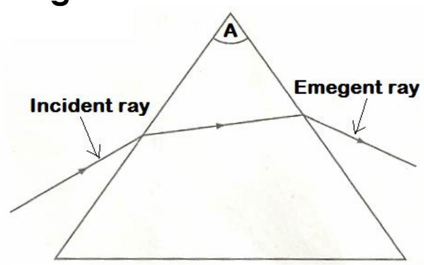
Where:

Rs = refracting surfaces
Apex =point two refracting surfaces of the prism meet is called the **refracting edge**
Base = surface parallel to apex
A = apical angle (A) of the prism

NB:

i. The most common triangular glass prisms are Equilateral prisms and Right angle prisms
ii. Triangular prism has two refracting surfaces.
iii. Light travels slower in glass than in air.
iv. Light rays are bent towards the normal on entering the prism.
v. Light rays are bent away from the normal on leaving the prism is called emergent ray
vi. rays leaving the prism is called **emergent ray**
vii. rays entering the prism is called **incident ray**

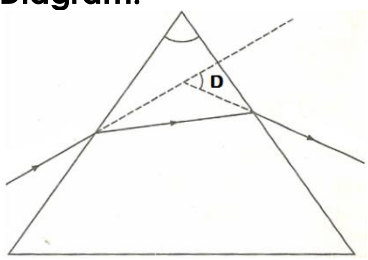
Diagram:



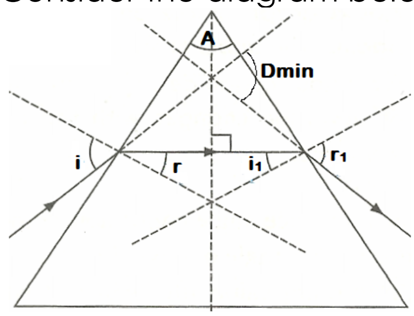
Angle of Deviation, D

Defn: angle of deviation is the angle formed by the intersection of the incident ray directions and the emergent ray directions.

Diagram:



Consider the diagram below



From Snell's Law

$_a\mu_g = \sin i/\sin r$ …………………….1
$_g\mu_a = \sin i_1/\sin r_1$…………………….2

Therefore:

$i = \sin^{-1}(_a\mu_g \times \sin r)$ …………………….3
$i_1 = \sin^{-1}(_g\mu_a \times \sin r_1)$ …………………….4

But:

$i = a + r$…………………..5

$r_1 = b + i_1$…………………..6

Therefore:

$a = i - r$…………………..7

$b = r_1 - i_1$…………………..8

Since: exterior angle of triangle = sum of the two opposite interior angle

$D = a + b$…………………..9

Then: Substitute equation 7 and 8 into eqn 9

$D = a + b$

$D = (i - r) + (r_1 - i_1)$ …………………..10

Since: A and A^1 is supplementary to each other

$A + A^1 = 180°$.

Therefore: $A^1 = 180° - A$…………………..11

But: $r + i_1 + A^1 = 180°$…………………..12

Then: $r + i_1 + (180°-A) = 180°$ - make r_1 subject

$r = A - i_1$ …………………..13

Then: Substitute equation 13 into equation 10

$D = (i - (A - i_1)) + (r_1 - i_1)$

$D = (i - A + i_1) + (r_1 - i_1)$

$D = i - A + i_1 + r_1 - i_1$

$D = i - A + r_1$

$\mathbf{D = I + r_1 - A}$

The angle of deviation depends on

i. the apical angle of the prism, A
ii. the angle of incidence, i
iii. The refractive index of the glass prism.

NB:

Angle of deviation decreases with an increase in the angle of incidence and vice versa

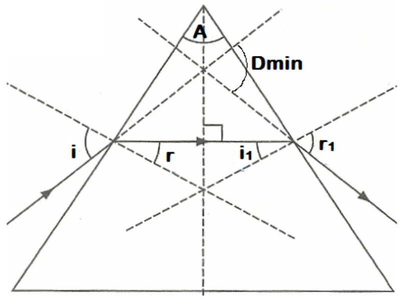
Minimum Angle of Deviation, Dmin

Defn: minimum angle of deviation is the deviation angle occurs when the emergent ray is refracted at an angle equal to the angle of incidence

NB:

i. Prism material has a unique minimum angle of deviation.
ii. At the angle of minimum deviation, the refracted ray from the first surface travels through the prism perpendicular to the bisector of the apical angle

Diagram:



Since: $r = i_1$ and $i = r_1$, D = Dmin

Substitute: $r = i_1$ and $i = r_1$, D = Dmin

Also: $A = r + i_1$

$A = r + r = 2r$

But: $D_{min} = i + r_1 - A$ – substitute $A = r + i_1$

Then: $D_{min} = i + r_1 - (r + i_1)$

$D_{min} = i + i - (r + r)$

$D_{min} = 2i - 2r$

$D_{min} = 2(i - r)$ – make I subject

Then: $i = (D_{min}/2) + r$

From: Snell's law

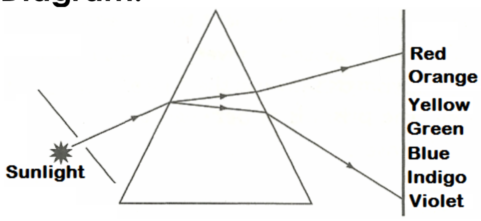
$${}_a\mu_g = \frac{\sin i}{\sin r} = \frac{\sin(\frac{D_{min}+A}{2})}{\sin(\frac{A}{2})}$$

$$\mathbf{{}_a\mu_g} = \frac{\sin(\frac{D_{min}+A}{2})}{\sin(\frac{A}{2})}$$

Dispersion of White Light

Defn: Dispersion of white light is the splitting of white light beam into its component colours. This band of colours produced is called **Spectrum**. The process of splitting is called **Dispersion.**

Diagram:



Types of White Colour

i. Polychromatic light
ii. Monochromatic light

Polychromatic Light

Defn: Polychromatic light is the white colour where consists more than one colour. Example, sunlight

Monochromatic Light

Defn: Monochromatic light is the white colour where consists only one colour. Example, red colour

NB:

i. Spectrum of colour is red, orange, yellow, green, blue, indigo and violet.
ii. Each of these colours has a different wavelength.
iii. These coloured lights are refracted differently on passing through the prism
iv. The velocity of light in a medium (refractive index) depends on the wavelength of incident light. As a result different wavelengths are refracted by different amounts.

$$\mu = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

v. white colour split due to difference in wave length
vi. shorter wavelengths have higher refractive indices and get bent more than longer wavelengths

Wavelengths of the Colours of White Light

S/N	Colour	Wavelength (nm)
1	Red	625 - 740
2	Orange	590 - 625
3	Yellow	565 - 590
4	Green	520 - 565
5	Blue	440 - 520
6	Indigo	420 - 440
7	Violet	380 - 420

Types of Spectra

There are two types of spectra:
i. Pure spectra
ii. Impure spectra

Pure Spectra

Defn: pure spectrum is the one in which the colours are clearly separated from each other

Impure Spectra

Defn: Impure spectrum is the one in which the colours not clearly separated from each other

Recombining Colours of Light

Spectrum comes from white light can recombine to form white colour. The recombination of the colours of the white light spectrum may also be shown by the use of Newton's colour disc. The disc consists of sectors painted with the colours of the spectrum

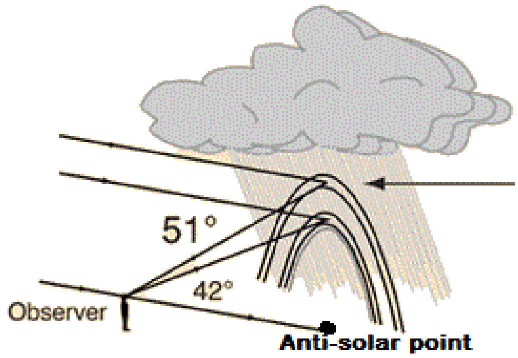
The Rainbow

Defn: The rainbow is a natural phenomenon of dispersion of sunlight by raindrop.

Formation of A Rainbow

It formed by dispersion of sunlight by drops of rain. Since water is denser than air the dispersion of sunlight on a drop of water is the same as when it falls on a glass prism.
The light is first refracted as it enters the surface of the raindrop, reflected off the back of the drop and again refracted as it leaves the drop.

Diagram



Types of Rainbow

i. primary rainbow
ii. secondary rainbow

Primary Rainbow

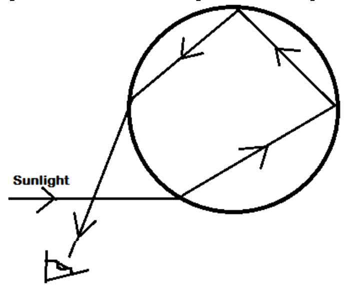
It is formed when light undergoes one total internal reflection (refracted twice and reflected once) in the water drops. The violet colour is inside and the red in the outside the bow. It formed between 40^0 and 42^0 from anti-solar point

Defn: anti-solar point is a point that lies directly opposite the sun from the observer, that is, on the line from the sun through the observer.

Secondary Rainbows

It is formed when light undergoes two total internal reflections in the water drops. The violet colour is outside and the red in the inside the bow.

Diagram:



Colour

Defn: Colour is the property of light that reaches our eyes.

Appearance of coloured objects under while light

The object seems to have kind of colour due to the fact that it absorbs all colours and reflect the colour that the object has.

Example, :

i. Yellow flower is yellow because it absorbs all the other colours in the light and reflects only the yellow colour.
ii. Blue object absorbs the entire colour in white light except blue.

Appearance of white objects under coloured light

When a coloured object is viewed under a coloured light, it takes the colour of that light.

Example, :

The object will appear blue in blue light and red in red light.

A colour filter is work on this principle.

Defn: Colour filters are materials made of glass or celluloid that let through light of certain colours only.

Example, :

Green filters allow green colour to pass through.

The colour of an object depends on the colour of the light falling on it and the colour(s) it absorbs or reflects.

Appearance of a white object to coloured light

White object	coloured light	Colour of object
White object	Red filters	Red colour
White object	Yellow filters	Yellow colour
White object	Green filter	Green colour
White object	Blue filter	Blue colour

Types of Colour

i. Primary colour
ii. secondary colour

Primary colour

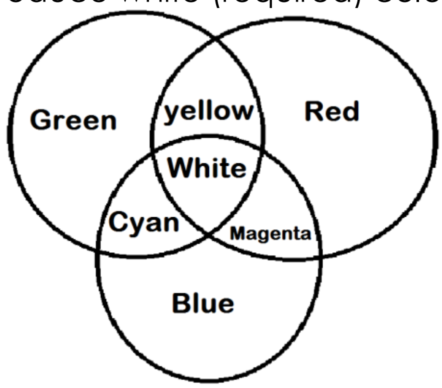
Defn: primary colour is a colour that cannot be created by mixing other colours. Example, red, Blue and Green

Secondary colour

Defn: secondary colour is a colour created by mixing other colours. Example, cyan, magenta and yellow

Complementary Colour

Defn: Complementary Colour is the colour that when mixed in a definite ratio yield/produce white (required) colour.



NB:

i. We are only concerned with colours of light and not with coloured substances (pigments)
ii. The complementary colour of white light is green, red and blue
iii. The complementary colour of yellow light is green and red.

Additive and Subtractive Mixing Of Colours

The primary colours (pigments) for mixing paints, inks and dyes are not the same for mixing lights, therefore *The primary colours for mixing in pigments used in colouring, photography and printing are* ***cyan, magenta*** *and* ***yellow****.*

Additive Mixing Of Colours

The more colours you add, the closer the result draws to white. Therefore, mixing of coloured lights is called an additive colour mixing system.

Nb:

i. Additive mixing of colour deals with primary colour of light colour not primary colour of pigments(paints and dyes)
ii. Adding different colours of light together increases the number of wavelengths present

Subtractive Mixing of Pigments

The primary colours of pigments (paints and that is magenta, cyan and yellow, absorb (subtract) light wavelengths and reflect back that defines the colour.

Example, of Subtractive Mixing of Pigments

i. Cyan + magenta = blue ………………..1
But: Cyan = green + blue ………………..2
Magenta = red + blue …………….3
Then: substitute eqn 2 and 3 into eqn 1
Cyan + magenta = blue
Green + blue + red + blue = blue……..4
But: green + blue + red = white ………..5
Then: substitute eqn 5 into eqn 4
Green + blue + red + blue = blue
Also: white + blue = blue
Since: white absorbed and blue reflected
Now: blue = blue

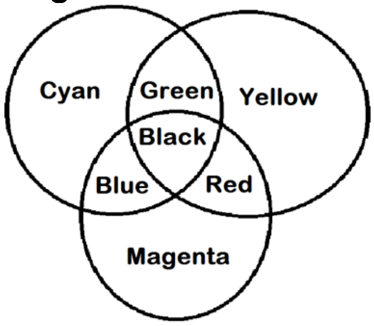
ii. Magenta + yellow = red
But: Cyan = green + blue ………………..2
Yellow = green + red ………………..3
Then: substitute eqn 2 and 3 into eqn 1
Magenta + yellow = red
Green + blue + green + red = red……..4
But: green + blue + red = white ………..5
Then: substitute eqn 5 into eqn 4
Green + blue + green + red = red
Also: white + red = red
Since: white absorbed and red reflected
Now: red = red

iii. Yellow + cyan = green
iv. Cyan + magenta + yellow = black

Nb:

i. Mixing two primary pigments produces a secondary pigment
ii. The pigments act as filters that subtract one or more colours from the visible spectrum
iii. Blue, red and green are, therefore, the secondary pigments.
iv. Subtractive complementary colours combine to produce black.

Diagram:



v. Each primary pigment absorbs one primary colour:
   a. Yellow absorbs blue and reflects red and green
   b. Magenta absorbs green and reflects blue and red
   c. Cyan absorbs red and reflects green and blue.
vi. A secondary pigment absorbs two primary colours and reflects one:
   a. Red absorbs green and blue and reflects red.
   b. Green absorbs red and blue and reflects green.
   c. Blue absorbs - red and green and reflects blue.
vii. The primary pigments are the secondary colours of light and the secondary pigments are the primary colours of light.
viii. If you mix a primary pigment with a secondary pigment you get total absorption (black).
Blue + yellow = black
ix. The primary pigments are the complements of the three primary colours of light Cyan complements red, magenta complements green and yellow complements blue.

Optical Instruments

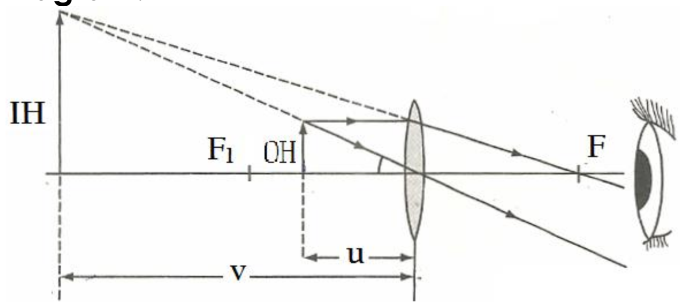
Optical instruments are devices which are used to help the human eye view small or distant objects more clearly. It uses a combination of lenses and/or mirrors to produce an enhanced image of an object.

(i) simple Microscope
(ii) compound Microscope
(iii) astronomical Telescopes
(iv) simple lens Camera
(v) projector lantern

Simple Microscope

It consists of a biconvex lens which may be hand-held or placed in a simple frame. It is sometimes referred to as a **magnifying glass**.

Diagram:

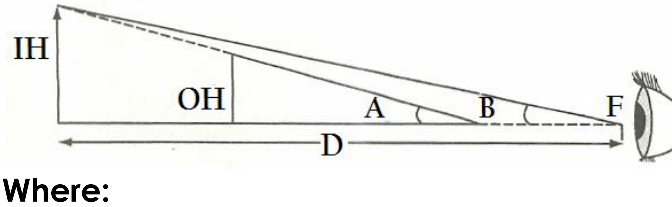


NB:

i. Object is placed at a distance shorter than the focal length of the lens. U < f so object is between f and lens
ii. Virtual, upright and magnified image of the object is formed.
iii. The image appears clearest when it is about 25 cm from the eye, U = 25cm. This distance is called the **near point** (D).
iv. The nearer the object is to the lens, the further and larger the image formed.

Magnification

Consider the diagram below



Where:

A = angle subtended by the object
B = angle I subtended by the virtual image
D = distance between F and image

Lateral Magnification

The lateral magnification of a simple lens is the ratio of the image height (IH) to the object height (OH).

M = IH/OH

Linear Magnification

Linear magnification is also given by the ratio of the image distance v to the object distance u.

M = V/U

Angular Magnification

The angular magnification (M) of a simple microscope is the ratio of the angle subtended at the eye by the object when viewed through the magnifying glass (B) to the angle subtended at the eye by the object when viewed with naked eyes (A)

M = B/A

From the diagram above
Tan B = IH/D
Since: angle B is small, it can be expressed as
B = IH/D
If the angle B subtended by the virtual image. Ignoring the small distance between the eye and the magnifying lens
B = IH/V = OH/V
B = OH/V …………….. 1
Then: Tan A = OH/D
Since: angle B is small, it can be expressed as.
A = OH/u …………… 2
Substitute eqn 1 and 2 in the formula M = B/A
M = (OH/U)/ (OH/V)
M = (OH/U) x (V/OH)
M =V/U

When the image is at the near point, v = 25 cm. Therefore, using the lens formula,
1/f = 1/u + 1/25 – make u subject
U = 25f/(25+f) – substitute into M = V/U
M = v/(25f/(25+f))
Therefore:
M = (25/f) + 1

NB:
Angular magnification also is known as the **magnifying power**

Example,

A simple microscope with a focal length of 5 cm is used to read division of scale 1.5 mm in size. How large will the size of the divisions as seen through the simple microscope be?

Data given:
Focal length, f = 5cm
Object height, OH = 1.5mm
Image height, IH = ?

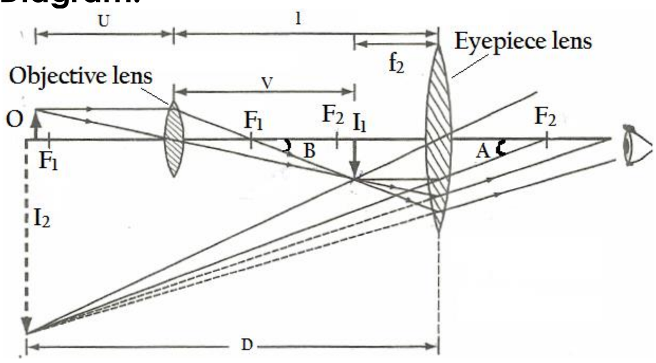
Solution:
From: M = (25/f) + 1
M = (25/5) + 1
M = 5 + 1
M = 6
Then: from M = IH/OH – make IH subject
IH = OH x M
IH = 1.5 x 6
IH = 9mm = 0.9cm
Therefore each division will appear to have a size of 9 mm when viewed through the simple microscope.

Uses
(i) It is used to view specimen in the laboratory
(ii) It is used to read small print

Compound Microscope
It composed of two convex lenses of short f placed in a tube. It separated by a certain fixed distance.

Mode of Action
Objective lens enlarge object to form image, I_1, then eyepiece enlarge to form image I_2. The image produced is magnified, virtual and inverted compared to the original object

Diagram:



Magnification
Magnification produced by the objective lens
MO = V/U
But: v = l - F_2
Then: **MO = (l - F_2)/U**

Magnification produced by the eyepiece lens
ME = **D/F_2**

The total magnification the linear magnification lens (M0) multiplied magnification of the (ME)
M = MO X ME
M = (l - F_2)/U X D/F_2
M = ((l - F_2) D) /(U X F_2)
NB: To produce large magnification, f_1 and f_2 must be very small compared to l.
Therefore: l - f_2 ≈ l
Since: The object must also be near f_2
Then: u ≈ f_2
Substitute u and l - f_2 into equation M = ((l - F_2) D) /(U X F_2)
Thus: M = Dl/f_2xf_1

M = Dl/f_2xf_1
This expression is used to determine the magnification produced by a compound microscope.

Example,
A compound microscope consists of two lenses of focal length 12 cm and 6 cm for the objective lens and the eyepiece lens, respectively. The two lenses are separated by a distance of 30 cm. The microscope is focused so that the image is formed at infinity Determine the position of the object.

Data given
Focal length of objective lens, f_1 = 12cm
Focal length of eyepiece lens, f_2 = 6cm
Distance between eyepiece and objective lens, l = 30cm
Distance of first image, u = ?
Distance of first image, u = ?

Solution
From: 1/f = 1/u + 1/v – make u subject
U = vf/(v-f)
U = (24 x 12)/(24-12)
U = (24 x 12)/12
U = 24 cm

Uses
i. Observing Brownian motion in science

ii. Studying microorganisms and cells in biology
iii. check for infections caused by microorganisms

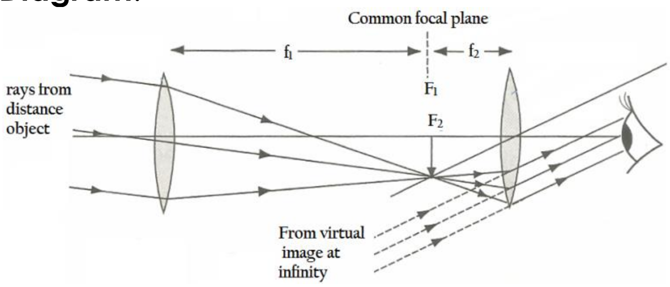
Astronomical Telescope

It uses two convex lenses: the objective lens and the eyepiece lens. The objective lens has a large focal length while the eyepiece lens has a much shorter focal length as you compare to compound microscope

Mode of Action

The objective lens forms a real, inverted and diminished image of a distant object at its focal point, F_1. This becomes the object for the eyepiece lens. The position of the eyepiece lens is adjusted until the object is at its focal point, F_2. This adjustment makes the final image to be formed at infinity.

Diagram:



NB:

i. The final image obtained in the astronomical telescope is small compared to the original object.
ii. The image looks larger because it is very much closer to the observer's eye.

Magnification

From: angular magnification

M = B/A

But: angles they subtend at the eye are the same as those they subtend at the objective and at the eyepiece lens, respectively.

Assuming: angle A and B are small

$B = h/f_2$

$A = h/f_1$

Since: M = B/A - substitute

$M = (h/f_2)/(h/f_1)$

$\mathbf{M = f_1/f_2}$

Therefore the magnification produced by an astronomical telescope is the ratio of the focal length of the objective lens to that of the eyepiece lens, i.e.

Uses

An astronomical telescope is used to view distant objects like stars and other objects in space.

Projection Lantern

Projection lanterns are used to display a large image on a screen. One Example, is the slide projector that is the optical inverse of a camera.

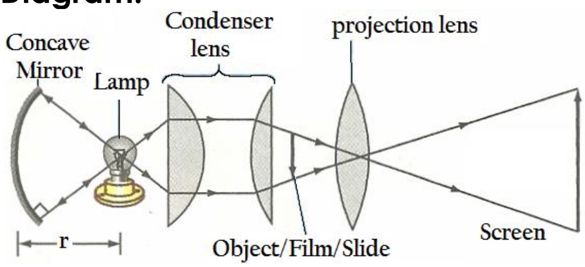
Mode of Action

An incandescent bulb positioned at the C of a concave mirror. Concave is reflects light travelling away from the concave mirror through the C to the condenser lens (usually identical). In order to focus the light p into a convergent beam

The beam falls on the slide or the photographic transparency (positioned between f and 2f) and proceeds through the image-forming projection lens.

The image formed on a distant screen. The image is focused on the screen by adjusting the projection lens in or out to changes the distance of the lens from the slide.

Diagram:



Magnification

It given by

M= V/U = IH/OH

Example,

A projection lantern is used to project a slide measuring 3 cm x 3 cm onto a screen 12 m from the projection lens. If the size of the screen is 1.5 m x 1.5 m, how far from the lens must the slide be for the image to fill the entire screen?

Data given:

Image height, IH = 1.5 m = 150 cm
Object height, OH = 3 cm
Image distance, v = 12 m = 1200 cm
Object distance, u =?

Solution

From: M= V/U = IH/OH
V/U = IH/OH – make u subject
U = (v x OH)/IH
U = (1200 x 3)/150
U = 3600/150
U = 24 cm.

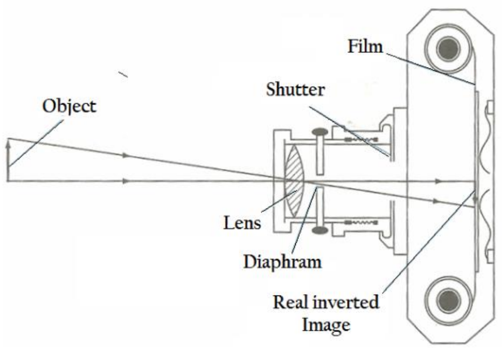
Uses

i. Projection of films, slides and transparencies.
ii. Projection of opaque objects, i.e. episcopic projection.
iii. In searchlights and headlights.
iv. In projection apparatus in industry for gauge and screw thread testing.
v. In physical experiments such as projection of the spectrum, polarisation experiments and interference experiments.
vi. Projection of minute objects, i.e. the projection microscope.

Lens Camera

The lens is the image-forming device on a camera.

Diagram:



Basic Types of Lenses

There are three basic types of lenses

i. Normal /standard lens
ii. wide angle lens
iii. telephoto/long-focus lens

Normal Lens

The viewing is much wider-about 50 degrees. The objects appear normal in size and shape, relative to the picture background

Wide Angle Lens

The viewing is much wider-about 90 degrees. Used to make smaller objects look larger or to photograph large objects from close up.

Telephoto Lens

It has wider fields of view than normal lenses. They show an enlarged detail of the image over the same film area.

Diaphragm/Stop

The diaphragm determines the amount of light that passes through the lens by changing the size of the aperture.

Shutter

The shutter is a mechanical device that acts as a gate, controlling the duration of time that light is allowed to pass through the lens and fall on the film.

Viewfinder

The viewfinder defines the area covered by the lens that is in use on the camera.

Film

The film is a light-sensitive surface of the camera. Exposure of the film (Silver halide is a compound of silver with fluorine, chlorine, bromine, or iodine) to light produces an invisible change on the silver halide grains yielding a latent image. The image becomes visible on being treated with certain chemicals in a process known as **developing**.

Mode of Action

When shutter opens to allow light to enter and expose the film to form an image of the object being photographed.

Magnification

Since magnification is given by
M = IH/OH
M = V/U – make v subject
V = M u

Substitute v into 1/f = 1/u + 1/v
V = M u
1/f = 1/u + 1/Mu
1/f = (M-u)/ Mu
1/f = (M-u)/Mu – reciprocal both sides

f = Mu/(M-u) – make M subject

M = f/(u-f)

Example,

A lens camera of focal length 10 cm is used to take the picture of a girl 1.5 m tall. Determine the magnification of the image if the girl is 11m from the camera.

Data given:

Focal length, f = 10 cm = 0.1 m

Image height, IH = 1.5 m

Object distance, u = 11m

Magnification, M =?

Solution:

From: M = f/(u-f)

M = 0.1/(11-1.0)

M = 0.1/10.9

<u>M = 0.009</u>

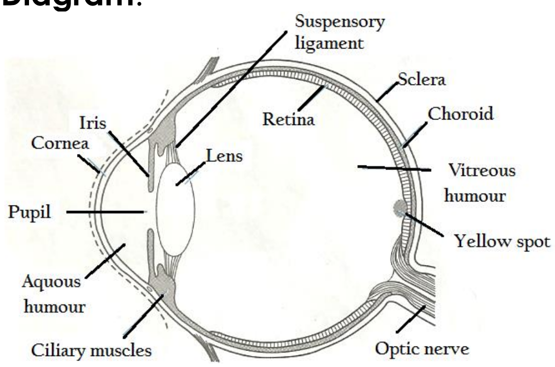
Uses of Lens Camera

i. The sine or video camera is used to take motion pictures.
ii. High-speed cameras used to record movement of particles.
iii. Closed-circuit television cameras used for surveillance in high-security
iv. Digital cameras used to capture images

The Human Eye

It is able to focus on objects from billions of kilometers away to those a few centimeters away. It can also detect colour.

Diagram:



Parts of the Human Eye

1. **Cornea**
   The cornea is the transparent, outer part of the eye. It is the primary focusing tool of the eye. The outer layer of the cornea is known as the **epithelium**.

   Function of cornea
   Its main job is to protect the eye

2. **Iris**
   The iris is the part of the eye which is responsible for one's eye colour.

3. **Function of Iris**
   It dilating and constricting the pupil to allow more or less light into the eye.

4. **Pupil**
   The pupil is the dark opening in the centre of the coloured iris that controls the amount of light that enters the eye.

   NB:
   The pupil functions in the same way as the aperture of a camera. The size of the pupil determines the amount of light entering the eye.

5. **Lens**
   The lens is the part of the eye immediately behind the iris.

   Function of lens
   To focus light rays on the retina. In persons under 40 years of age, the lens is soft and flexible, allowing for fine focusing from a wide variety of distance

6. **Retina**
   The retina is the membrane lining the back of the eye that contains photoreceptor cells it reacts to the presence and intensity of light by sending an impulse to the brain via the optic nerve.
   NB: The retina compares to the film in a lens camera.

7. **Optic nerve**
   The optic nerve (million nerve fibres) is the structure which takes the information to the brain

8. **Sclera**
   The sclera is the white, tough wall of the eye.

   Function of Sclera

To protect the eye

9. **Vitreous humour**
   The vitreous humour is a jelly-like substance that fills the body of the eye. It is normally clear

   The Function of vitreous humour
   i. To maintains the eye pressure.
   ii. It also helps in focusing light rays

Accommodation

Defn: Accommodation is the process whereby an eye focal length adjusted to see distance object

Eye Defects

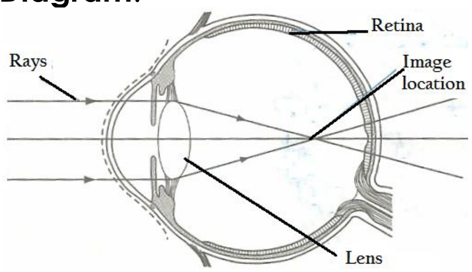
Eye defect is the phenomenon where by eye defeat to see clearly. There are two common eye defects.

i. Myopia/short-sightedness defect
ii. Hypermyopia /long-sightedness defect

Myopia

Occur when a person can see near objects clearly but cannot see distant objects clearly.

Diagram:



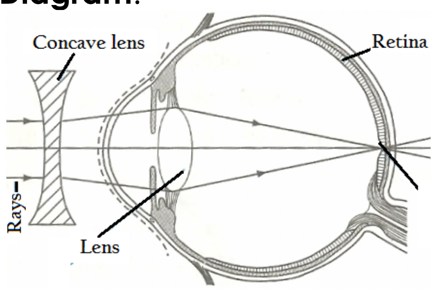
Causes

When the eyeball is longer than normal along the horizontal

Correction

To wear suitable concave lenses to diverge the rays from distant objects before they reach the eye.

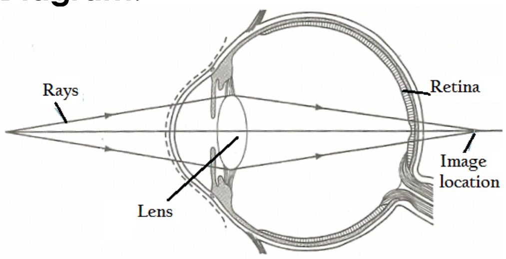
Diagram:



Hypermyopia

Occur when a person cannot see near objects clearly but can see distant objects clearly.

Diagram:



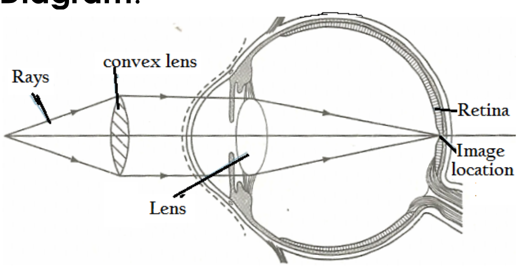
Causes

When the eyeball is shortening than normal along the

Correction

To wear suitable convex lenses to diverge the rays from distant objects before they reach the eye.

Diagram:



Similarities of Human Eye and Lens Camera

i. They both have a convex lens system to focus the image
ii. Both form a real, reduced and inverted image
iii. The amount of light entering is controlled by a variable aperture
iv. They both have surfaces on which the image is formed

Differences of Human Eye and Lens Camera

i. The eye focuses by altering the shape of the lens while the camera focuses by altering the distance between the lens and the film.
ii. The image formed on the film is processed chemically to produce the final image while the image in camera formed is converted to an electrical signal travels along the optic nerve
iii. Eye remain open to constant changing pictures with continuous motion while

shutter open to allow photo to be taken

iv. Eye have fluid for refraction while camera contain air

Thermal Expansion

Defn: *Thermal expansion is the tendency of matter to change in volume due to change in temperature*. Expansion it results

i. When the ball of ball and ring when heated it does not fit in the ring since its volume increases
ii. When the ball of ball and gap when heated it does not fit in the ring since its volume increases
iii. Bimetallic strip to bend
iv. The bridge or roof is fixed while the other side rests on rollers so that movements of the bridge or roof are allowed for during expansion and contraction
v. Rail lines are laid in such a way that a gap is left at the junction of two rail bars
vi. Bottle containing cold liquid cracks if placed near a strong fire
vii. Thick walled glass tumblers are known to break when hot substances are poured into them

Terminologies

i. **Thermonuclear fusion** is the process whereby the sun generates
ii. **Thermal energy** is the energy possessed by a body due to its temperature also called the **heat content of the body.** Increase in temperature also thermal energy increase
iii. **Heat** is a form of energy transferred from one body to another due to difference in temperature. Transferred until reach thermal **equilibrium,** It denoted by letter 'Q'
iv. **Thermal equilibrium** is the situation whereby the temperature of two or more body are equal
v. **Temperature** is the degree of coldness or hotness of a body.
vi. **Geothermal energy** is the heat energy delivered from the earth core
vii. **Nuclear energy** is energy generated from nuclear reactions. . In nuclear reactions, the nuclei of certain elements are split (nuclear fission) or combined (nuclear fusion)
viii. **Amplitude** is the maximum distance where the object moves and fro.
ix. **Expansion** is the process whereby object increase its volume due to increase in temperature
x. **Contraction** is the process whereby object decrease its volume due to decrease in temperature

Sources of Thermal Energy

The sources of thermal energy include;

i. the sun
ii. combustion of fuels
iii. nuclear reactions and
iv. geothermal energy

Nb:

i. Most sources of thermal energy on earth derive their energy from the sun
ii. Geothermal energy reaches the earth's surface in form of geysers, hot springs and fumaroles
iii. Geothermal energy is a renewable and a non-polluting energy

Why Substance Expand?

When a substance is heated the kinetic energy of the particles is increased , its particles move around more vigorously and tend to move away or separate farther from each other thus why the volume of substance increase and vice versa. All states of matter (solids, liquids and gases) expand when heated.

Thermal Expansion of Solids

The expansion of solid substance is so small that it is difficult to observe its changes

Linear Expansivity/Coefficient of Linear Expansion

Defn: Linear expansivity is the increase in length per unit length of the substance when its temperature rises by 1°C or 1 K. The SI unit for linear expansivity is K^{-1}

Mathematically:

Linear expansivity = $\frac{\text{increase in length}}{\text{originsl lenth x rise in temperature}}$

$$\boldsymbol{\alpha} = \frac{\Delta l}{l1 \; x \; \Delta\theta}$$

Since: $\Delta l = l2 - l1$

$$\boldsymbol{\alpha} = \frac{l2 - l1}{l1 \; x \; \Delta\theta}$$

Since: θ = (θ2 – θ1)

$$\alpha = \frac{(l2 - l1)}{l1 \times (\theta 2 - \theta 1)}$$

Where:
α = Linear expansivity
Δθ = (θ2 – θ1) = rise in temperature
θ2 = initial temperature
θ1 = final temperature
Δl = (L2 – l1) = increase in length
L1 = original length
L2 = new length

NB:
i. Linear expansivity is different for different substances.

Linear Expansivities between (0 – 100)°C

Substance	**Linear expansivity (K^{-1}) x 10^{-4}**
Aluminium	25.5
Brass	18.9
Copper	16.7
Iron	10.2
Steel	10.5
Glass	8.5
Pyrex glass	3.0
Invar	0.9

Example,
A block of concrete 5.0 m long expands to 5.00412 m when heated from 25°C to 100°C. Determine the linear expansivity of concrete.
Data given
Initial temperature, θ1 = 25°C
Final temperature, θ2 = 100°C
Temperature rise, Δθ = (100 – 25)°C = 75°C
Original length, L1 = 5.0 m
New length, L2 = 5.00412 m
Increase in length, (5.00412 – 5.0) = 0.004 m
Linear expansivity, a = ?
Solution
From: $a = \frac{\Delta l}{l1 \times \Delta\theta}$

$a = \frac{0.00412}{5.0 \times 75}$

$a = \frac{0.00412}{5.0 \times 75}$

a = 1.1 x 10^{-5} ℃ = 1.1 x 10^{-5} K^{-1}

Example: NECTA 2013 QN: 4(c)
A metal pipe which of 1M long at 40°C increases in length by 0.3% when carrying a stream at 100°C. Find the Coefficient of Linear Expansion
Data given
Initial temperature, θ1 = 40°C
Final temperature, θ2 = 100°C
Temperature rise, Δθ = (100–25)°C = 60°C
Original length, L1 = 1 m
New length, L2 = L1 + (L1x 0.03%) = 1 + 1x0.3 = 1.003 m
Increase in length, (1.003 - 1) = 0.003 m
Coefficient of Linear Expansion, a =?
Solution
From: $a = \frac{\Delta l}{l1 \times \Delta\theta}$

$a = \frac{0.003}{1 \times 66} = \frac{0.003}{60} = 5 \times \underline{10^{-5}}$

a = 5 x 10^{-5} ℃ = 5 x 10^{-5} K

Example,
A brick (30 cm x 18 cm x 10 cm) at 20°C, If the brick heated to a temperature of 150°C, what will be its new dimensions? (The coefficient of linear expansion of concrete is 1.2 x 10^{-5} K^{-1}
Data given
Initial temperature, θ1 = 20°C
Final temperature, θ2 = 150°C
Rise in temperature, Δθ = (θ2 – θ1) = (150 – 20)°C = 130°C
Linear expansivity, a = 1.2 x 10^{-5} K^{-1}
Original length, L1l = 30 cm
Original width, L1w = 18 cm
Original height, L1h = 10 cm
New length, L2l = ?
New width, L2w = ?
New height, L2h = ?
Solution
From: $a = \frac{l2 - l1}{l1 \times \Delta\theta}$ make l2 subject
L2 = (l1 x Δθ)a + l1
L2 = (l1 x Δθ)a + l1

1st solve for L2l when L1l = 30 cm
L2l = ((30 x 130)1.2 x 10^{-5}) + 30
L2l = (390 x 1.2 x 10^{-5}) + 30
L2l = (390 x 1.2 x 10^{-5}) + 30 = 30.05 cm
L2l = 30.05 cm

2nd solve for L2w when L1w = 18 cm
L2w = ((18 x 130)1.2 x 10^{-5}) + 18
L2w = 18.03 cm

3rd solve for L2h when L1h = 18 cm
L2h = ((10 x 130)1.2 x 10^{-5}) + 10
L2h = 10.02 cm

Therefore:
The new dimension is 30.05 cm x 18.03 cm x 10.02cm

Example,
An iron plate at 20°C has a hole of radius of 8.92 mm in the centre, an iron rivet with radius of 8.95 mm at 20°C, inserted into the hole. To what temperature the plate heated for the rivet to fit into the hole. (Linear expansivity of iron is $1.24 \times 10^{-5}K^{-1}$).

Data given
Initial temperature, θ1 = 20°C
Original length, L1 = 8.92 mm
New length, L2 = 8.95 mm
Increase in length, Δl = (L2 – l1) = (8.95 – 8.92) = 0.03 mm
Linear Expansivity, a =1.24 x10^{-5} K^{-1} = 0.0000124 K^{-1}
Final temperature, θ2 = ?

Solution
From: a = $\frac{\Delta l}{l1 \; x \; (\theta 2 - \theta 1)}$ make θ2 subject

θ2 = $\frac{\Delta l}{\alpha \; x \; l1} + \theta 1$

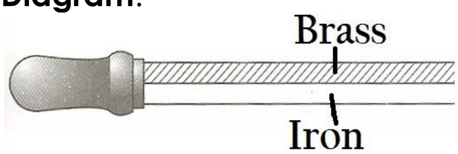
θ2 = $\frac{0.03}{0.0000124 \; x \; 8.92} + 20$

θ2 = 271.23 ℃

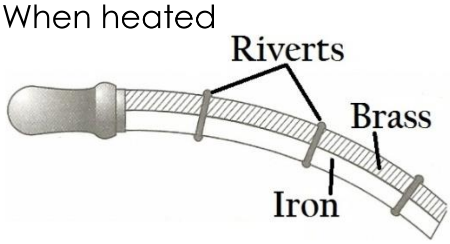
This is the temperature iron plate must undergo. Since initial temperature is 20°C the plate must be heated to (20 + 271.23) °C = 291.23 °C or slightly higher

The Bimetallic Strip
The bimetallic strip consists of two different metals that expand at different rates when heated through the same temperature change.

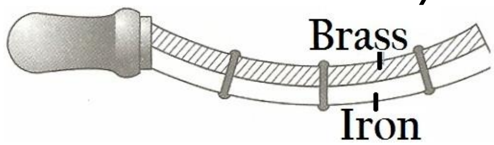
Diagram:



When heated



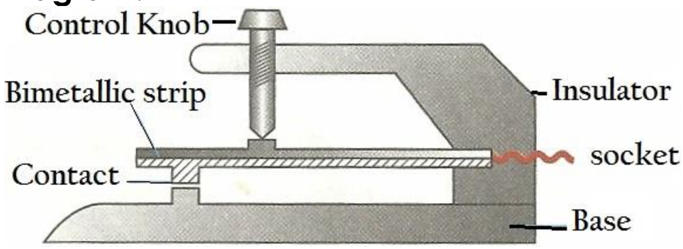
When cooled



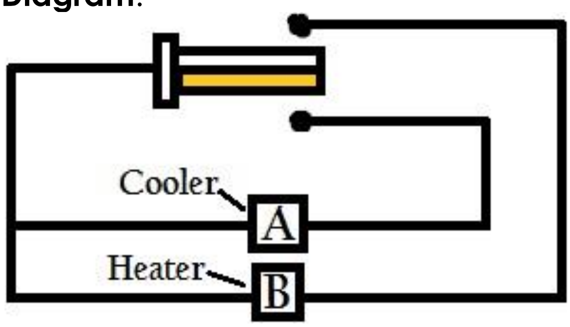
Nb:
i. The metal that expands faster forms the outside part of the curve while the one that expands more slowly is on the inside of the curve.
ii. Brass expands and contracts twice as fast as steel.
iii. temperature must be measured in Kelvin

Applications of the Expansion of Solids
1. The bimetallic strip used in thermostats, thermometers and valves. Thermostats are used in many appliances such as electric irons, heaters, refrigerators, air conditioners, fire alarms and Valves

Electric iron
When metallic strip bend to break a circuit
Diagram:



Heater
When metallic strip bend to break/close a circuit to maintain temperature inside the refrigerator
Diagram:

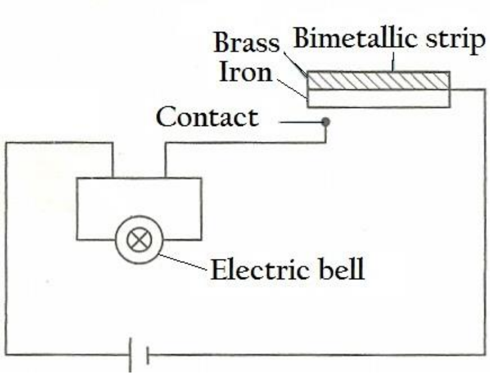


Refrigerator
When metallic strip bend to break/close a circuit to maintain temperature inside the refrigerator

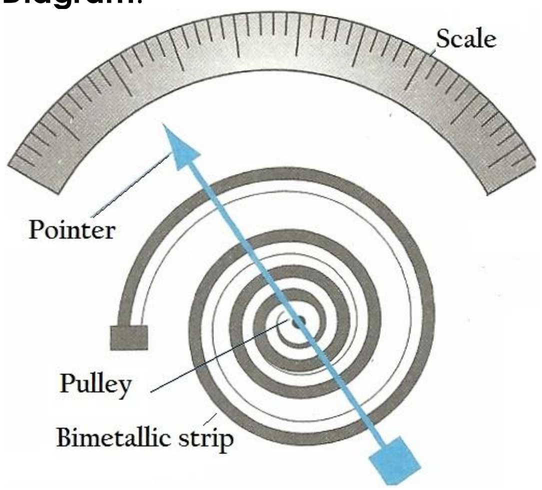
Air conditioner

When metallic strip bend to break/close a circuit to maintain required temperature

Fire alarms circuit
When temperature rise metallic strip bend to close a circuit which complete the circuit and bell start to ring.
Diagram:

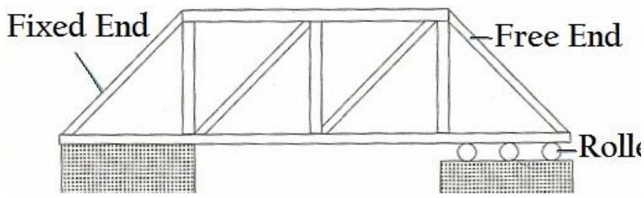


Bimetallic thermometer
When temperature rise metallic strip bend results the pointer to rotate across pulley
Diagram:

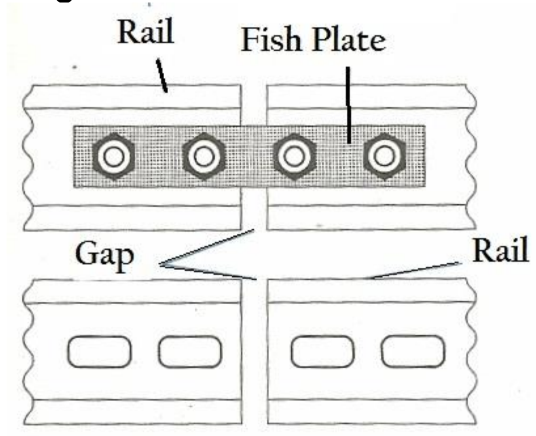


Bimetallic Valve
When metallic strip bend to close or open valve

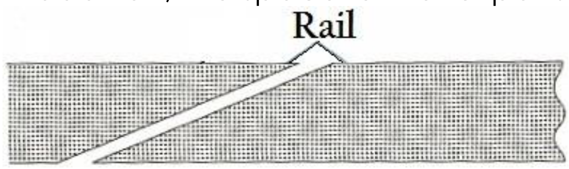
2. **applied in the design of bridges/house roofs etc**
In order to prevent expansion one end left free with roller so when bridge expand fee end move forward and backward without break



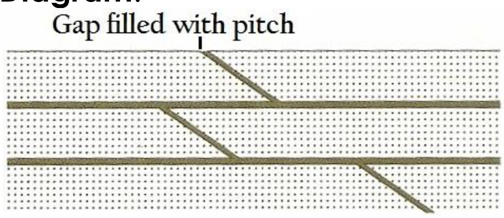
3. **railway lines construction**
In order to prevent expansion always gape left between two rails
Diagram:



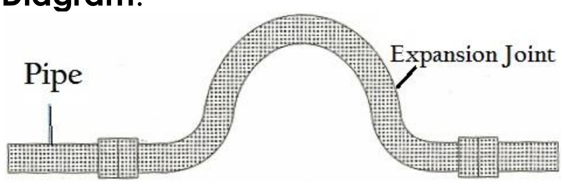
In addition, the space left for expansion



4. **construction of road and pavement**
In order to prevent expansion always gape left between the slabs. Gape filled with pitch
Diagram:



5. **applied in hot-water pipe**
In order to prevent destruction which arise from expansion, pipe are fitted with expansion joint
Diagram:



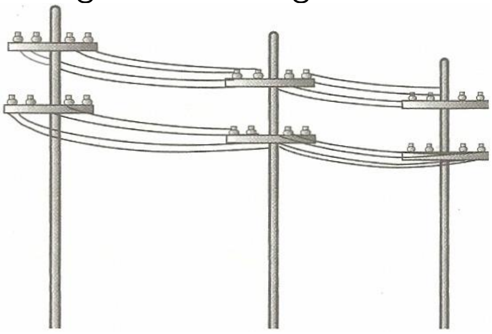
6. **applied in the design of pendulum clocks**
Pendulums and balance wheels in clocks are compensated for expansion so that the clocks keep correct time even when temperatures change
7. **the riveting of metals**

Car wheels and train wheels fitted when red-hot. On cooling, they contract and fit very tightly and therefore do not require screws and nuts

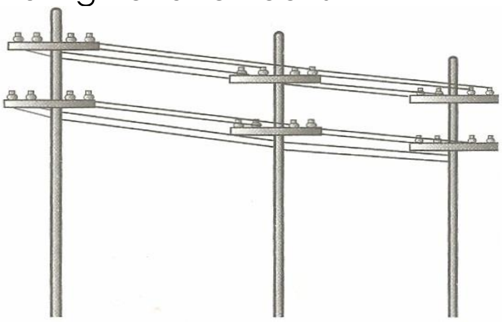
8. Overhead telephone and electrical cables left sagging during installation on a hot day to allow for contraction

Diagram:

During cold mornings



During hot afternoons



Thermal Expansion of Liquids

It is easier to observe expansion in liquids than in solids. This is because liquids expand much more than solids for equal changes of temperature.

What Happens When Water Heated?

The level of the water will first drop due to increase in the volume of the container on heated. The increase in volume is due to the expansion of the container. The level of the water will then keep rising as the container due to the expansion of the water, its density decrease.

Apparent Volume Expansion of A Liquid

Defn: apparent volume expansion/apparent volume expansion of a liquid is equal to the actual expansion of the liquid less the increase in volume of the containing vessel up to the liquid level

Volume Expansivity of a Liquid

Defn: volume expansivity is the fractional change in volume per unit temperature change. Its unit is K^{-1} or $°C^{-1}$. It also called **coefficient of volume of expansion**

Volume expansivity = $\frac{\textit{increase in volume of liquid}}{\textit{original volume x rise in temperature}}$

$$\beta = \frac{v2 - v1}{v1 \times \Delta\theta}$$

Where:

Original/initial volume of liquid = v1

Final volume = V2

Increase in volume of liquid = v2 – v1

Initial temperature = θ1

Final temperature = θ2

Rise in temperature = Δθ = (θ2 – θ1)

Volume expansivity = β

Linear Expansivities Between (0 – 100)°C

Liquid	**Volume Expansivity (K^{-1}) X 10^{-5}**
Benzene	124
Gasoline	95
Glycerin	53
Kerosene	99
Mercury	18
Methanol	122
Water at 20°C	21
Water at 35°C	35
Water at 90°C	70

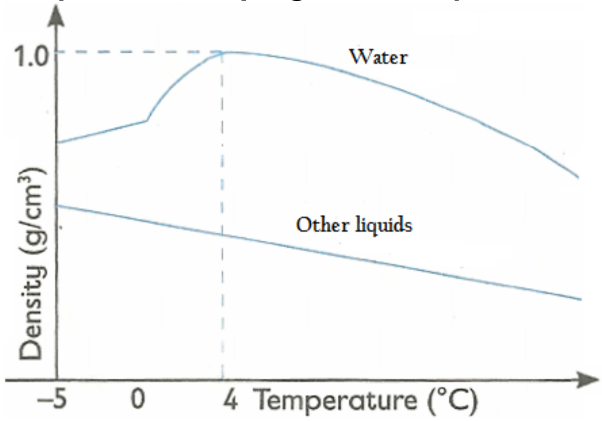
Anomalous Expansion of Water

Defn: Anomalous expansion of water is the decrease in the density of water cooled from 4°C to 0°C.

What Happens Below 4°C TO 0°C

At 4°C, just above the freezing point, water reaches its maximum density. As the water cool further toward its freezing point, the liquid water expands to become less dense.

Graph of Density against Temperature °C



Effect of Water Anomalous Expansion

i. A glass bottle filled with water and sealed cracks if cooled in a deep freezer

ii. If water freezes in a pipe, it may cause the pipe to burst open due to expansion.

iii. Icebergs, being less dense than water, float in oceans thus posing a danger to ships.

Applications of Expansion of Liquids

i. Due to small density from 4°C to 0°C ice float results fish and other aquatic life to survive in the water below the ice

ii. The expansion of liquids used in liquid thermometers.

Thermal Expansion in Gases

In subtopic we will discuss about Three importance properties of expansion of gases include are pressure, volume and temperature.

Nb:

The temperature must converted to Kelvin scale

Charles' Law

This law involves the relationship between the volume and the temperature of a fixed mass of a gas at constant pressure. The law state that

"***The volume of a fixed mass of a gas is directly proportional to the absolute (Kelvin) temperature provided the pressure remains constant***"

Mathematically

V a T

V= K T – make K subject

K= $\frac{T}{v}$

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

Where:

V1 = initial volume

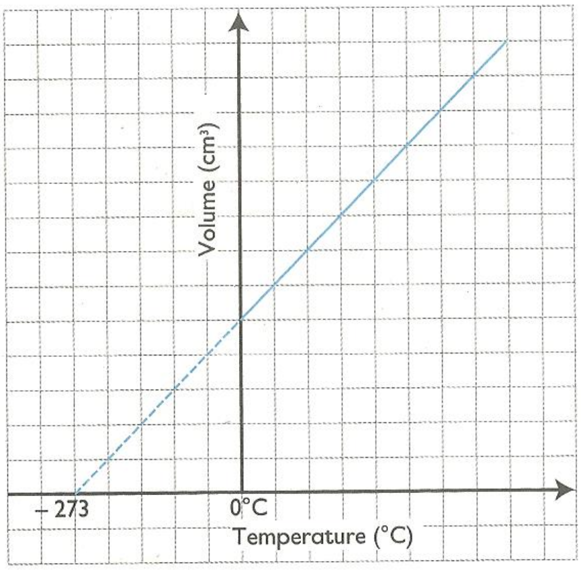
T1 = initial temperature

V2 = final volume

T2 = final temperature

Graphically:

Graph of Volume against temperature (K)



From the graph above it seems that as if temperature increased also volume increase and vice versa

Absolute Scale of Temperature

Defn: absolute zero temperature is the lowest temperature that can attained theoretically.

Conversion

T (K) = 273 +θ°C

θ°C = T(K) - 273

Example,

Change the following temperatures to Kelvin scale (a) 33°C (b) 57°C

Data given

(a) Temperature in Celsius, θ = 33°C

Temperature in Kelvin, K = ?

Solution

From: T (K) = 273 +θ°C

T (K) = 273 +33°C

T (K) = (273 + 33) = 306 K.

T (K) = 306 K

(b) Temperature in Celsius, θ = 57°C

Temperature in Kelvin, K = ?

Solution

From: T (K) = 273 +θ°C

T (K) = 273 +57°C

T (K) = (273 + 57) = 330 K.

T (K) = 330 K

Example

Change the following temperatures to Celsius scale (a) 4K (b) 292K

(a) Temperature in Kelvin, K = 4K

Temperature in Celsius, θ = ?

Solution

From: θ°C = T(K) – 273

θ°C = 4K - 273

θ°C = - 269°C

(b) Temperature in Kelvin, K = 292K

Temperature in Celsius, θ = ?

Solution

From: θ°C = T(K) – 273

θ°C = 292K - 273

θ°C = 19°C

Example

A 0.20m^3 container with a movable piston holds nitrogen gas at a temperature of 20°C. What will be the volume of the gas if the temperature increased to 50°C?

Data given

Initial volume, V1 = 0.20m^3

Initial temperature, T1 = 20°C = 293K
Final temperature, T2 =50° = 323K
Final volume, V2 = ?

Solution

From Charles' law: T1/V1 = T2/V2 – make V2 subject
V2 = (T2xV1)/T1
V2 = (323 x 0.2)/293
V2 = 0.22 m^3

Example,

A gas occupies a volume of 20 cm^3 at 27°C and at normal atmospheric pressure. Calculate the new volume of the gas if it heated to 54°C at the same pressure.

Data given

Initial volume, V1 = 20 cm^3
Initial temperature, T1 = 27°C = 300K
Final temperature, T2 =54° = 327K
Final volume, V2 = ?

Solution

From Charles' law: T1/V1 = T2/V2 – make V2 subject
V2 = (T2xV1)/T1
V2 = (327x20)/300
V2 = 21 cm^3

Boyle's Law

This law involves the relationship between the volume and the pressure of a fixed mass of a gas at constant temperature. The law state that

"The volume of fixed mass of a gas is inversely proportional to its pressure if the temperature is kept constant"

Mathematically

P a $\frac{1}{v}$

P = K $\frac{1}{v}$ - make K subject

Then:

K = P1V1 = P2V2

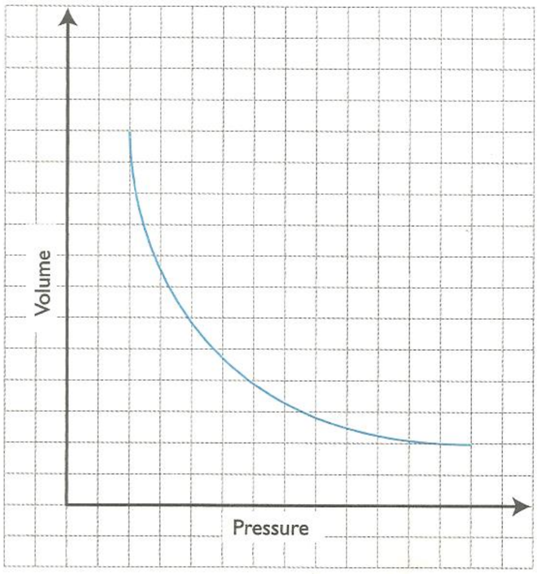
P1V1 = P2V2

Where:

P1 = initial pressure
V1 = initial volume
P2 = final pressure
V2 = final volume

Graphically:

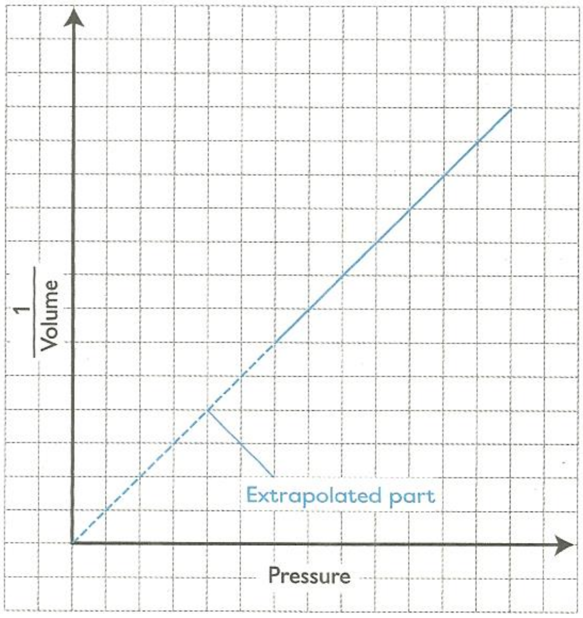
Graph of Volume against Pressure



From the graph above it seems that as if pressure increased also volume decrease and vice versa

Graphically:

Graph of inverse of Volume against Pressure



From the graph above it seems that as if pressure increased also inverse of volume increase and vice versa

Example,

A gas in a cylinder occupies a volume of 465 ml when the pressure on it is equivalent to 725 mm of mercury. What will be the volume of the gas when the pressure on it raise to 825 mm of mercury while the temperature is held constant?

Data given

Initial pressure, P1 = 725 mmHg
Initial volume, V1 = 465 ml
Final pressure, P2 = 825 mmHg

Final volume, V2 = ?

Solution

From Boyle's law: P1V1 = P2V2 – make V2 subject

V2 = P1V1/P2

V2 = (465 x725)/825

<u>V2 = 408.6 ml</u>

Example,

Bubble of gas, which has a volume of 0.4 $cm^{3,}$ released by a diver 30 m in under the surface of a lake, what will be the volume of the bubble when it reaches the surface? (Assume the barometric pressure is 10 m of water.)

Data given

Pressure under the water, P1 = 30 mHg

Volume under water, V1 = 0.4 cm^3

Pressure outside water, P2 = 10 mHg

Pressure under the water, V2 = ?

Solution

From Boyle's law: P1V1 = P2V2 – make V2 subject

V2 = P1V1/P2

V2 = (30 x0.4)/10

<u>V2 = 1.2 cm^3</u>

Pressure Law

This law involves the relationship between the temperature and the pressure of a fixed mass of a gas at constant volume. The law state that

"***The pressure of a fixed mass of a gas is directly proportional to the absolute temperature if the volume is kept constant***"

Mathematically

P a $\frac{1}{T}$

P = K $\frac{1}{K}$ - make K subject

Then:

K = P1T1 = P2T2

P1T1 = P2T2

Where:

P1 = initial pressure

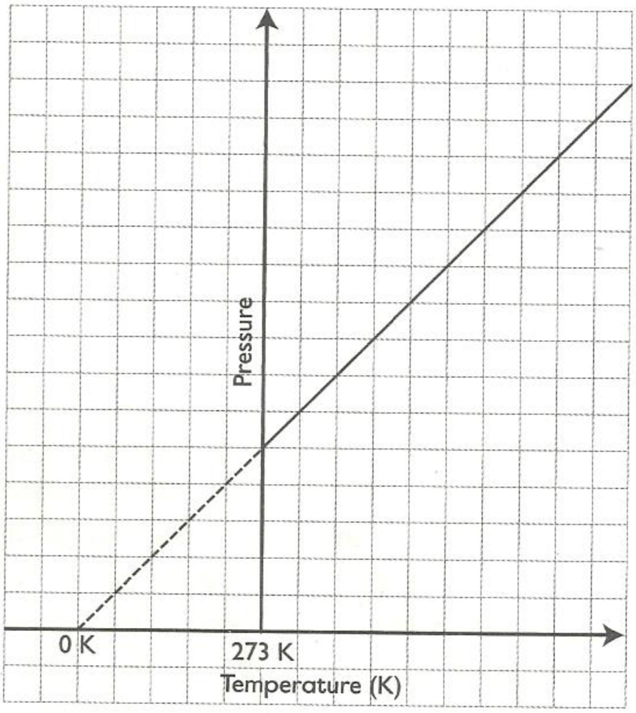
T1 = initial temperature

P2 = final pressure

T2 = final temperature

Graphically:

Graph of Pressure against temperature



From the graph above it seems that as if pressure increased also temperature increase and vice versa

Example,

A rigid metal container holds carbon dioxide gas at a pressure of 2 x 10^5 Pa and a temperature of 30°C. What temperature the gas be lowered for the pressure to reduce to half (1 x 10^5 Pa)?

Data given

Initial pressure, P1 = 2 x 10^5 Pa

Initial temperature, T1 = 30°C = 303K

Final pressure, P2 = 1 x 10^5 Pa

Final temperature, T2 =?

Solution

From pressure law: P1T1 = P2T2 – make T2 subject

T2 = (P1T1)/P2

T2 = (2 x 10^5 x 303)/ 1 x 10^5

<u>T2 = 151.5K = -121.5°C</u>

Example,

A gas in a fixed-volume container has a pressure of 1.6 x 10 Pa at a temperature of 27°C. What will be the pressure of the gas if the container heated to a temperature of 277°C?

Data given

Initial pressure, P1 = 1.6 x 10^5 Pa

Initial temperature, T1 = 27°C = 300K

Final temperature, T2 =277°C = 550K

Final pressure, P2 = ?

Solution

From pressure law: P1T1 = P2T2 – make P2 subject

P2 = (P1T1)/T2

P2 = (1.6 x 10^5 x 300)/ 550

P2 = 2.93 x 10^5

General Gas Equation/General Gas Law

Combine all laws

T α V – Charles' law …………….. 1

P α $\frac{1}{v}$ - Boyle's law ………………. 2

P α $\frac{1}{T}$ - pressure law …………….. 3

Combine equation 1, 2 and 3 we get

P α $\frac{V}{T}$

P = k$\frac{V}{T}$ - make k subject

K = $\frac{PV}{T}$ - since K is the constant then

$\frac{P1V1}{T1} = \frac{P2V2}{T2}$

Standard Temperature and Pressure (STP)

Defn: STP is a set of conditions for experimental measurements to enable comparisons between sets of data. The standard temperature is 0°C (273 K) while the standard pressure is 1 atmosphere (1.013 x 10 Pa or 760 mm of mercury).

Example,

A sample of oxygen gas has a volume of 0.11 m^3 at a temperature of 12°C and a pressure of 8.1 x 10^5 Pa while a sample of nitrogen gas has a volume of 0.18 m^3 at a temperature of 22°C and a pressure of 1.03 x 10^5 Pa. Which gas will have the larger volume at STP?

Data given

Initial pressure for oxygen, Po1 = 8.1 x 10^4 Pa

Initial temperature oxygen, To1 = 12°C = 285K

Initial volume oxygen, Vo1 = 0.11 m^3

Final temperature oxygen, To2 =0°C = 273K

Final pressure oxygen, Po2 = 1.013 x 10^5 Pa

Final volume oxygen, Vo2 = ?

Initial pressure for nitrogen, Pn1 = 1.03 x 10^5 Pa

Initial temperature nitrogen, Tn1 = 22°C = 295K

Initial volume nitrogen, Vn1 = 0.18 m^3

Final temperature nitrogen, Tn2 =0°C = 273K

Final pressure nitrogen, Pn2 = 1.013 x 10^5 Pa

Final volume nitrogen, Vn2 = ?

Solution

From general gas law: (P1V1)/T1 = (P2V2)/T2

For oxygen:

(Po1Vo1)/To1 = (Po2Vo2)/To2 – make Vo2 subject

Vo2 = (Po1.Vo1.To2)/(To1.Po2)

Vo2 = (8.1 x 10^4 x 0.11 x 273)/(285 x1.013 x 10^5)

Vo2 = (2.43 x 10^6)/(2.89 x 10^7)

Vo2 = 0.084 m^3

For nitrogen:

(Pn1Vn1)/Tn1 = (Pn2Vn2)/Tn2 – make Vn2 subject

Vn2 = (Pn1.Vn1.Tn2)/(Tn1.Pn2)

Vn2 = (1.03 x 10^5 x 0.18 x 273)/(295 x1.013 x 10^5)

Vn2 = (5.06 x 10^6)/(2.99 x 10^7)

Vn2 = 0.17 m^3

At STP, nitrogen gas would have a volume that is more than twice the volume of oxygen gas.

Example,

A fixed mass of gas has a volume of 1.25 litres at a pressure of 76.0 cm of mercury and a temperature of 27.0°C. The gas expands to a volume of 1.55 litres raising the pressure to 80.0 cm of mercury. What is the final temperature of the gas in °C?

Data given

Initial pressure for mercury, P1 = 76.0 cmHg

Final pressure mercury, P2 = 80.0 cmHg

Initial volume mercury, V1 = 1.25 dm^3

Final volume mercury, V2 = 1.55 dm^3

Initial temperature mercury, T1 = 27°C = 300K

Final temperature oxygen, T2 = ?

Solution

From: (P1V1)/T1 = (P2V2)/T2 – make T2 subject

T2 = (P2.V2.T1)/(P1.V1)

T2 = (80 x 1.55 x 300)/(76 x 1.25)

T2 = 37200/95

T2 = 391.58K = 118.58°

Example,

A fixed mass of gas occupies a volume of 0.001 m^3 at a pressure of 76 cmHg. What volume does the gas occupy at 17.0°C if its pressure is 72 cmHg?

Data given

Initial pressure for mercury, P1 = 76.0 cmHg
Final pressure mercury, P2 = 72.0 cmHg
Initial volume mercury, V1 = 0.001 m^3
Initial temperature mercury, T1 = 0°C = 273K
Final temperature oxygen, T2 = 17°C = 290K
Final volume mercury, V2 = ?

Solution:

From: (P1V1)/T1 =(P2V2)/T2 – make V2 subject
V2 = (P1.V1.T2)/(T1.P2)
V2 = (P1.V1.T2)/(T1.P2)
V2 = (76 x 0.001 x 290)/(273 x 72)
V2 = (22.04)/(19656)
V2 =1.12 x 10^{-3} m^3

Example,

100 cm^3 of gas A was collected at 10°C and 78.0 cmHg pressure, while 120 cm^3 of gas B was collected at 50°C and 70.0 cmHg pressure. Which of the two gases is denser at STP?

Data given

Initial pressure for A, PA1 = 78.0 cmHg
Initial temperature for A, TA1 = 10°C = 283K
Initial volume for A, VA1 = 100 cm^3
Final temperature for A, TA2 =0°C = 273K
Final pressure for A, PA2 = 76.0 cmHg
Final volume for A, VA2 = ?
Initial pressure for B, PB1 = 70.0 cmHg
Initial temperature for B, TB1 = 50°C = 323K
Initial volume for B, VB1 = 120 cm^3
Final temperature for B, TB2 =0°C = 273K
Final pressure for B, PB2 = 76.0 cmHg
Final volume for B, VB2 = ?

Solution

From general gas law: (P1V1)/T1 = (P2V2)/T2

For gas A:
(PA1VA1)/TA1=(PA2VA2)/TA2 –make VA2 subject
VA2 = (PA1.VA1.TA2)/(TA1.PA2)
VA2 = (78 x 100 x 273)/(283 x 76)
VA2 = (2129400)/(21508)
Vo2 = 99.00 cm^3

For gas B:
(PB1VB1)/TB1 =(PB2VB2)/TB2 – make VB2 subject
VB2 = (PB1.VB1.TB2)/(TB1.PB2)
VB2 = (70 x 120 x 273)/(323 x 76)
VB2 = (2293200)/(24548)
VB2 = 93.42 cm^3

At STP, gas B has large volume than gas A so gas A is denser than gas B

Example,

250 cm^3 of a gas are collected at 25°C and 750 mm of mercury. Calculate the volume of the gas at STP

Data given

Initial pressure for mercury, P1 = 750 mmHg
Final pressure mercury, P2 = 760 mmHg
Initial volume mercury, V1 = 250 cm^3
Initial temperature mercury, T1 = 25°C = 298K
Final temperature oxygen, T2 = 0°C = 273K
Final volume mercury, V2 = ?

Solution:

From: (P1V1)/T1 =(P2V2)/T2 – make V2 subject
V2 = (P1.V1.T2)/(T1.P2)
V2 = (P1.V1.T2)/(T1.P2)
V2 = (750 x 250 x 273)/(298 x 760)
V2 = (51187500)/(226480)
V2 =226.01 cm^3

Applications of the Expansion of Gases

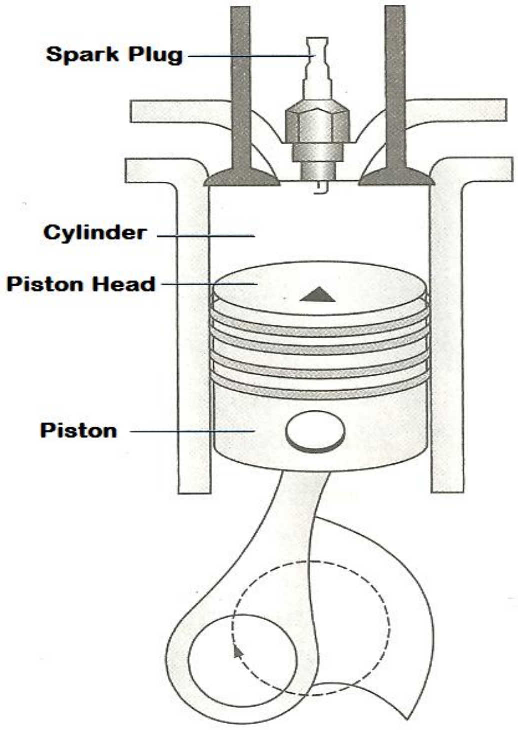
1. **Land and sea breezes**

Land and sea breezes are a result of expansion of air caused by unequal heating and cooling of adjacent land and sea surfaces.

2. **The piston engine**

The internal combustion engines used in vehicles have four basic parts

Diagram:



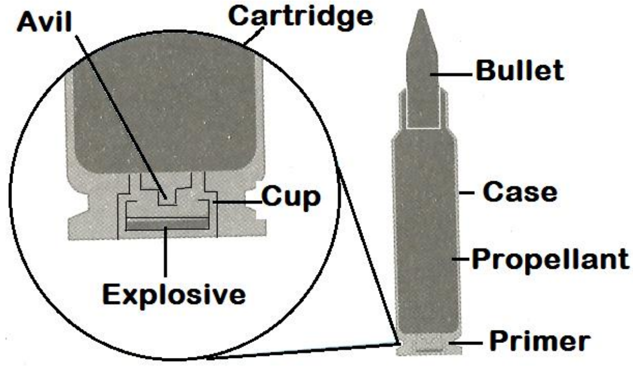
i. **Carburetor**
In this part fuel mixed with air or is sprayed through the fuel injector. This part also called **fuel injector**

ii. **Cylinders**
The mixture goes into a cylinder, which is a long air pocket like steel can with one end open

iii. **spark plugs**
In this part, the mixture is ignited and releasing heat. This heat increases the pressure inside the cylinder result push the piston head down the cylinder

iv. **Pistons**
The downward movement of the piston pushes a rod that turns a crankshaft. The turning crankshaft provides the motion to turn the wheels. As the piston pushed down in the cylinder, other engine parts keep it from blowing out of the cylinder. The piston then pushed back up into the cylinder.

3. Firing bullets from guns
Diagram:



When the trigger pulled, the firing pin/striker hits the primer resulting in a minor explosion. The flame from this explosion ignites the powder (contain nitrocellulose), which it burns very rapidly releasing a lot of heat, resulting in increased pressure within the casing

NB:
i. Nitrocellulose is a highly flammable material made by treating cellulose with concentrated nitric acid, used to make explosives and celluloid
ii. the expansion takes place in the cartridge or round of ammunition

Introduction of Heat Transfer

Heat is the energy it can transferred from one place to another in three ways include

i. conduction of heat
ii. convection of heat
iii. radiation of heat

Conduction of Heat

Defn: Conduction is the transfer of heat though matter from a region of high temperature to region of low temperature without actual movement of the medium

How Transferred?

When heat is supplied to one part of a solid, the atoms vibrate faster. This vibration is passed on to neighboring atoms through the bonds. This spreads the heat throughout the object.

Good and Bad Conductor

Materials which can allow heat to pass through which known as good conductor of heat due to presence of free electrons and others which cannot allow heat to pass through which known as bad conductor of heat

Good Conductor

Defn: good conductor is the Materials that allow heat to flow through them easily. For Example, iron etc. the conduction on liquid is minimal due to the large intermolecular spaces

Nb:

Conductor have different rate of heat conduction. Example, copper is the best conductor of heat while steel is the poorest conductor.

Bad Conductor

Defn: bad conductor is the Materials that cannot allow heat to flow through them easily. For Example, plastic, wood, glass etc. it also called **thermal insulator**

Factors Affect the Rate of Conduction

1. **Length of the material**
   The longer the material, the more the time it will take to conduct heat through it.
2. **cross-sectional area that is perpendicular to the heat flow**
   The larger the cross-sectional area, the faster the rate of heat conduction

3. **Difference in temperature between the two ends of the material**
   The higher the difference, the faster the rate of conduction

4. **Thermal conductivity of the material**.
   This is a measure of the rate at which a material conducts heat. The higher the thermal conductivity of the material, the faster the rate of conduction

How Can We Minimize Conduction?

It can be minimized by **thermal insulator**. Thus why in boiler, hot-water pipes and in the textile industry thermal insulator are used

Also can be prevented by keep the place vacuum or filling with fluid, Example, double-glazed windows used in our house in cold region.

Not only that in our houses we use carpets curtains and drought excluders

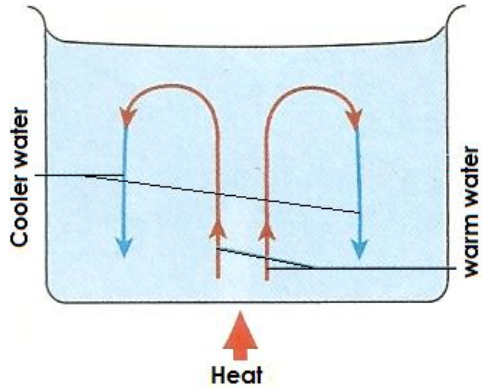
Application of Conduction

i. Cooking vessels are made of metal, which are good conduct.
ii. Aluminium is used in making motor engines, piston and cylinders due to its low density and high thermal conductivity
iii. Our closes is thermal insulator in order to prevent heat loss from our body
iv. The bottoms of cooking pots need periodic cleaning to remove layers of soot, which impede the flow of heat
v. Fiberglass is used under roofs of buildings to prevent heat loss in cold areas
vi. Sawdust is used for lagging hot-water pipes

Convection of Heat

Defn: convection is the transfer of heat in fluid (liquids and gases) which involves actual movement of the medium. If temperature of fluid increases it tend to cause convection current which circulate heat continuously throughout the fluid.

Diagram:



How Can We Minimize Convection?

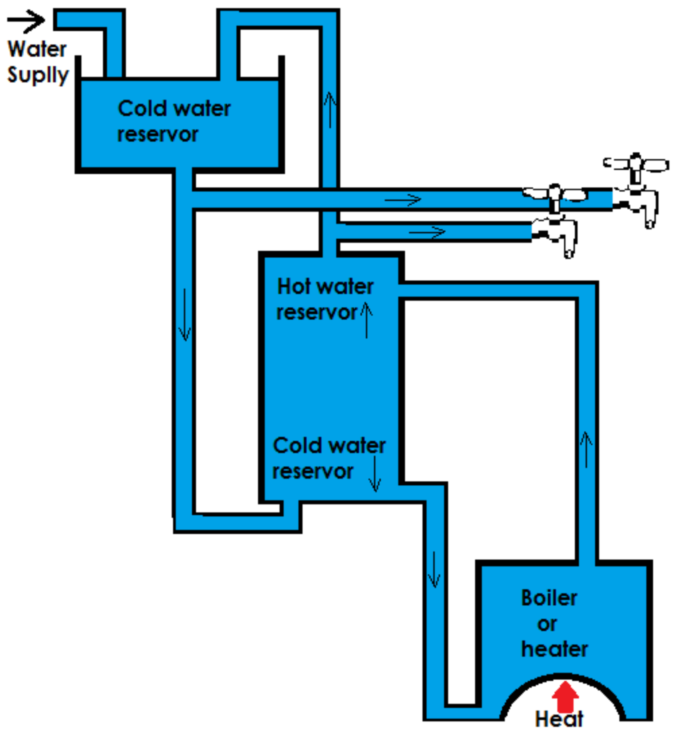
It can prevented by keep the place vacuum, Example, vacuum flask prevent heat loss by vacuum.

Application of Convection

i. **Domestic hot water supply system**

This system uses convection current to move warm water from the boilers to where it is used.

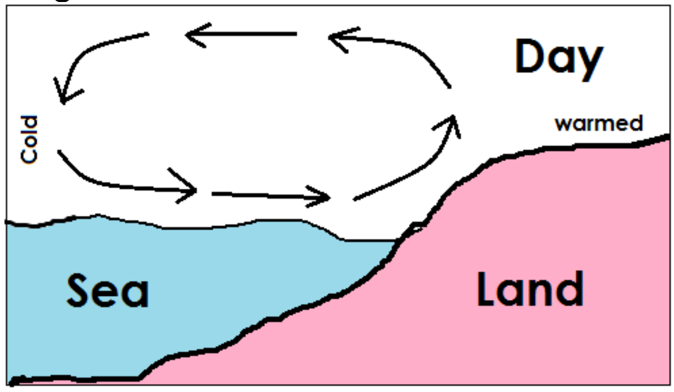
Diagram:



ii. **Land and sea breezes**

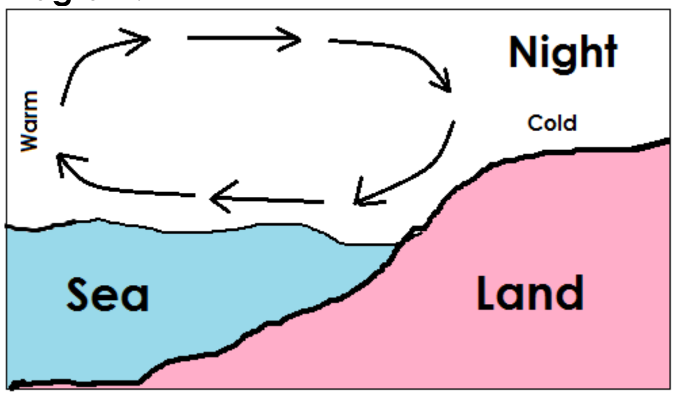
During the day the heat from the sun warm the land with its air than the sea surface with its air. The warmed air in the land increases kinetic energy and tends to decrease its density which cause the air to rise, the cold air from the sea surface comes to replace the warmed air, which result wind from the sea to the land. This called **sea breeze**

Diagram:



During the night the land lose heat and become cold than sea surface which result air at sea surface to increases kinetic energy and tends to decrease its density which cause the air to rise, the cold air from the land surface comes to replace the warmed air which result wind from the land to the sea. This called **land breeze**

Diagram:



iii. **Air condition**

This system uses convection current to move warm air from one point to another. When are cold, room heater are placed on the floor of a room and when are hot the air condition are placed top of the wall or around the ceiling

Radiation of Heat

Defn: radiation is the heat transfer between two or more bodies by means of electromagnetic waves that do not need material medium.

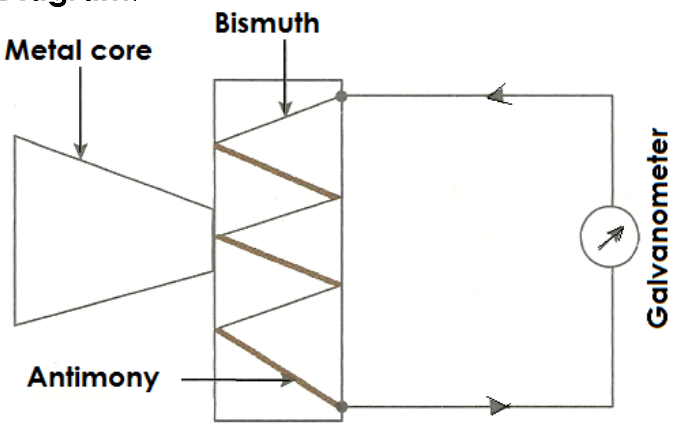
NB:

i. It takes place in a vacuum

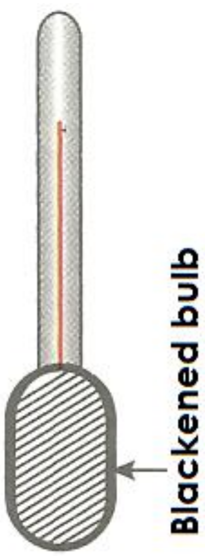
ii. All bodies at temperature above absolute zero emit some radiant energy
iii. Between the sun and the earth's atmosphere is a vacuum
iv. Radiant travels with the speed of light
v. Radiant can be reflected
vi. Radiant can be absorbed
vii. Radiant can be transmitted

Radiant Detector
There are two instrument which can be detect radiation, include
i. Thermopile
ii. Liquid in thermometer

Thermopile
When radiation falls on the hot junction, the thermal energy is converted/transformed into electrical energy which cause the galvanometer to deflect
Diagram:



Liquid in Thermometer
The bulb should blackened
Diagram:



Absorbers, Emitters and Reflectors

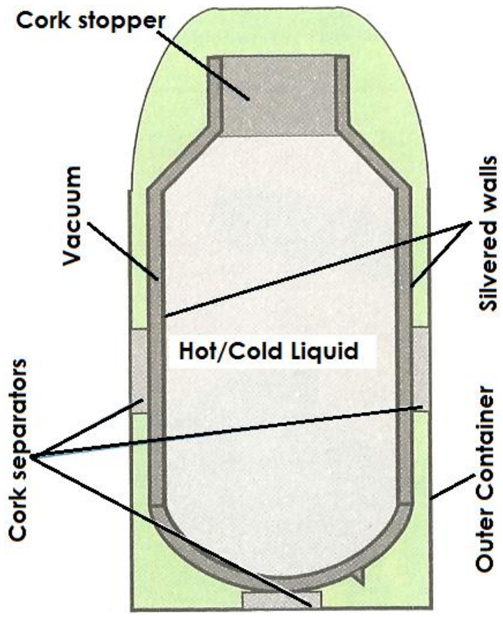
Absorber
Defn: absorber is the material/surface that delivers/gain all radiant energy. A surface that absorbs all radiant is called **black body.** Example, black cooking vessel, black clothes dry faster than others coloured clothes etc

Emitter
Defn: emitter is the material/surface that lost/delivers out all radiant energy. A surface that emitters all radiant is called **black body**

Reflector
Defn: reflector is the material/surface that bounces back all radiant energy. Example, solar cookers etc

How Can We Minimize Radiation?
It can prevent by keep the place shine/polished.

Thermos Flask
Defn: Thermos flask is a device used to hold hot or cold liquid for long period. It consists of a double-walled glass (polished by coated with a thin layer of aluminium) container with vacuum between the walls. It has a stopper made of insulating materials especial cork
Diagram:



How Thermos Flask Prevents Heat Lost?
It holds by ensure that heat loss by conduction, convection and radiation minimized or prevented

Ways Conduction and convection prevented by:

i. Insulated stopper
ii. Vacuum
iii. The separators

Ways Radiation prevented by:

iv. Polished one which is silvered walls

Metal Foils

Defn: metal foils is the polished/shines ones used to cover items to minimize heat loss by radiation. For Example, aluminium foils are used to wrapping hot food.

How Metal Foils Prevents Heat Lost?

Metal foils prevents radiant energy by reflect radiant energy

Heat Content

Defn: Heat content is the Energy possessed by a body due to its temperature. In addition, it called **internal thermal energy**

Nb:

i. Heat content is due to random motion of the particles that make up the object
ii. Different materials have different heat content
iii. Measurement of thermal energy involve indirect measurement
iv. The heat content of a substance determined by its heat capacity

Factors That Determine the Heat Content

The heat content of a substance is determined by its

i. Mass of that substance
ii. Temperature change of that substance
iii. Specific heat capacity

Heat Capacity of a Substance

Defn: Heat capacity of a substance is the amount of heat required to raise the temperature of a given mass of a substance by 1K. It denoted by letter C, SI unit of heat capacity is J/K

Mathematically:

Heat capacity, C = $\frac{\text{quantity of heat absorbed,H}}{\text{change in temperature,}\Delta\theta}$

C = $\frac{\mathbf{H}}{\Delta\theta}$

Example,

In an experiment to determine the heat capacity of steel, 100KJ of heat energy was supplied to a block of steel initially at 22°C. If the final temperature of the block was Δθ, determine the heat capacity of steel.

Data given

Initial temperature, $\theta 1$ = 22°C
Final temperature, $\theta 2$ = 219°C
Temperature change, Δθ=(219-22)°C =197°C=197K
Heat supplied, H = 100KJ = 100000J
heat capacity, C = ?

Solution

From: C = $\frac{H}{\Delta\theta}$

Then: C = H/Δθ = 100000/197 = 507.60J/K

C = 507.60J/K

Specific Heat Capacity

Defn: specific heat capacity of a substance is the heat required to produce a 1K or 1°C in 1kg. It denoted by letter c, SI unit of specific heat capacity is J/kg K

Mathematically:

Specific Heat capacity, c=$\frac{\text{quantity of heat absorbed,H}}{\text{mass x change in temperature,}\Delta\theta}$

$$c = \frac{H}{m \times \Delta\theta}$$

Make H subject

H = mcΔθ

Specific Heat Capacities of Some Materials

Materials	Specific heat capacity(J/kgK)
Water	4200
Sea water	3900
Paraffin	2200
Methylated spirit	2500
Ice	2100
Mercury	1395
Aluminium	900
Glass	700
Steel	500
Copper	390
Brass	320
Iron	480
Lead	130

Example,

How much heat is required to raise the temperature of a 25kg sample of mercury from 20°C to 30°C?

Data given

Mass of mercury, m = 25kg
Initial temperature of mercury, $\theta 1$ = 20°C
Final temperature of mercury, $\theta 2$ = 30°C
Temperature change, Δθ=(30-20)°C =10°C=283K
Specific heat capacity of mercury, C = 1395 J/kgK
Heat supplied, H = ?

Solution

From: H = mcΔθ
H = 25 x 1395 x 283
H = 9 869 625J

Example,

The temperature of a 6kg block of copper rises from 15°C to 30°C on being heated. Determine the amount of heat energy supplied to the block. (Specific heat capacity of block is 390Jkg°C)

Data given

Mass of mercury, m = 6kg

Initial temperature of copper, $\theta 1$ = 15°C

Final temperature of copper, $\theta 2$ = 30°C

Temperature change, $\Delta\theta$=(30-15)°C =15°C

Specific heat capacity of copper, C = 390Jkg°C

Heat supplied, H = ?

Solution

From: H = mc$\Delta\theta$

H = 6 x 390 x 15

H = 35 100J

Example,

How much heat energy is given out by an iron block of 20g mass when it cools from 920°C to 20°C.

Mass of mercury, m = 20g = 0.02kg

Initial temperature of copper, $\theta 1$ = 920°C

Final temperature of copper, $\theta 2$ = 20°C

Temperature change, $\Delta\theta$=(920-20)°C = 900°C

Specific heat capacity of iron, C = 480Jkg°C

Heat supplied, H = ?

Solution

From: H = mc$\Delta\theta$

H = 0.02 x 480 x 900

H = 8 640J

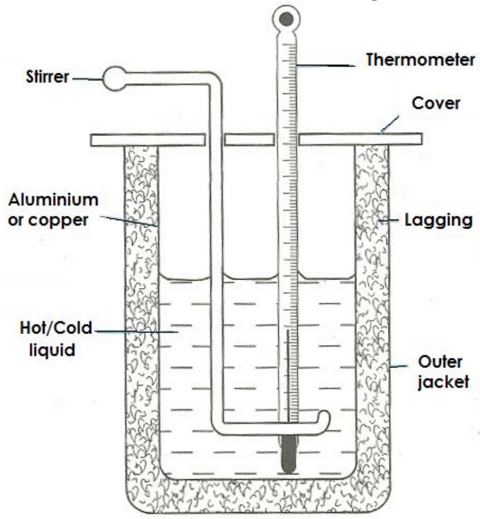
Determination of Specific Heat Capacity

If the heat loss controlled when mixing the water, the heat energy gained by the cold water is equal to the heat energy lost by hot water due to the principle of conservation of energy.

Calorimeter

Calorimeter used to control the loss of heat energy when determining specific heat capacities

Diagram:



i. Inner container and stirring rod are made of the same material always aluminium or copper
ii. The heat loss is reduced by the lagging materials (bad conductor) and the cover

How Specific Heat Capacity Determined

If a liquid of known mass and temperature putted in the inner container and a solid/liquid of known mass and temperature is added to the liquid the specific heat capacity of any substance can be calculated/determined of one of substance specific heat capacity are known.

Assume Hot Iron Is Added To the Calorimeter Contain Cold Water

Mass of water = m1

Mass of copper and stirrer = m2

Mass of hot iron = m3

Initial temperature of water and calorimeter = $\theta 1$

Initial temperature of hot iron = $\theta 2$

Final temperature (iron + water + calorimeter) = $\theta 3$

Specific capacity of water = C1

Specific capacity of calorimeter = C2

Specific capacity of iron = C3

But:

If the hot iron added to the cold water, the hot iron loss heat energy and cold water gain heat energy

From:

Principle conversion of energy

Heat gain = heat loss

Therefore:

Heat gain by water + Heat gain by calorimeter = heat loss by hot iron

But:

Heat gain by water = $m1c1(\theta3 - \theta1)$

Heat gain by calorimeter = $m2c2(\theta3 - \theta1)$

Heat lost by iron = $m3c3(\theta2 - \theta3)$

Then:

Heat gain by water + Heat gain by calorimeter = heat loss by hot iron

$m1c1(\theta3 - \theta1) + m2c2(\theta3 - \theta1) = m3c3(\theta2 - \theta3)$

$((m1c1 + m2c2)(\theta3 - \theta1) = m3c3(\theta2 - \theta3)$ make c3 subject

c3 = $\frac{((m1c1 + m2c2)(\theta3 - \theta1)}{m3(\theta2 - \theta3)}$

Example,

A piece of copper of mass 40g at 200°C is immersed into a copper calorimeter of mass 60g containing 50g of water 25°C. Neglecting heat losses, what will the final temperature of the mixture is?

Data given

Mass of water, m1 = 50g = 0.05kg

Mass of calorimeter, m2 = 60g = 0.06kg

Mass of copper, m3 = 40g = 0.04kg

Initial temperature of water +calorimeter, $\theta1$ = 25°C

Initial temperature of copper, $\theta2$ = 200°C

Specific capacity of water, C1 = 4200 J/kgK

Specific capacity of copper, C2 = 390 J/kgK

Specific capacity of calorimeter, C3 = 390 J/kgK

Final temperature (water + copper + calorimeter), $\theta3$ = ?

Solution:

From:

Principle conversion of energy

Heat gain = heat loss

Therefore:

Heat gain by water + Heat gain by calorimeter = heat loss by hot iron

$m1c1(\theta3 - \theta1) + m2c2(\theta3 - \theta1) = m3c3(\theta2 - \theta3)$

$((m1c1 + m2c2)(\theta3 - \theta1) = m3c3(\theta2 - \theta3)$ - make $\theta3$ subject

$(m1c1 + m2c2)\theta3 + m3c3\theta3 = m3c3\theta2 + (m1c1 + m2c2)\theta1$

$(m1c1 + m2c2 + m3c3)\theta3 = m3c3\theta2 + (m1c1 + m2c2)\theta1$

$\theta3 = (m3c3\theta2 + (m1c1 + m2c2)\theta1)/ (m1c1 + m2c2 + m3c3)$

$\theta3 = (0.04x390x200 + 0.05x4200x25 + 0.06x390x25)/ (0.05x4200 + 0.04x390 + 0.06x390)$

$\theta3 = 8955/249 = 36°C$

$\underline{\theta3 = 36°C}$

Example,

A brass of cylinder of mass x was heated to 100°C and then transferred into thin aluminium can of negligible heat capacity containing 150g of paraffin at 11°C. If the final steady temperature of the paraffin attained was 20°C determine the value of x

Data given

Mass of brass, m1 = x

Mass of paraffin, m2 = 150g = 0.15kg

Initial temperature of paraffin, $\theta3$ = 100°C

Initial temperature of brass, $\theta1$ = 11°C

Final temperature (paraffin + brass), $\theta2$ = 20°C

Specific capacity of paraffin, C2 = 2200 J/kgK

Specific capacity of brass, C1 = 320 J/kgK

Solution:

From:

Principle conversion of energy

Heat gain = heat loss

Therefore:

Heat gain by water = heat loss by metal block

Then:

$m1c1(\theta3 - \theta1) = m2c2(\theta2 – \theta3)$ - make m1 subject

m1 = $\frac{(m2c2(\theta2 - \theta3)}{c1(\theta3 - \theta1)}$

$m1 = (m2c2(\theta2 – \theta1))/(c1(\theta3 – \theta2)$

m1 = (0.15 x 2200(20 - 11))/(320(100 - 20)

m1 = (330x 9)/(320 x 80)

m1 = 2970/25600

<u>m1 = 0.116 kg</u>

A brass of cylinder of mass x is 0.116 kg = 116g

Example,

A block of metal of mass 0.20kg at a temperature of 100°C is placed in 0.40kg of water at 20°C.if the final steady temperature of the water is 24°C, determine the specific heat capacity of the metal. (Neglect heat absorber by the container)

Data given

Mass of water, m1 = 0.2kg

Mass of metal block, m2 = 0.4kg

Initial temperature of water, θ1 = 20°C

Initial temperature of metal block, θ2 = 100°C

Final temperature (water + metal block), θ3 = 24°C

Specific capacity of water, C1 = 4200 J/kgK

Specific capacity of metal block, C2 = ?

Solution:

From:

Principle conversion of energy

Heat gain = heat loss

Therefore:

Heat gain by water = heat loss by metal block

Then:

m1c1(θ3 - θ1) = m2c2(θ2 – θ3) - make c2 subject

$c2 = \frac{(m1c1(\theta3 - \theta1)}{\mathrm{m2(\theta2 - \theta3)}}$

c2 = (m1c1(θ3 - θ1))/(m2(θ2 - θ3)

c2 = (0.4 x4200(24 - 20))/(0.2(100 - 24)

c2 = (1680x 4)/(0.2 x 76)

c2 = 6720/15.2

c2 = 442.11 J/kgK

Example,

A block of aluminum of mass 0.5kg at a temperature of 100°C is dipped in 1.0kg of water at 20°C. Assuming that no thermal energy is lost to the environment, what will the final temperature of the water to be at thermal equilibrium?

Data given

Mass of water, m1 = 1.0kg

Mass of aluminum, m2 = 0.5kg

Initial temperature of water, θ1 = 20°C

Initial temperature of aluminum, θ2 = 100°C

Final temperature (water + aluminum), θ3 = ?

Specific capacity of water, C1 = 4200 J/kgK

Specific capacity of metal block, C2 = 900 J/kgK

Solution:

From:

Principle conversion of energy

Heat gain = heat loss

Therefore:

Heat gain by water = heat loss by metal block

Then:

m1c1(θ3 - θ1) = m2c2(θ2 – θ3) - make θ3 subject

m1c1θ3 - m1c1θ1 = m2c2θ2 – m2c2θ3

m1c1θ3 + m2c2θ3 = m2c2θ2 + m1c1θ1

(m1c1 + m2c2)θ3 = m2c2θ2 + m1c1θ1

θ3 = (m2c2θ2 + m1c1θ1)/(m1c1 + m2c2)

θ3=((0.5x900x100)+(1x4200x20))/((1x4200)+(0.5 x900))

θ3 = (45000+84000)/(4200+450)

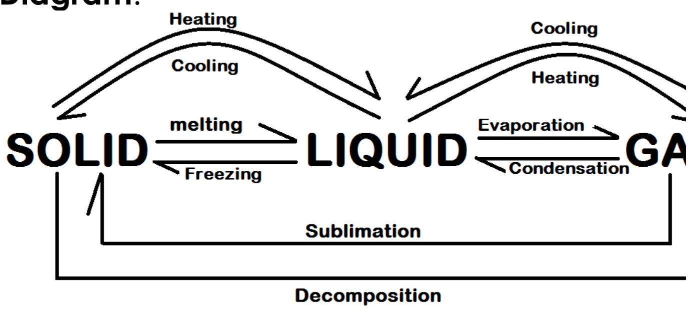
θ3 = 129000/4650

θ3 = 27.74°C

Change of State

As we studied at form one matter can under goes three states include solid, liquid and gas. Consider the diagram below.

Diagram:



Melting Point

Melting is the change of state from solid to liquid and **Melting point** is the definite temperature of a pure substance to melt. At melting point the substance absorbs heat but the temperature does not change until the substance has completely melted.

Freezing Point

Freezing is the change of state from liquid to solid and **freezing point** is the Temperature at which a liquid changes into a solid without a change in temperature. During solidification a substance loses heat to its surround but its temperature does not fall

Nb:

The freezing point of a pure substance is the same as its melting point. Example, water freeze and melt at 0°C

Factors Affecting Freezing Point

The freezing point is affected by the presence of:

i. Impurities
ii. Pressure change

Nb:

i. The disrupt the freezing point by impurities is called **freezing point depression**
ii. **Regelation is** the phenomenon of melting under pressure and re-freezing when the pressure is reduced.
iii. The melting point of ice falls by 0.0072°C for every additional 100000 Pa (1×10^5 Pa) of pressure applied. For Example, a pressure of 1.27×10^7 Pa is needed for ice to melt

Boiling Point

Boiling point is the temperature at which all liquid change into gas

Mechanism of Boiling

The molecules at the surface of the liquid gain more kinetic energy move faster and are able to overcome intermolecular forces holding them together and hence escape.

NB:

i. At the boiling point the vapour pressure of the liquid becomes equal to atmospheric pressure
ii. Each pure substance has an exact boiling point.
iii. At the boiling point the heat energy supplied is used to change the water from the liquid to vapour state
iv. At the boiling point does not raise the temperature.

Boiling Point of Some Pure Substance

Substance	Boiling point (°C)
Helium	-269
Hydrogen	-253
Oxygen	-183
Ethyl alcohol	78.4
Benzene	80.2
Water	100
Mercury	357
Aluminium	2 467
Copper	2 567
Iron	2 750

Factors Affecting Boiling Point

The boiling point is affected by the presence of:

i. Impurities
ii. Pressure change

Nb:

i. impurities raise the boiling point of a liquid
ii. pressure raise the boiling point of a liquid
iii. the boiling point of water is 100°C at pressure of 1×10^5 Pa of pressure and

101°C at pressure of 1.05×10^5 Pa of pressure

iv. as altitude increased also pressure decrease hence boiling point lowers

Boiling Point Of Water at Different Altitudes

Altitude(m)	Pressure (mmHg)	Boiling point (°C)
300	732	99.0
600	706	98.0
900	681	97.0
1200	656	96.0
1500	632	95.0
1800	609	93.9
2100	586	92.9
2400	565	91.9
2700	543	90.8
3000	523	89.8

Evaporation

Evaporation is the change of state from liquid to gas (vapour)

NB:

i. it takes place at any temperature

ii. evaporation is more rapidly when there is **windy**, **sunny** and **less humidity**

iii. evaporation is differ from boiling

iv. if evaporation occurs the liquid loss heat (**latent heat**) and final cool if there is no continuous of heat, this phenomenon is called **cooling effect**

Different Between Boiling and Evaporation

Boiling	Evaporation
Occurs at a definite temperature which is boiling point	Occurs at any temperature
Occurs within a liquid with formation of bubbles	Occurs at the surface of the liquid
Has no cooling effect	Has cooling effect
Takes place rapidly	Takes place slowly

Latent Heat

Defn: latent heat is the heat absorbed/gives out when matter changes his state of matter without change in temperature.

Latent Heat of Fusion

Defn: latent heat of fusion is the heat absorbed when matter changes from solid to liquid without change in temperature.

Nb:

i. if matter melt it means latent heat of fusion increase

ii. if the liquid change to solid means the latent heat of fusion gives up or decreased

Specific Latent Heat of Fusion

Defn: specific latent heat of fusion of a substance is the quantity of heat energy required to change completely a unit mass (1kg) of the solid to liquid at its melting point. Its SI Unit is **J/kg**

Mathematically:

$L_f = H/m$

$\mathbf{H = m \times L_f}$

Melting/Freezing Point Of Substance at STP

substance	melting/freezing point (°C)	latent heat of fusion (J/kg)
Aluminum	659	396000
Copper	1086	134000
Iron	1535	293000
Water	0	335000
Mercury	-39	11000
Ethyl alcohol	-117	105000

Latent Heat of Vaporisation

Defn: latent heat of vaporisation is the heat absorbed when matter changes from liquid to gas (vapour) at normal boiling point.

Nb:

iii. if matter form vapour means latent heat of vaporisation increase

iv. if the vapour change to liquid means the latent heat of vaporisation gives up or decreased

Specific Latent Heat of Vaporisation

Defn: specific latent heat of vaporisation of a substance is the quantity of heat energy required to change completely a unit mass (1kg) of the liquid to gas at its boiling point. Its SI Unit is **J/kg**

Mathematically:

$L_v = H/m$

H = m x Lv

Example,

How much heat would be required to change 1.5kg of ice at -10°C to stream at 120°C.? The specific heat capacities of ice, water and stream are 2144J/kg°C, 4186 J/kg°C and 2010 J/kg°C respectively

Data given

Mass of ice/water/stream, m = 1.5kg

Ice Temperature change, Δθi = (0 - -10)°C = 10°C

Water Temperature change, Δθw = (0-100)°C = 100°C

Stream Temperature change, Δθs = (120-100)°C = 20°C

Specific capacity of ice, Ci = 2144 J/kg°C

Specific capacity of water, Cw = 4186 J/kg°C

Specific capacity of stream, Cs = 2010 J/kg°C

Specific Latent heat of fusion, Lf = 335000 J/kg

Specific Latent heat of vaporisation, Lv = 227000J/kg

Heat require to raise the ice temperature, Hi = ?

Heat require to melt ice, Hm = ?

Heat require to raise the water temperature, Hw = ?

Heat require to convert water to stream, He = ?

Heat require to raise the stream temperature, Hs = ?

Heat required to change ice to stream, Ht = ?

Solution:

But: Ht = Hi + Hm + Hw + He + Hs

Then:

Hi = mciΔθi = 1.5 x 2144 x 10 = 3216J

Hm = m x Lf= 1.5 x 335000 = 502500J

Hw = mcwΔθw = 1.5 x 4186 x 100 = 627900J

He = m x Lv = 1.5 x 227000 = 3,405,000J

Hs = mcsΔθs = 1.5 x 2010 x 20 = 60300J

From: Ht = Hi + Hm + Hw + He + Hs

Ht = 3,2160J + 502, 500J + 627, 900J + 3,405,000J + 60,300J

Ht = 4, 627, 860J

Nb:

Stream has much more thermal energy than liquid thus why steam is used in engines to convert thermal energy to mechanical energy

Cooling Effect of Evaporation

When liquid evaporate latent heat of is absorbed from the liquids if no heat is supplied from outside this result cooling.

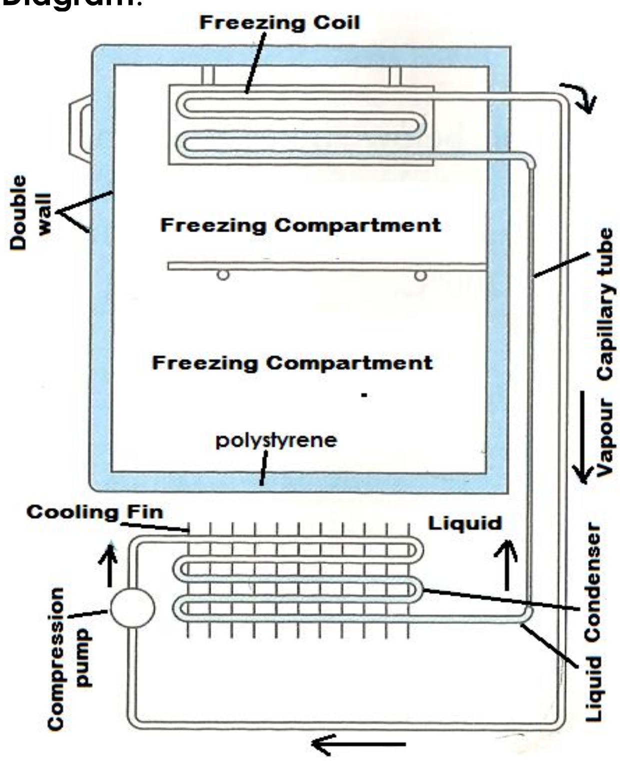
i. **Cooling Of Human Body**

When it is too hot, sweat glands release water which then evaporates from the skin taking away latent heat of vaporisation. This cause body to cool

ii. **The Refrigerator**

Cooling of refrigerator is due to evaporation of Freon (chlorofluorocarbons (CFCs) which contribute to global warming) inside a copper coil surrounding the freezing unit. It uses polystyrene as thermal insulator.

Diagram:



Mechanism of Refrigerator

{a} Compression pump compress Freon vapour to liquid and pump to cooling fin which gives up latent heat of vaporisation which changes Freon vapour to liquid at condenser of high pressure due to height.

{b} capillary tube rise Freon liquid to widens freezing coil, at freezing coil the compression pump suck the Freon liquid which reduce the pressure in the compartment and the Freon liquid evaporate.

{c} When Freon evaporate it draws the latent heat of vaporisation required from the surrounding (the compartment) causing the temperature to go down.

{d} The Freon vapour is then pumped back to the condenser outside the refrigerator

{e} This process repeater and cause the temperature in the refrigerator become quite low.

Evaporation of Liquids

Defn: Evaporation is gradual change of state from liquid to gas that occurs at the surface of a liquid.

Nb:

i. Liquid evaporate when molecules at water surface absorb greater thermal energy than molecules forces at water surface
ii. For liquid with strong intermolecular force (bonds) takes long time to evaporate
iii. Since evaporation cause cooling effect the left liquid is evaporated so the kinetic energy decreases by evaporated one.
iv. Liquid evaporate quickly is called volatile liquid Example, spirit

Factors Affecting Evaporation

There are four main one include;

i. Temperature
ii. Surface area
iii. Concentration of vapour liquid
iv. Rate of air flow (wind)

Temperature

Temperature is directly proportional to the evaporation increase in temperature increases the rate of evaporation

Surface Area

Surface area is directly proportional to the evaporation increase in Surface area increases the rate of evaporation

Concentration of Vapour Liquid

Concentration of vapour liquid (the same or different molecules) is inversely proportional to the evaporation. Because the surrounding air has little space for the escaping gaseous molecules comes from evaporation

Wind

Wind is directly proportional to the evaporation increase in Wind increases the rate of evaporation. Wind lowers the Concentration of vapour liquid

Vapour Pressure (VP)

Defn: vapour pressure is the pressure Created by the vapour of a substance. Evaporation continues until dynamic equilibrium reached.

Nb:

i. Dynamic equilibrium is the point in which molecules leaves and re-enter liquid in equal rate
ii. During dynamic equilibrium the vapour is said to be saturated.

Types of Vapour Pressure (VP)

It into three categories include

i. Saturated vapour pressure
ii. Unsaturated vapour pressure
iii. Ambient pressure

Saturated Vapour Pressure (SVP)

Defn: saturated vapour pressure is the pressure created by the vapour of the same a substance when dynamic reached substance

Unsaturated Vapour Pressure (USVP)

Defn: unsaturated vapour pressure is the pressure created by the vapour of the same substance when dynamic not reached

Ambient Pressure (AP)

Defn: Ambient pressure is the pressure created by the vapour of a substance and other gas pressure

Nb:

i. A substance of high vapour at room temperature is called **volatile**

ii. At SVP the rate of evaporation and condensation is equal
iii. Each liquid has its SVP
iv. Liquid boil when SVP and AP are equal
v. Increase in Temperature the rate evaporation increases

Measurement of SVP
Since saturated vapour pressure is pressure it measured by mercury barometer. It given by
SVP = (760 - x) mmHg
Where:
SVP = saturated vapour pressure
760 mmHg = atmospheric pressure (atm)
X mmHg = vapour pressure

Humidity
Defn: humidity is the water vapour presence in the atmosphere

Sources of Humidity
i. Evaporation from rivers, lakes and oceans
ii. Transpiration (evaporation of plant leaves)

Nb:
i. Water vapor from atmosphere forming clouds, dew and frost
ii. frost is deposit of small white ice crystals formed on the ground or other surfaces when the temperature falls below freezing
iii. Earth's surface may or not saturated
iv. Saturation depend temperature and water availability
v. The density of water vapour in saturated air is called **absolute humidity (AH)**

DEW
Dew is water in the form of droplets that appear on exposed objects in the morning or evening.

Dew Point (DP)
Dew point is the temperature at which the air becomes saturated with water vapour

Nb:
i. DP is measured by Renault hygrometer
ii. DP occurs when RH of air is 100%
iii. below DP clouds, dew or frost formed
iv. frost is the dew takes the form of ice below freezing point

Factors Influence the Formation of Dew
Dew is influenced by
i. Temperature
ii. Wind
iii. Water vapour

Temperature
The temperature but be below dew point

Wind
As wind increase the rate of evaporation, thus it prevents the formation of water droplets

Water Vapour
The atmospheric air must be saturated with water vapour

Relative Humidity (RH)
By den: Relative humidity is the ratio of the saturated vapour pressure at the dew point to the saturated vapour pressure at the current air temperature
Mathematically:
RH = $\frac{\boldsymbol{SVP\ at\ dew\ point}}{\boldsymbol{SVP\ at\ air\ temperature}}$

By den: Relative humidity is the ratio of the Actual vapour density to the saturated vapour density
Mathematically:
RH = $\frac{\boldsymbol{actual\ vapour\ density}}{\boldsymbol{Saturated\ vapour\ density}}$ **x 100%**

Actual vapour density and Saturated vapour density has equal volume, therefore relative humidity can also defined as
By den: Relative humidity is the ratio of the mass of water vapour in a given volume of air to the mass of water vapour required to saturate the same volume of air at that temperature
Mathematically:
RH = $\frac{\boldsymbol{M1}}{\boldsymbol{M2}}$ **x 100%**

Where:
M1 = mass of water vapour in a given volume of air

M2 = mass of water vapour required to saturate the same volume of air at that temperature

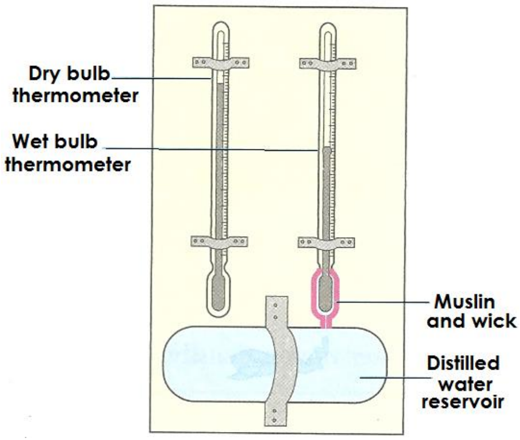
Measurement of Relative Humidity

It measured by **dry and wet bulb hygrometer** and **Renault hygrometer**

Dry and Wet Bulb Hygrometer

It consist dry bulb thermometer which used to measure the temperature of the surrounding air while wet bulb which is wrapped with piece of cloth around the bulb which immersed in a reservoir of water which cool the wet thermometer

Diagram:



The wet bulb thermometer reads a lower temperature than the dry bulb thermometer. After that the different between two thermometer is help us to got exactly relative humidity by using **psychometric table**

NB:

{i} If RH 100% means no evaporation or condensation

{ii} If RH 100% means wet and dry thermometer read the same temperature

{iii} If RH 0% means evaporation rate is high than condensation rate

{iv} A small different indicate a high RH and vice versa

{v} If RH (0-10)% means the clouds is clear

{vi} If RH (10-50)% means the clouds is partial clouds

{vii} If RH (50-90)% means the clouds is partial sunny

{viii} If RH (90-100)% means the clouds is overcast

Psychometric Table

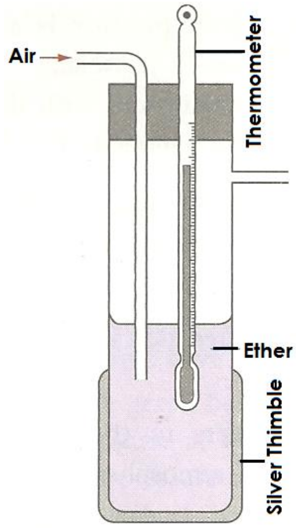
Psychometric table is the table used to read relative density at particular temperature

Dry-Bulb Thermometer (^0C)	**Relative Humidity (%) Difference Between Dry Bulb Thermometer And Wet Dry Thermometer**																					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
0	81	63	45	28	11																	
2	83	67	51	36	20	6																
4	85	70	56	42	27	14																
6	86	72	59	46	35	22	10	0														
8	87	74	62	51	39	28	17	6														
10	88	76	65	54	43	33	24	13	4													
12	88	78	67	57	48	38	28	19	10	2												
14	89	79	69	60	50	41	33	25	16	8	1											
16	90	80	71	62	54	45	37	29	21	14	7	1										
18	91	81	72	64	56	48	40	33	26	19	12	6	0									
20	91	82	74	66	58	51	44	36	30	23	17	11	5	0								
22	92	83	75	68	60	53	46	40	33	27	21	15	10	4	0							
24	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4	0						
26	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9	5						
28	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12	8	2					
30	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16	12	8	4				
32	93	86	80	73	68	62	56	51	46	41	36	32	27	22	19	14	11	8	4			
34	93	86	81	74	69	63	58	52	48	43	38	34	30	26	22	18	14	10	8	5		
36	94	87	81	75	69	64	59	54	50	44	40	36	32	28	24	21	17	13	10	7	4	
38	94	87	82	76	70	66	60	55	51	46	42	38	34	30	26	23	20	16	13	10	7	5
40	94	89	82	76	71	67	61	57	52	48	44	40	36	33	29	25	22	19	16	13	10	7

Renault Hygrometer

It consists of an enclosed thin silver tube containing ether and a thermometer. There is also a tube through which air can be pumped into the ether.

Diagram:



Mechanism of Renault Hygrometer

The heat transfer from atmosphere to ether by convection in a tube, Ether evaporates result cooling of the silver tube surface. Cooling continues until air adjacent to the outside surface of the tube becomes saturated with water vapour. Some water vapour condense outside the tube to form **dew**

Applications of Humidity

i. It used by meteorological departments to forecast the weather
ii. It used to determine the appropriate site to locate cotton
iii. Electrical and electronic components are usually transported and stored in a dry air
iv. RH at operation room in hospital is 50%
v. It used in storage and transport of food items

Example,

The dry bulb temperature reading of a hygrometer is 22^0C and the wet bulb temperature reading is 18^0C. What is the RH?

Data given

Dry bulb thermometer, $\theta 1 = 22^0C$
Wet bulb thermometer, $\theta 2 = 18^0C$
Change in thermometer, $\Delta\theta = (22 - 18)^0C = 4^0C$
From psychometric table the relative density is 68%

Example,

The dry bulb temperature reading of a hygrometer is 40^0C and the wet bulb temperature reading is 30^0C. What is the RH?

Data given

Dry bulb thermometer, $\theta 1 = 40^0C$
Wet bulb thermometer, $\theta 2 = 30^0C$
Change in thermometer, $\Delta\theta = (40 - 30)^0C = 10^0C$
From psychometric table the relative density is 48%

Example,

The relative density of a place was measured at 25^0C and found to be 53.6%. if the absolute humidity is $23.05 g/m^3$, determine the actual water vapour density at this experiment

Data given:

Current temperature, = 25^0C
Absolute humidity, AH = $23.05 g/m^3$
Relative humidity, RH = 53.6%
Actual vapour pressure, AP =?

Solution

From: RH = $\frac{actual\ vapour\ density}{Saturated\ vapour\ density}$ x 100%
RH = $\frac{AP}{AH}$ x 100% - make AP subject
AP = (RH x AH)/100
AP = (53.6 x 23.05)/100
AP = 1235.48/100
AP = $12.35 g/m^3$

Current Electricity

Defn: electric current is *the rate of flow of charge*. It Measured by **Ammeter**

Mathematically:

I = Q/t

Where:

I = electric current

Q = quantity of charge

t = time taken by charge to rotate circuit

Make subject Q

I = Q/t – multiply by t both sides

Q = It

From: I =Q/t

I = Coulombs/Second = c/s = ampere = A

The common SI unit of I is ***ampere (A)***

Electric Potential Different (P.d)

Defn: electric potential different is the work done per unit charge in moving electric charge from one to another point

Mathematically:

P.d = work done/charge moved

V = w/Q

From: V =w/Q

I = Joules/ Coulombs = J/c = Volt = 1

The common SI unit of P.d is ***Volt (v)***

Electromotive Force (e.m.f)

Defn: electromotive force of a cell is a potential different across the cell terminals when there is no current flowing through it. It also called **voltage**. It measured **VOLTMETER**

NB:

{a} e.m.f is not a force

{b} e.m.f is a process of convert mechanical energy to electrical energy

{c} cell provide e.m.f which set up potential different

{d} e.m.f driving electric current in a circuit

{e} e.m.f of simple cell is 1.0V and e.m.f of dry cell is 1.5V

{f} terminal voltage is the voltage across the cell when electric current drawn

{g} Resistance across a cell is called **internal resistance.** dry cell has internal resistance about 0.5 Ω

Ohm's Law

It's States that;

"***At constant temperature and other physical factors, a current in conductor is directly proportional to the potential different across its end***"

Mathematically:

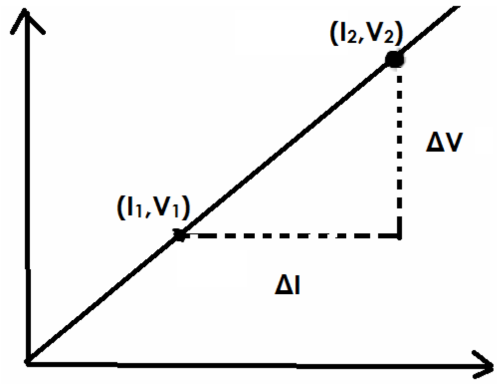
V a I

V=KI

Where:

K= constant = R = resistance

Graphically:



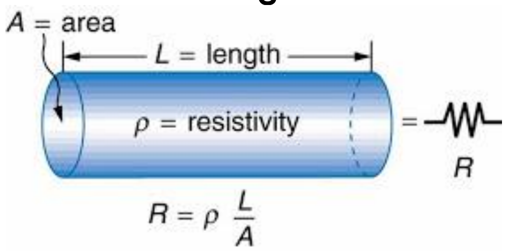
From the graph above

Slope = ΔV/ΔI = m

Slope = Resistance

Factor Affect Resistance

Consider the diagram:



5. Length of the conductor

The longer the wire the higher the resistance and vice versa

6. Temperature

The higher the temperature, the higher the resistance and vice versa

NB:

c. **Constant wire. (Copper alloy),** Changes to a very small extended thus why used in a standard resistance.

d. Connecting wire used in a circuit has a very low resistance to prevent energy wasted in form of heat to maximum.

7. **Types of material**

   Nichrome wire has more resistance than a copper wire of a same dimension.

Nb:

i. Nichrome wire is used in heating element of electric fires
ii. Copper wire is mostly used for connecting wires

8. **Cross-section area**

   A thin wire has more resistance than a thick conductor.

   R α 1/A

Combine the relation R α 1/A and R α L

Then:

R α L/A – remove proportionality constant

R = KL/A

Where:

k = resistivity which denoted by letter ϸ

R = ϸL/A – make ϸ subject

Þ = RA/L

Defn: resistivity is the ability of a material to oppose the flow of an electric current. It SI unity is **Ohm metre (Ωm).**

Resistivity of Material at 20⁰C

MATERIAL	RESISTIVITY (ΩM)
Aluminium	27×10^{-8}
Chromium	1.3×10^{-7}
Copper	1.68×10^{-8}
Iron	9.71×10^{-8}
Lead	2.1×10^{-7}
Silver	1.6×10^{-8}
Constantan	4.9×10^{-7}
Manganin	4.8×10^{-7}
Nichrome	1.0×10^{-6}
Glass	$1 \times 10^{9} - 1 \times 10^{13}$
Rubber	$1 \times 10^{13} - 1 \times 10^{15}$
Quartz	7.5×10^{17}

Example,

What is resistance of a copper wire of length 20m and diameter of 0.080 cm?

Data given:

Length, l = 20m

Diameter, d = 0.080m = 0.0008m

Radius, r = 0.0004m

Area, A = $\pi r^2 = \pi \times 0.0004^2 = 5.024 \times 10^{-7} m^2$

Resistivity, ϸ = 1.68×10^{-8} ΩM

Resistance, R = ?

Solution

From: R = ϸL/A

R = ϸL/A

R = $(1.68 \times 10^{-8} \times 20)/5.024 \times 10^{-7}$

R = $3.36 \times 10^{-7}/5.024 \times 10^{-7}$

R = 0.67Ω

Example,

A steel bar has a length of 2.3m and diameter of 2×10^{-5} m. what is resistance? (Resistivity is 10.5×10^{-8} ΩM)

Data given:

Length, l = 2.3m

Diameter, d = 2×10^{-5} m

Radius, r = 1×10^{-5} m

Area, A = $\pi r^2 = \pi \times (1 \times 10^{-5})^2 = 3.14 \times 10^{-10} m^2$

Resistivity, ϸ = 10.5×10^{-8} ΩM

Resistance, R = ?

Solution

From: R = ϸL/A

R = ϸL/A

R = $(10.5 \times 10^{-8} \times 2.3)/3.14 \times 10^{-10}$

R = $2.415 \times 10^{-7}/3.14 \times 10^{-10}$

R = 768.72 Ω

Resistor

Defn: Resistor is a device which offers resistance to the flow of an electric current. It used to control the magnitude of current and voltage according to ohms law

Types of Resistor

It divided according to the material used to made it and the value of resistance offered

Types of Resistor Due To Material Used

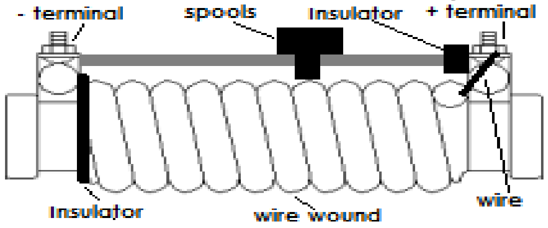
There different resistor which made from different material, include the following

i. Wire wound resistor
ii. Carbon resistor
iii. Metal film resistor
iv. Metal oxide film resistor

Wire Wound Resistor

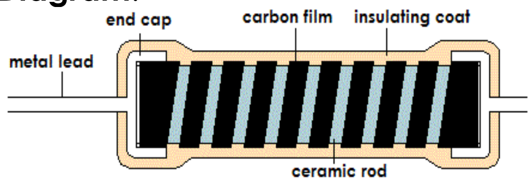
It made up winding wires made of certain metallic alloys into spools (used to control amount of resistance)

Diagram:



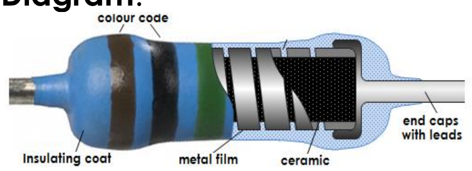
Carbon Resistor
It made by mixing carbon granules with varying amount of clay and moulding them into cylinders

Diagram:



Metal Film Resistor
It made up of a stable ceramic core coated with metal oxide such as nickel chromium. It more accuracy and more expensive than carbon resistor

Diagram:



Metal Oxide Film Resistor
It made up of a stable ceramic core coated with metal alloys such as tin oxide

Types of Resistor Due To Value Offered
Resistor created from different value may be fixed or variable resistance value

i. Fixed resistor
ii. Variable resistor

Fixed Resistor
It has a resistor value which cannot change. For Example, 2Ω, 3Ω, 4Ω etc. Example, most carbon resistor are fixed resistor

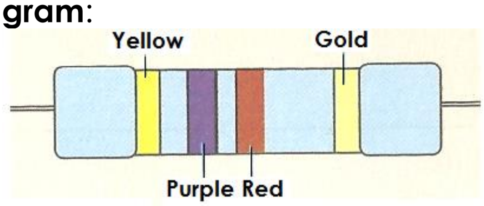
Variable Resistor
It has a resistor value which can change. Example, potentiometers, thermistors and photo resistors and rheostat

Resistor Colour Codes
Resistor which used electronic device always painted different colour texture called **band**. The band represent the exactly value of resistance. It contain fourth band with different meaning.

Table of Colour Codes

Colour number	Colour	tolerance
0	Black	
1	Brown	±1%
2	Red	±2%
3	Orange	
4	Yellow	
5	Green	
6	Blue	
7	Purple	
8	Grey	
9	White	
	Gold	±5%
	Silver	±10%
	No colour	±20%

Diagram:



i. First band – first digit
ii. Second band – second digit
iii. Third band (**multiplier**) – number of zero
iv. Fourth band (**tolerance**) – percentage accuracy

The value is given by

R = 4th band of 1st digit 2nd digit multiplier

Example,
From a the diagram of resistor above find the exactly resistance

i. First band (yellow) – 4
ii. Second band (purple) – 7
iii. Multiplier (red) – 2 = 00 number of zero
iv. Tolerance (gold) – ±5%

Therefore: R = ±5% of 4700Ω

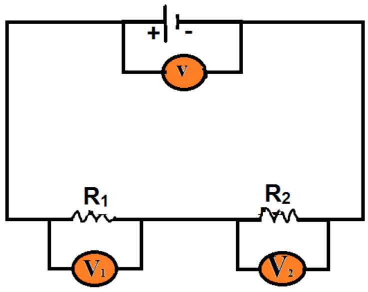
The actual value resistance is ±5% of 4700Ω

Combination of Resistors
There are two main methods of connecting circuits component include:

iii. Series connection
iv. Parallel connection

Series Connection

In this series arrangement the resistors are connected end to end.



From:

P.d across the battery = Sum of P.d around a conducting path

Therefore: $V = V_1 + V_2$ --------- (1)

But: I = same at all points round circuit

From: $V = IR$

Now: $V = IR_t$ --------- (2)

$V_1 = IR_1$ --------- (3)

$V_2 = IR_2$ --------- (4)

Substitute: equation (2),(3) and (4) into (1)

Then: $R_t = R_1 + R_2$

Therefore:

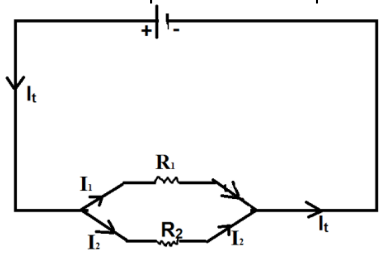
Total resistance (R_t) for resistor in series is equal to the sum of individual resistance.

$\mathbf{R_t = R_1+R_2 + ... + R_n}$

Where: Rn = the last resistor

Parallel Connection

Resistors are connected across two common points in a parallel arrangement.



Therefore: $I_t = I_1+I_2$ --------- (1)

But: V = same at all points round circuit

From: $I = V/R$

Now: $I_t = V/R_t$ --------- (2)

$I_1 = V/R_1$ --------- (3)

$I_2 = V/R_2$ --------- (4)

Substitute: equation (2), (3) and (4) into (1)

Then: $1/R_t = 1/R_1 + 1/R_2$

Therefore:

Total resistance (R_T) for resistor in series is equal to the sum of individual resistance.

$\mathbf{1/R_T = 1/R_1 + 1/R_2 + ... + 1/R_n}$

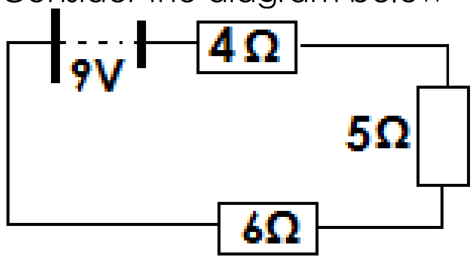
Where: Rn = the last resistor

NB:

i. In series the total resistance is higher than individual resistors
ii. In parallel the total resistance is lower than individual resistors
iii. Parallel arrangement result low resistance
iv. Parallel connection uses in house wiring

Example,

Consider the diagram below



{a} What is the total resistance of the circuit?

{b} What current flows in the circuit?

{c} What is the potential drop across each resistor?

{d} What is the electric potential at point A?

Data given

Electromotive force, E = 9V

First resistor, R1 =4 Ω

Second resistor, R2 =6 Ω

Third resistor, R3 =5 Ω

Total resistance, Rt = ?

Electric current, I = ?

Potential drop across R1, V1 = ?

Potential drop across R2, V2 = ?

Potential drop across R3, V3 = ?

Electric potential at point A, Va = ?

Solution:

{a} Total resistance, Rt = ?

Since arrangement is series

$Rt = R1 + R2 + R3$

$Rt = 4 + 6 + 5$

$Rt = 15\ \Omega$

{b} Electric current, I = ?

From: $I = E/Rt$

$I = 9/15$

$I = 0.6A$

{c} Potential drop across R1, V1 = ?

From: $V1 = IR1$

$V1 = 0.6 \times 4$

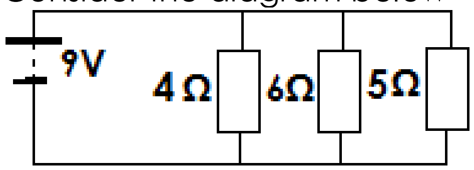
$V1 = 2.4V$

Potential drop across R2, V2 = ?
From: V2 = IR2
V2 = 0.6 x 6
V2 = 3. 6V

Potential drop across R3, V3 = ?
From: V3 = IR3
V3 = 0.6 x 5
V3 = 3.0V

{d} Electric potential at point A, Va = ?
Va = Vt – V1
Va = 9 – 2.4
Va = 6.6V

Example,
Consider the diagram below



{a} What is the total resistance of the circuit?
{b} What total current flows in the circuit?
{c} What is current across each resistor?
{d} Withal total current through the circuit?

Data given
Electromotive force, E = 9V
First resistor, R1 =4 Ω
Second resistor, R2 =6 Ω
Third resistor, R3 =5 Ω
Total resistance, Rt = ?
Total Electric current, It = ?
Electric current across R1, I1 = ?
Electric current across R2, I2 = ?
Electric current across R3, I3 = ?

Solution:
{a} Total resistance, Rt = ?
Since arrangement is series
1/Rt = 1/R1 + 1/R2 + 1/R3
1/Rt = 1/4 + 1/6 + 1/5
1/Rt = 0.25 + 0.17 + 0.2
1/Rt = 0.62
Rt = 1.61 Ω

{b} Total Electric current, It = ?
From: It = E/Rt
It = 9/1.61
It = 5.59 A

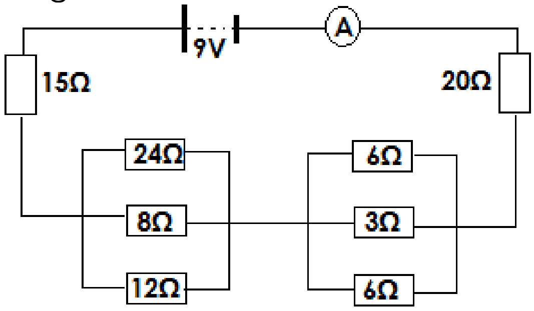
{c} Electric current across R1, I1 = ?
From: I1 =V/R1
I1 = 9/4
I1 = 2. 25V

Electric current across R2, I2 = ?
From: I2 = V/R2
I2 = 9/6
I2 = 1. 5V

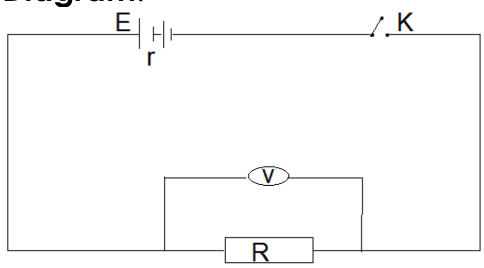
Electric current across R3, I3 = ?
From: I3 = V/R3
I3 = 9/5
I3 = 1.8V

{d} Total Electric current, It = ?
It = I1 + I1 + I3
It = 2.25 + 1.5 + 1.8
It = 5.59 A

Example,
Determine the current reading on the ammeter in the circuit shown in the diagram below



Internal Resistance of a Cell
Cell has internal resistance that opposes flow of electric current result potential drop across this resistance.
Diagram:



Where:
E = V_t = e.m.f
K = switch
R = external resistance
r = internal resistance
From: ohm's law when close the switch, k
V = IR
But: R and r are in parallel, the effective resistance is R + r
Then: E = I(R+r)

$E = IR + Ir$

$V_t = V + V_1$

Where:

$Ir = V_1$ = voltage drop of the cell

$IR = V$ = voltage across resistor

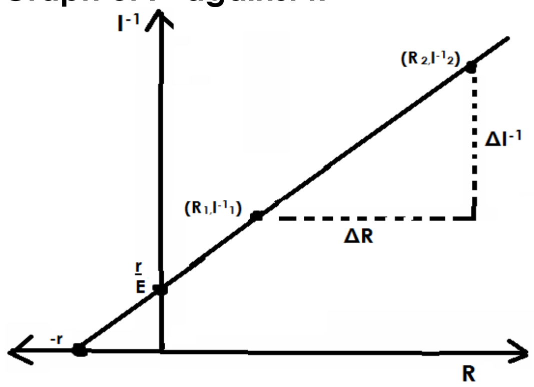
Graphically:

Assume E is constant, therefore r will be constant and R is variable.

From: $E = I(R+r)$ – make I^{-1} subject

$I^{-1} = R/E + r/E$

Graph of I^{-1} against R



Where:

Slope = $\Delta I^{-1}/\Delta R = E^{-1}$

Slope = electromotive force (e.m.f)

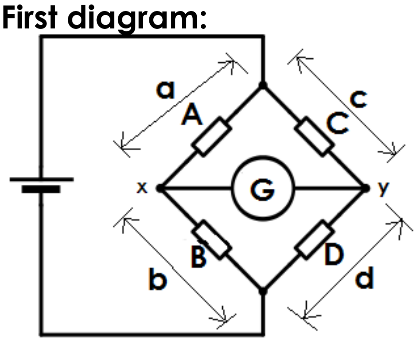
I^{-1}(when, $R/E = 0$) intercept = r/E

R (when, $I^{-1} = 0$) intercept = r

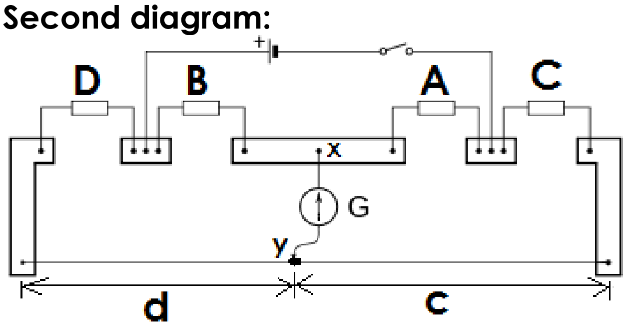
Wheatstone bridge

Defn: Wheatstone bridge is an electric bridge circuit used to measure the unknown resistance of a conduct. Also is called **Meter Bridge**

First diagram:



Second diagram:



Where:

The thick-edged areas are busbars of almost zero resistance

How to Use Meter Bridge

i. Connect known resistor A, B, C and unknown resistor D.
ii. Move voltage (p.d) gauge until no deflection (no p.d across xy)
iii. Measure the length a, b, c and d
iv. If no p.d across xy means

AB = CD = ab = cd

The expression can be used to determine the value of unknown resistor

Heating Effect of an Electric Current

We already study about relation between temperature and resistance. The resistance result heat energy.

Factors Affect Heat Quantity

It depends on the following factors

i. Resistance of conductor
ii. Magnitude of electric current
iii. Time taken the current pass

Resistance of Conductor

The higher the heat, the higher the resistance and vice versa

Magnitude of Electric Current

The higher the heat, the higher the electric current and vice versa

Time Taken the Current Pass

The time taken the heat, the higher the temperature and vice versa

Joule's Law

It tells us the relation between resistance, current and heat generated. State that

"The rate at which heat is produced in a resistor is proportional to the square of the current flowing through it, if the resistance is constant."

Mathematically:

$H/t \propto RI^2$

$H \propto tRI^2$ - remove proportionality constant

$H = ktRI^2$ – constant, K = 1

$\mathbf{H = tRI^2}$

But: R = v/I – substitute in the formula above

$H = (tvI^2)/I = tVI$

$\mathbf{H = tIV}$

But: I = v/R – substitute in the formula above

$H = tV(v/R) = t(V^2/R)$

$\mathbf{H = t(V^2/R)}$

Therefore: $H = t(V^2/R) = tIV = tRI^2$

Electrical Power

Defn: electrical power is the rate of potential different or electrical power is the rate at which electrical energy is dissipated

$P = p.d/time = w/t$

$P = QV/t = ItV/t = IV$

$\mathbf{P = IV}$

Example,

An electric kettle draws a current of 10A when connected to the 230V mains supply. If all the energy produced in 5 minutes is used to heat 2kg of water. Calculate

i. the power of the kettle
ii. the energy produced in 5 minutes
iii. the rise in temperature

(Specific heat capacity of water = 4200 $Jkg^{-1}K^{-1}$)

Data given:

Electric current, I = 10A

Electromotive force, V = 230V

Mass of water, m = 2kg

Tame taken foe current, t = 5min = 300sec

Specific heat capacity of water, c = 4200 $Jkg^{-1}K^{-1}$

Solution

i. Power of the kettle, p ?

$P = Energy/time = H/t = ItV/t = IV$

$P = IV = 10 \times 230 = 2300W = 2.3\ kW$

$\underline{P = 2300W = 2.3\ kW}$

ii. Energy produced, H = ?

$H = power \times time = pt = 2300 \times 300$

$H = 2300 \times 3000 = 690000J = 690\ kJ$

$\underline{H = 690000J = 690\ kJ}$

iii. Rise in temperature, $\Delta\theta$ = ?

Heat = energy gained by water

$H = mc\Delta\theta$ – make $\Delta\theta$ subject

$\Delta\theta = H/(mc)$

$\Delta\theta = 960000/(2 \times 4200) = 960000/8400$

$\underline{\Delta\theta = 82.14K}$

Electrical Appliance

Defn: Electrical appliance is the device uses heating element to produce heat energy. Nichrome wire is among of heating elements due to its high melting point. The common Electrical appliance include

i. Heaters
ii. Electric iron
iii. Bulbs, kettles
iv. Cookers
v. fridges
vi. Televisions
vii. Air condition

Rating Of the Electrical Appliance

Defn: rating of the appliance is the rate at which the appliances dissipate energy. Each electrical appliance has rating which enables us to know energy dissipated

For Example, an appliance marked 3000W, 240V dissipates energy at the rate of 3000Joules per second when connected to 240V

Power Ratings of Electrical Appliance

electrical appliance	power ratings at 240V
Immersion heater	2000W (2KW)
Electric heater	2000W (2KW)
Electric iron	1000W (1KW)
Electric cattle	2500W (2.5KW)
Hair dryer	400W
Colour TV	300W
Refrigerator	120W
Light bulb	25W - 150W

Nb:

i. When voltage lowed results decrease in rating. For Example, when mains supply fall to 230V instead of 204V the rating will decrease to 1836.8W instead of 2000W.
ii. If voltage increased result increase in rating which damage the appliance due to over heating

Measurement of Electrical Power

Power companies like TANESCO usually measure the electrical energy in **kilowatt hours (KWh)**

1KWh = (1KW x 1hour)J = (1000W x 60 x 60)J

1KWh = 3600000J = 3600KJ

Example,

A television set rated 200W is switched on for 5Hours every day. How much energy does it consumer in 30 days

Data given

Power released, P = 200W

Time taken, t = 5Hrs = 3600x5x30 = 540000 s

Energy released, E = ?

Solution

From: P = E/t – make E subject

E = Pt

E = 540000 x 200

E = 108000000J = 1.08 x 10^8J= 1.08 x 10^5kJ

Example,

A house has five rooms, each with a 60W, 240V bulb. If the bulbs are switched on 7:00p.m to 10:300p.m determined the power consumer by bulbs per day.

Data given

Time taken, t = 3.5Hrs

Energy released by each bulb, E = 60W

Energy released by 5 bulb, Eb = ?

Power released, P = ?

Solution

Energy released by 5 bulb, Et = 60 x 5 = 300W

Power released, P = Eb x t = 300x3.5

P = 300x3.5 = 1.05

P = 1.05kWh

Electrical Installation of a House

Domestic electricity is supplied by two cables, live (L), Neutral (N), the third cable is Earth to provide extra safety

i. Live cable (L)
ii. Neutral cable (N)
iii. Earth cable (E)

Live Cable (L)

The live cable is 240V relative to the neutral. The current in the live cable alternates 60 times a second (60 Hz). It represent by **brown colour** or **red colour**

Neutral Cable (N)

The Neutral cable is earthed at the power station. This to ensure current at neutral cable remains **zero potential** so it cannot give an electric shock on touching. It represent by **blue colour** or **black colour**

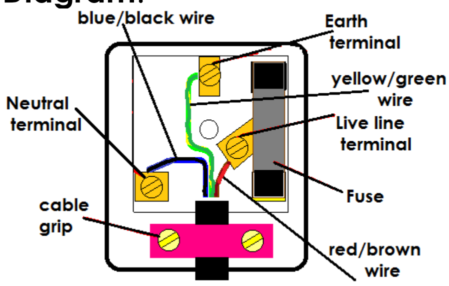
Earth Cable (E)

The earth cable introduces to provide extra safety especially in electrical appliances. It represent by **yellow colour** or **green colour**

Three Pin Plug

It consist of all three cables include Live cable, Neutral cable and Earth cable with a fuse connected to live cable, sometimes fuse can connected to neutral cable which is not safe

Diagram:



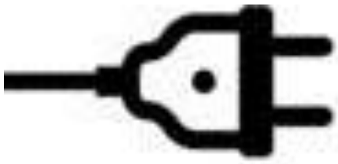
NB:

i. The earth pin usually longer than the other two which used to open socket
ii. Switch must be off when you push the plug into the socket

Two Pin Plug

It consist only two cables include live cable and Neutral cable an appliance use two pin plug its body not connected to earth

Diagram:



NB:

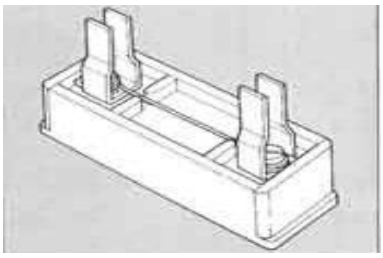
i. All connection should be tight, with no loose strands of wire
ii. The live cable should be short others two cable, due the fact that well pulled out be the first

iii. Cable should firmly clamped without damage insulation
iv. Fuse for collect rating

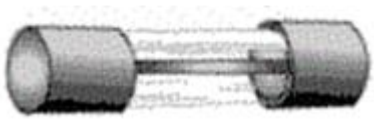
Fuses
Defn: fuse is a safety device used to protect an electric circuit against excess of current. It may be piece of copper or tin lead wire (inside casing) which melts when current through it exceeds a specific predetermined value

Types of Fuse
There are several types of fuses in use, includes
i. Rewireable fuse
ii. Cartridge fuses

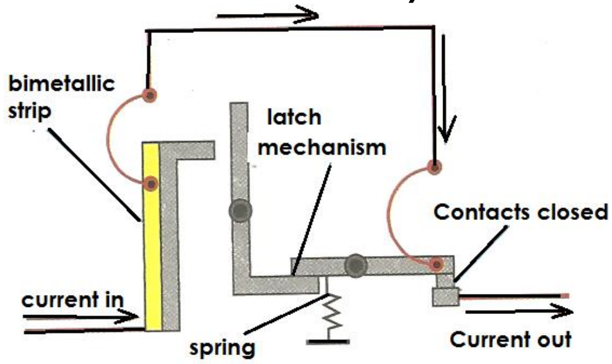
Rewireable Fuse
This kind of fuse, fuse element is carried in a removal fuse link made of porcelain or other insulating material
Diagram:



Cartridge Fuses
It consists of a porcelain tube with metal end caps to which the fuse element is attached
Diagram:

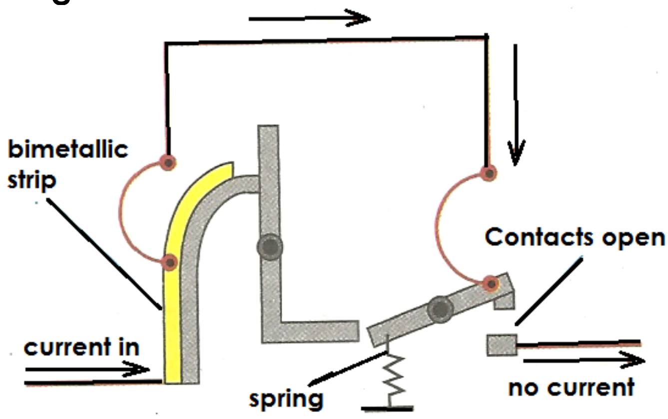


Circuit Breakers
Defn: Circuit breaker is a type of switch that cuts off the flow of electric current when the current exceeds a specific value.
Diagram:



Mechanism of Circuit Breakers
When current exceed tend to increase the temperature and bimetallic strip bend to push latch mechanism, enable the spring to cut off current

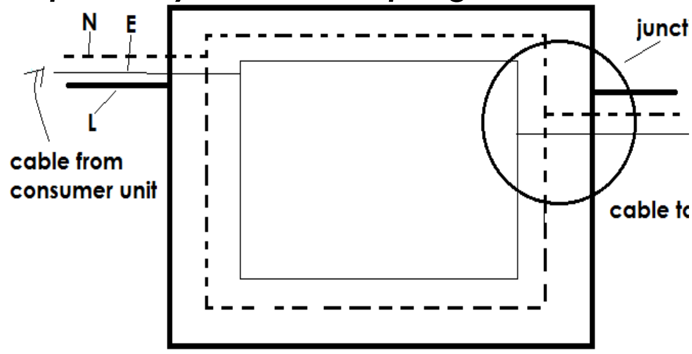
Diagram:



Domestic Wiring Circuit
The current from power plant connected to consumer unit where house wiring starts.
Defn: Consumer unit is the single box/unit where main switch, main fuse and distribution board

Types of Domestic Wiring Circuit
There two types include
i. Ring main circuit
ii. Lighting circuit

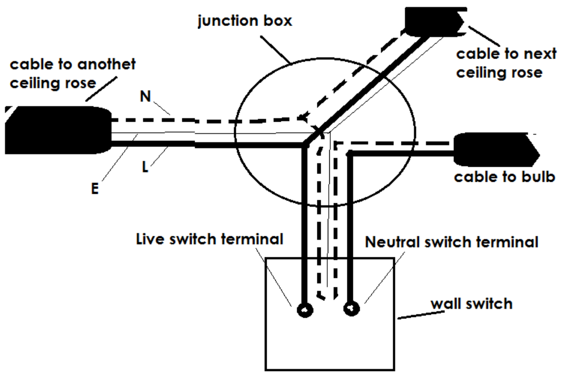
Ring Main Circuit
This is a cable which begins and ends at the consumer unit. It three cables are forming ring around part of house. It compose 30A fuse
Diagram:



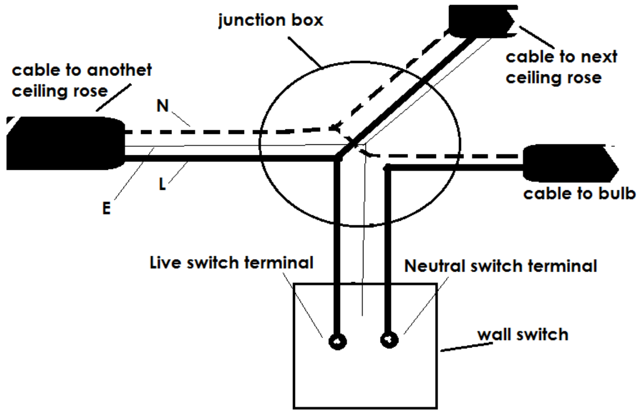
Lighting Circuit
In this circuit the first lamp connected from the customer unit, in turn is connected to the second lamp and so on.

Types of Lighting Circuit
There are two types
i. Loop in lighting circuit
ii. Junction box lighting circuit

Loop In Lighting Circuit
All three cables from consumer unit run to each ceiling roses, one after the other. From Each rose another set of cables runs to the switch which operates the light
Diagram:

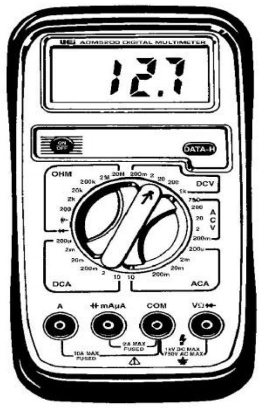


Junction Box Lighting Circuit
All three cables from consumer unit run to one junction box to another, where one cable runs to the light and another run to the switch for that light.
Diagram:

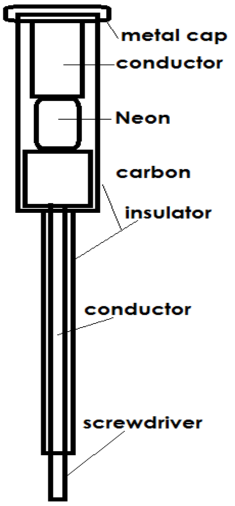


Repairing Electrical Appliances Faults
Multimeter and **Live mains lead indicator** are device important when checking electrical appliances faults.

Multimeter
Multimeter is the single meter for measure current (both a.c and d.c) voltage and resistance. It has a range switch precise readings can be taken. It divided into **moving coil Multimeter** and **digital Multimeter**
Diagram:



Live Mains Lead Indicator
It made up of for, of a screwdriver with a hollow insulting handle containing a tiny neon discharge tube. One electrode connected to metal probe of the screwdriver and another electrode connected to metal cap of the handle through a high carbon resistor
Diagram:



Mechanism
When metal probe inserted into live socket and touch the metal cap with finger, the current leaks to the earth through the body and the neon tube glows.

Repair Faults Procedure
If electrical appliance fails to work the following procedure should be done
- i. Check by using live mains lead indicator if there is power or not
- ii. Check the cable from the socket to the appliance
- iii. If no fault open the plug and check the fuse, if no is detected
- iv. Check each cable for continuity by using a Multimeter
- v. If cable are working good, check the fault is in the element by using a Multimeter
- vi. If element is in fault, replace element as repair may not be possible
- vii. If element is no fault , look for loose connection, these should be made firm and/or cleaned of rust and other dirt

Source of Faults
Faults in domestic system can arise due to
- i. When fuse blows or melt
- ii. Wire cutting
- iii. Wire joining
- iv. Socket getting dirty
- v. Switches breaking

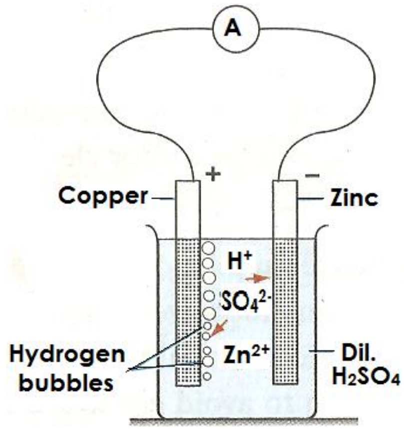
Cells
Defn: cell is a set up used to cause a flow of electric current in a conductor. Cells store chemical energy so current caused by reaction to release and accept electrons. Also is called **electrochemical cell**

Types of Electrochemical Cell
- i. Primary cell
- ii. Secondary cell

Primary Cell
Primary cell is the kind of cell in which current generated through electrolysis. Electrolytes replaced after some time. It called voltaic cell. Example, of primary cell
- i. A Simple cell
- ii. Leclanché cell
- iii. Dry cell

Simple Cell
Made from copper as anode, zinc as cathode and Dilute sulphuric acid electrolyte

Diagram:



Dissociation:

$H_2SO_{4\,(aq)} \xrightarrow{yields} 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

$HO_{2\,(l)} \xrightarrow{yields} H^+_{(aq)} + OH^-_{(aq)}$

Cation present: only H^+

Anion present: $OH^-_{(aq)}$ and $SO_4^{2-}{}_{(aq)}$

At anode:

Zinc metal dissolved into solution to form zinc Cation which reacts with sulphate anion to form zinc sulphate until sulphate anion fished from electrolyte

$Zn^+ + SO_4^{2-} \xrightarrow{yields} ZnSO_4$

At cathode:

Hydrogen cation discharge to liberate hydrogen gas (bubbles)

$2H^+ + 2e \xrightarrow{yields} H_2$

Defects of a Simple Cell

Current drop is the main reason why simple cell is no longer used as a source of electric current due to the following reason

i. Formation of hydrogen bubbles on zinc plate
ii. Polarization

Formation of Hydrogen Bubbles

Formation of hydrogen bubbles on zinc plate due to impurities from zinc reacts with acid. It referred as **local action.**

HOW to Minimize Local Action

Local action is reduced by using **pure zinc** or by **rubbing mercury** on zinc plate to form an **amalgam**

Polarization

In the copper plate the hydrogen bubble to forms another cell with the zinc which oppose the zinc-copper cell. Also hydrogen bubbles insulate copper plate

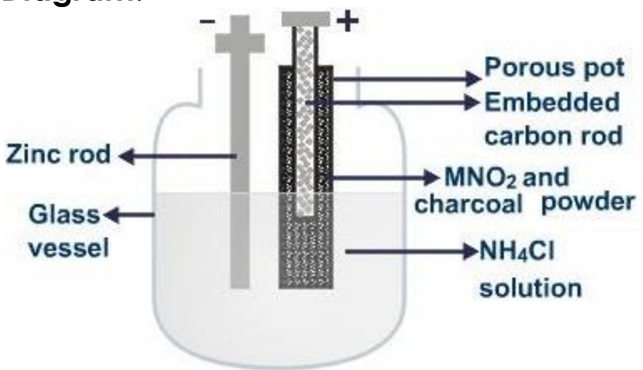
How to Minimize Polarization

Polarization minimized by adding a depolarizer. Example, potassium dichromate which oxidizes the hydrogen to water

Leclanché Cell

Made from carbon as anode, zinc as cathode, ammonium chloride (NH_4CL) solution and depolarizer manganese dioxide (MnO_2)

Diagram:



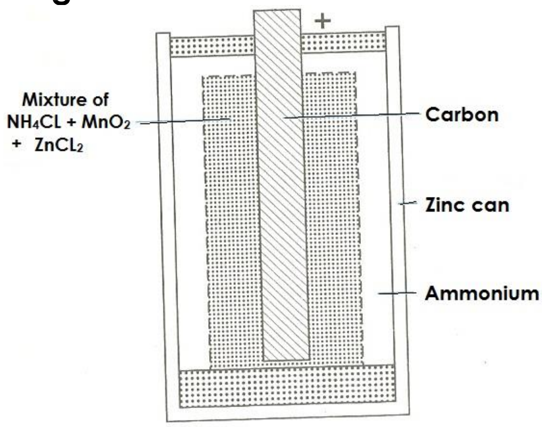
Nb:

i. Polarization is reduced by manganese dioxide (slow depolarizer) but when large current is drawn Polarization takes place
ii. leclanché cell exist today as dry cell

Dry Cell

Dry cell use paste instead of electrolytes. Made from carbon as anode, zinc as cathode and paste (ammonium chloride (NH_4CL), manganese dioxide (MnO_2) and zinc chloride)

Diagram:



NB:

i. Ammonium chloride (NH_4CL) and zinc chloride act as electrolyte
ii. manganese dioxide depolarizer mixed with zinc anode

Uses of Dry Cell

It used to operating radios, electronic calculators and other small electrical device

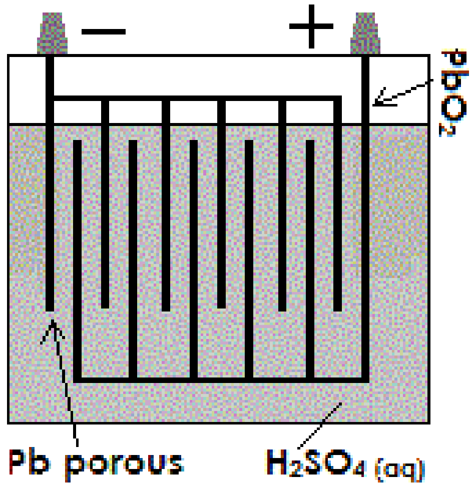
Secondary Cell

Secondary cell is the cell which can be recharged. It means the chemical reaction inside the cell is reversible. For Example, **lead acid cell** and **nickel ferrous cell**. Also called **accumulators**

Lead Acid Battery

It consist more than one lead ferrous cell, made up of **lead peroxide** as anode, **porous lead metal** as cathode and **sulphuric acid** as electrolytes. An electrode is separated by insulator called **separator**. Cathode joining together to form negative terminal while anode joining together to form positive terminal

Diagram:



Discharge of Lead Acid Battery

Defn: discharge is the process of cells to provide electrical energy. Energy is produced by reaction between electrolyte and active material of the electrode. This low concentration of the electrolyte (sulphuric acid), during discharge lead peroxide become lead sulphate and porous lead become lead sulphate

Charging Of Lead Acid Battery

The aim of charging is to drive all the acid out of the plate and return it to the electrolyte. When charging positive dc terminal connected to negative terminal of lead acid accumulator and negative dc terminal connected to positive terminal of lead acid accumulator, during charging lead sulphate of anode become lead peroxide and lead sulphate of cathode become porous lead

NB:

i. When battery full charged battery are said to be **sulphated**
ii. Main advantage of lad acid cell is its ability to recharge
iii. Its major disadvantage are its size and weight
iv. Never allow lead acid cell fully discharged

Taking Care of Accumulators

The following are some care tips on how to care for lead acid batteries

i. Cell should be charged regularly and should never left discharges
ii. The acid level is should be maintained by adding distilled water when necessary
iii. Terminal should be clean and greased
iv. Rough handling should be avoided
v. The cells should be not be short circuited, Example, if you connect two terminal
vi. The rate specified by manufacture should not exceeded during charging

Uses of Accumulators

i. Used to provide power in motor vehicles
ii. Used to provide power to power domestic appliances such as radio
iii. Used to store solar power

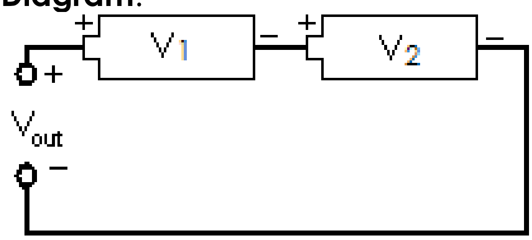
Cell Arrangement of Cells

i. Series arrangement
ii. Parallel arrangement

Series Arrangement of Cells

In this series arrangement the positive terminal of one cell connected negative terminal of another cell

Diagram:



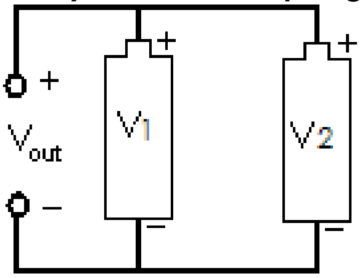
Nb:

i. Electric current same at each cell
ii. Total voltage across cells is equal to the sum voltage of the individual cells, **thus why torch light uses this arrangement**

Parallel Arrangement of Cells

In this series arrangement, all positive terminals of cells connected together and negative terminal of cells connected together

Diagram:



Nb:

i. voltage same at each cell
ii. Total Electric current across cells is equal to the sum Electric current of the individual cells, thus **why lead acid accumulator uses this arrangement**

Wave

Defn: *Wave is a progressive disturbance propagated from a point in a medium (matter) on space without the movement of the points themselves*. For Example, **light**, **sound** and **water** waves

Terms Used

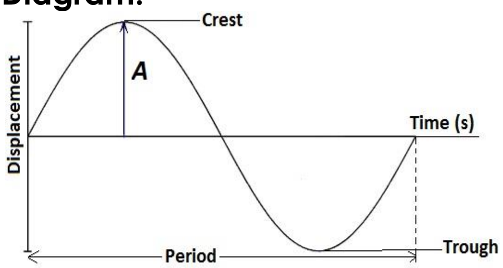
i. **Period:** period is the time taken for complete a cycle. It represented by letter T. it SI unit is **second (s)**

ii. **Amplitude:** Amplitude is the maximum displacement of the wave from the equilibrium position. It represented by letter **A**. it SI unit is **metre (m)**

iii. **Crest:** Crest is the point of maximum positive displacement of the wave from the equilibrium position

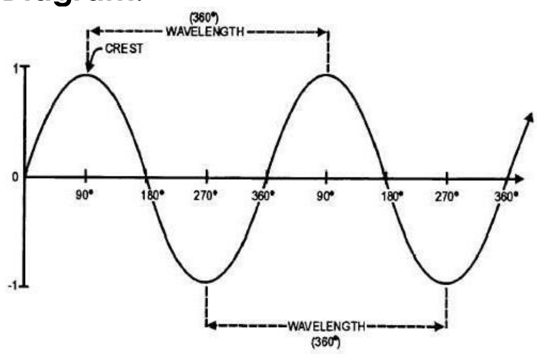
iv. **Trough:** Trough is the point of maximum negative displacement of the wave from the equilibrium position

Diagram:



v. **Wavelength:** Wavelength is the distance between two successive or adjacent crests **or** troughs. It represented by letter **Lambda (λ)**

Diagram:



vi. **Frequency:** Frequency is the number of crest or trough that passes a given point per unit time. It represented by letter $\boldsymbol{f}$. Its SI unit is **1hertz (Hz) = 1per second (s^{-1})**

Mathematically:

$$\boldsymbol{f = \frac{1}{T}}$$

vii. **Defn: Wave velocity:** Wave velocity is the speed at which the wave moves through a medium

Or

Defn: Wave velocity is the displacement of the wave per unit time. It represented by letter **v**

Mathematically

$V = \frac{\lambda}{T} = \lambda \times \frac{1}{T}$

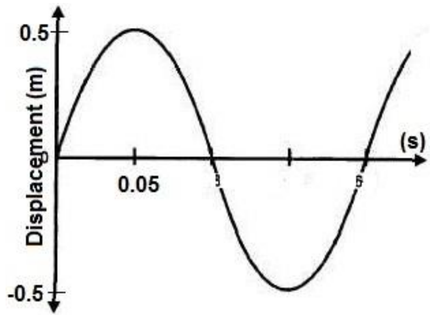
But: $f = \frac{1}{T}$

$V = \lambda \times f = \lambda f$

$\boldsymbol{V = \lambda f}$

Example,

From the diagram below, determine the amplitude, period and frequency of the wave



Solution

From the graph

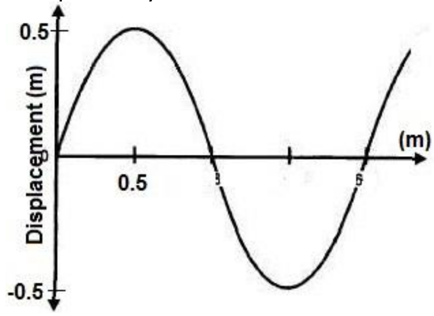
Amplitude, A = 0.5m

Period, T = 0.2

Frequency, f = 1/T = 1/0.2 = 5Hz

Example,

From the diagram below, determine the wavelength and velocity of the wave, frequency of the wave is 5Hz



Solution

From the graph

Wavelength, λ = 2m

Velocity, v = ?

But: Frequency, f = 5Hz

From: $V = \lambda f$

Then: V = 2 x 5 = 10m/s

V = 10m/s

Types of Waves
There are two types include
i. Electromagnetic wave
ii. Mechanical wave

Electromagnetic Wave
Defn: electromagnetic wave is the kind of waves in which do not require a medium to transfer energy.

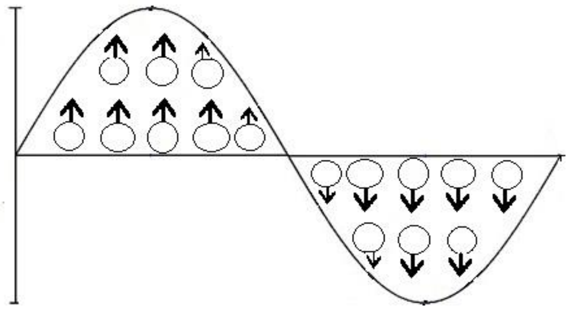
Properties of Electromagnetic Wave
i. The disturbance made up of electric and magnetic fields
ii. can travel through vacuum
iii. Example, visible light and sun rays etc

Mechanical Wave
Defn: mechanical wave is the kind of waves in which require a medium to transfer energy.

Properties of Mechanical Wave
i. mechanical travel through a medium the particle that make up the medium are disturbed from their rest or equilibrium position
ii. can travel through medium
iii. Example, sound wave etc

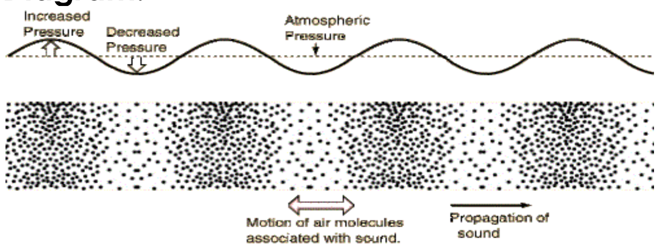
Types of Mechanical Wave
There are two types include
i. Transverse wave
ii. Longitudinal wave

Transverse Wave
Defn: transverse wave is the mechanical wave in which particles of the medium vibrate in a direction perpendicular to the direction of movement of the wave. For Example, water wave
Diagram:



This vibration of medium cause boat on the ocean moves up and down while the waves themselves move toward the shore

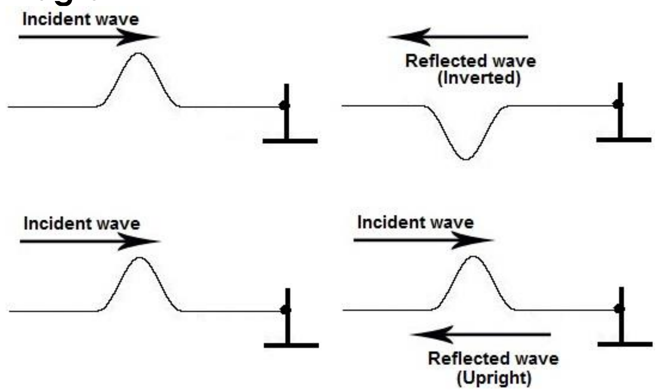
Longitudinal Wave
Defn: longitudinal wave is the mechanical wave in which particles of the medium vibrate in a direction parallel to the direction of movement of the wave. For Example, sound wave
Diagram:



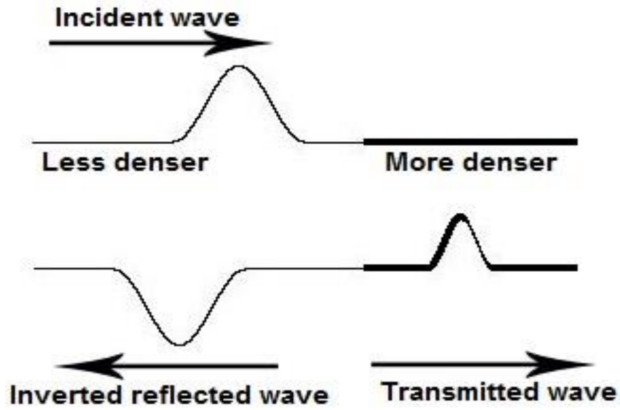
It consist **compression** where the particles packed closely together and **rarefactions** where the particles are spread out

Behaviour/Properties of Waves
If waves travel from one to another point it may the following characteristics
i. Reflection of waves
ii. Refraction of waves
iii. Interference of waves
iv. Diffraction of waves

Reflection of Waves
When wave encounter a boundary through which it cannot pass it will be reflected. If boundary fixed the reflection inverted
Diagram

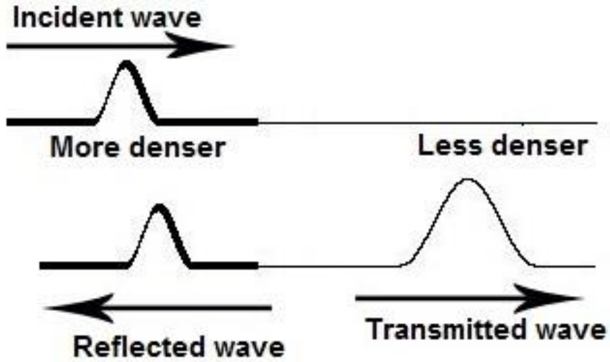


If the wave travel from less denser medium to denser medium the reflection will inverted
Diagram



If the wave travel from denser medium to less denser medium the reflection will not inverted

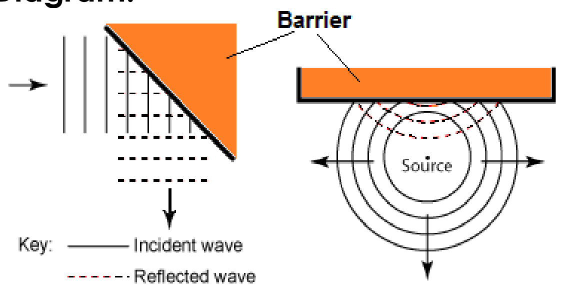
Diagram



LAWS OF REFLECTION of waves

Consider the figure below

Diagram:



Reflection of Plane Wave Reflection of Circular Wave

From above diagram, the laws of reflection of waves states that

1st. *"the incident direction of propagation, the reflected direction of propagation and the normal all lie in the same plane"*

2nd.*"The angle of incidence equals to the angle of reflection"*

NB:

i. Direction of waves is represented by an arrow called a ray which drawn perpendicular to wave fronts in straight surface

ii. If water waves encounter an parabolic (concave/convex) Barrier the waves change direction to focal point of parabolic barrier and spread out water

Applications of Reflection of Waves

i. Reflection of light waves is used in the designing of plane mirror

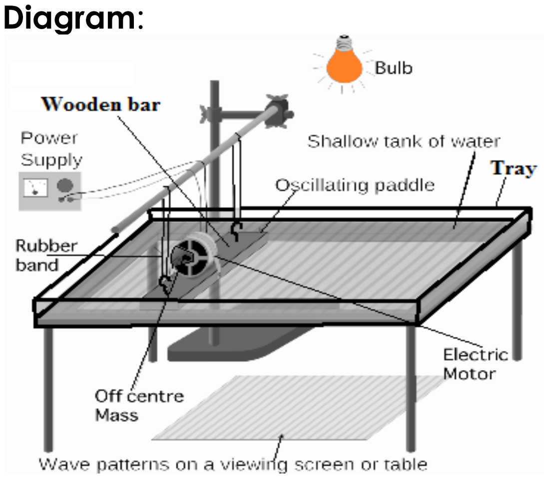
ii. Reflection of waves(sound waves) used on measuring distance

iii. Sonar system rely on the reflection of sound waves to assist ships in navigating, communicating and detect other vessels

Ripple Tank Experiment

Ripple tank experiment consists of water pool in shallow rectangular dish with a clear glass base, wooden/metal bar for generating water waves

Diagram:



Main Parts of Ripple Tank

The basic components of ripple tank experiment are ripple tank, water, power supply, stroboscope, electric motor, wooden bar (vibrator), bulb and white board or white sheet (screen)

i. metal bar (wooden bar)

ii. Shallow tank of water

iii. Motor

iv. Oscillating paddle

v. Lamp

vi. Paper sheet

vii. Various obstacles. E.g. Laying glass

viii. stroboscope

Metal bar

A metal bar (wooden bar) is screwed to the electric motor and suspended above the ripple tank with rubber (elastic) bands and touching the water surface

Shallow tank of water
Shallow tank of water is the source of waves in which an oscillating paddle generates parallel water waves

Motor
The rotating armature (axle) of an electric motor makes the wooden/metal bar to vibrate on water surface and generating ripples

Oscillating paddle
Oscillating paddle is the one in which transform mechanical energy generated by motor by off centre mass to wave energy in a Shallow tank of water

Lamp/ Bulb/ filament
Bulb or filament which used to illuminate the water surface to see the water waves onto the white board or white sheet below the ripple tank

Paper sheet
Paper sheet used to display shadow of the wave pattern placed under the tank

Various obstacles
Various obstacles is paced in the tray to observe properties of waves e.g. reflection, refraction, interference and diffraction. Example, **laying glass**, **rectangular barrier**, **curved barrier** (concave and convex barrier) etc

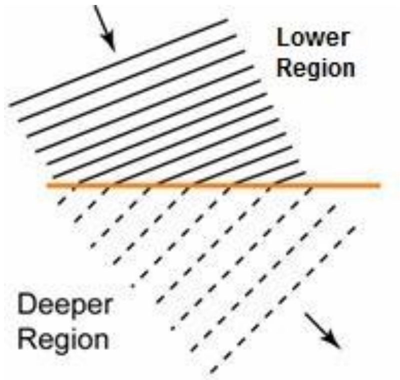
Stroboscope
The stroboscope enables the observer to see the waves as stationary

Laying glass
Laying glass used to vary the depth (tray thickness) of the water. This allows observing waves travelling from one to another medium

Power supply
Power supply for electric motor

Refraction of Waves
Refraction of waves involves a change in direction of waves as they travel from one to another medium due to a chance in speed (v) and wave length (λ). It obey **Snell's law**

Diagram:



NB:
(a) When wave is refracted into an less median The frequency of wave increases and vice versa
(b) When wave is refracted into an less median The speed of wave increases and vice versa
(c) When wave is refracted into an less median the wave length of wave increases and vice versa
(d) When wave is refracted into an less median The wavelength of wave does not change (unaltered) and vice versa

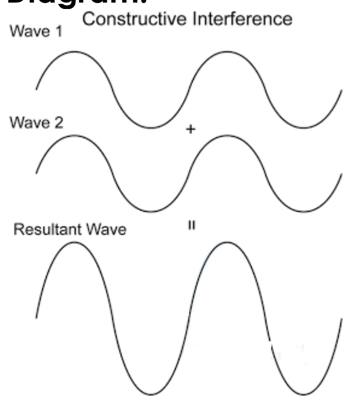
Application of Refraction of Waves
i. It is used in optical instruments which focus or spread light. For Example, microscopes and telescopes
ii. It is used in dispersion of light waves
iii. It is used to determine the eye's refractive error

Interference of Waves
Interference of waves involves meets of two or more waves. Interference also known as **addition/superposition** which result a new wave pattern

Principle of Superposition
It states that
"***The resultant displacement at any points is equal to the sum of the displacements of different waves at the point***"

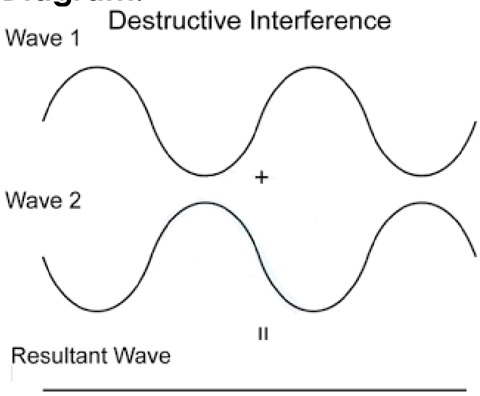
Nb:
i. When two different crests meet at the same point in the same direction results greater amplitude than individual, this refers as **constructive interference**

Diagram:



ii. When crest and trough meet at the same point in the opposite direction results smaller amplitude than individual, this refers as **destructive interference**

Diagram:

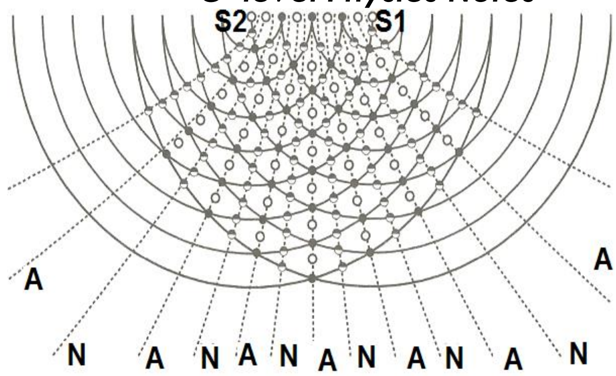


iii. Consider the table below

Wave A amplitude	Wave B amplitude	resultant amplitude
+1	+1	+2
+2	-1	+1
-1	+1	0
+1	-2	-1
-1	-1	-2

iv. When waves interfere, the lines of increase disturbance (constructive interference) is called **antinodal lines** while When waves interfere, the lines of zero disturbance (destructive interference) is called **nodal lines.**

Diagram:



Where:
S1= first wave source
S2= second wave source
Dark circle = crest meet crest
Blank circle = trough meet trough
Half–dark = crest meet trough
A series (Lines) = antinodal
N series (Lines) = nodal

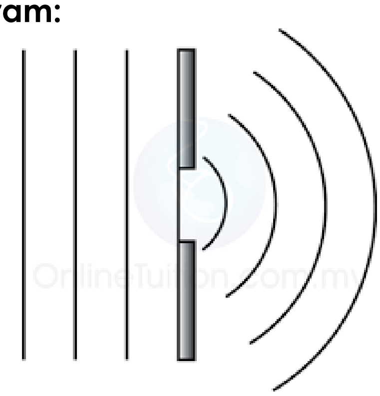
Application of Wave Interference

i. Creation of hologram. holograph is a photograph of an interference pattern which is able to produce a three dimensional image when suitably illuminated
ii. Noise reduction system. For Example, earphones capture environment sound which destructed by second computer sound
iii. Concert and auditoriums designed to reduce destruction interference by introduce sound absorber

Diffraction of Waves

Defn: wave diffraction is the apparent bend when encounter an obstacle and spread out of wave when they go through a gape.

Diagram:



Nb:

i. The gap is inversely proportional to wave diffraction (spreading), small the width of gape the large wave diffraction (spreading)

ii. Diffraction of wave is greater when the wave length and width of gap is the same
iii. We hear someone sound even she/he behind the building due to diffraction of wave sound

Characteristics of Diffracted Wave

i. Wavelength does not change.
ii. Frequency does not change.
iii. Speed of diffracted does not change.
iv. The amplitude of the wave decreases after diffraction.

Factors Affecting Diffraction

The magnitude of diffraction (or angle of diffraction) depends on

i. The wavelength
ii. The size of the opening gap

Applications of Diffraction Of Wave

i. It is used in determine the crystal structure of materials
ii. It is used in measuring the coefficient of thermal expansion, crystalline size and thick of thickness of thin films
iii. It is used in determine the types and phases present in a specimen where the spacing of obstacles (atoms) is between 1 and 3nm

Sound Waves

Defn: Sound wave is a longitudinal wave that produced by vibrating object. For Example, **turning fork**

Propagation of Sound Wave

Sound travels by vibrating of particles to transfer energy to the next particle until the sound reaches another point

Question: why solid materials transfer sound faster than liquid/gas

Answer: the molecules/particles of solid materials are packed together

Sources of Sound Wave

Almost everything ranging from **people**, **animals**, **plants** and **machines**

Musical Instruments

Musical instrument is designed to produce specific types of sounds include **guitars**, **violins**, **organs**, **recorders**, **flutes**, **drums**, **marimbas** etc

Factors Affect Speed of Sound In Air

Speeds of sound can be affected by the following factors

i. Temperature
ii. Direction of wind
iii. Humidity
iv. Density of air

Temperature

Sound is the form of kinetic energy. Molecules at higher temperature have more energy, thus they can vibrate faster so sound waves can travel more quickly

$V \propto T$

Direction of Wind

Sound will travel faster toward direction of wind while in opposite direction the speed of sound decreased

Wind direction: $V \propto W$

Wind in opposite direction: $V \propto \frac{1}{W}$

Humidity

Sound is the form of kinetic energy. Molecules at low temperature (humidity) have lower energy, thus they can vibrate slowly so the speed of sound decreased

$V \propto \frac{1}{H}$

Density of Air

Increase in temperature tend to decrease the density of air so increase in density of air tend to decrease speed of sound in air

$V \propto \frac{1}{\rho}$

Audibility Range

Defn: Audibility range is the range of frequency detected by ear

Nb:

i. The ear is most sensitive to sound with a frequency around **3000Hz**
ii. Sound below 20Hz is called **Infrasonic sound**

iii. Sound above 20000Hz is called **ultrasonic sound**
iv. Dogs, cat, bat and dolphins detect ultrasonic sound
v. Human ear can distinguish two simultaneous sound if their frequencies differ by at least **7Hz**

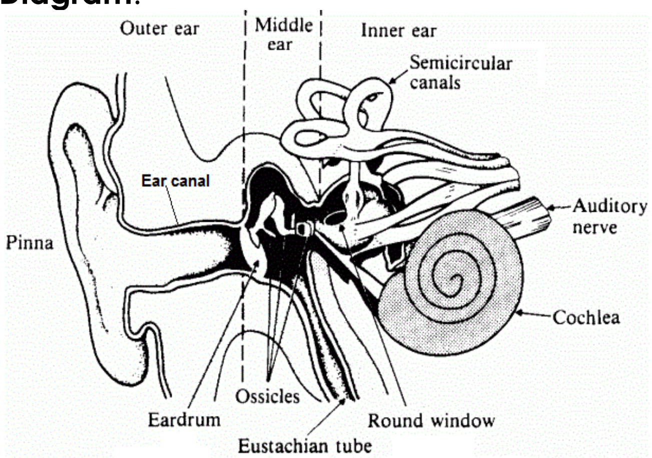
Audio Range Table

Animal	Audio range (Hz)
Chicken	125 – 2000
Penguin	100 – 15000
Owl	200 – 12000
Cattle	23 – 35000
Sheep	100 – 30000
Dog	67 – 45000
Cat	45 – 64000
Rabbit	360 – 42000
Horse	55 – 33500
Rat	500 – 64000
Blue whale	5 – 12000
Risso's dolphin	8000 - 100000

The Human Ear

Human ear is the human organ responsible for conversion of sound energy to mechanical energy to nerve impulse that transfers to the brain for interpretation. It can distinguish/discriminate frequency, amplitude and direction.

Diagram:



Part of Human Ear

It consists three basic parts include

i. outer ear
ii. Middle ear
iii. Inner ear

Outer Ear

Outer ear consist **earflap** and the **ear canal**. Sound reach outer ear in the form of pressure with an alternating pattern of high and low pressure regions

Middle Ear

Middle ear is air filled cavity that consists of an **ear drum** and three small interconnected bones **Hammer**, **anvil** and **stirrup**. **Eustachian tube** connect mouth and middle for regulation of pressure

Inner Ear

Inner ear consists of the **cochlea**, **semicircular canals** and the **auditory nerve**.

Cochlea

Cochlea is the auditory portion of the inner ear. It consist nerves called **cochlea nerve** or **auditory nerve** or **acoustic nerve.** Auditory nerves are differ in length for unique natural sensitive to particular frequency of vibration

Semicircular Canals

Semicircular canal is filled with fluid known as **endolympth**. It have nerve which responsible for balancing the body

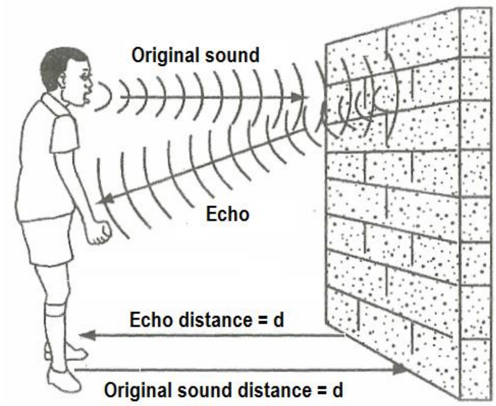
Mechanism of Hearing

Earflap collect sound wave, which pass through the ear canal to hit drum which results vibration of interconnected bones where vibrate cochlea fluid through (oval window) results vibration of hair cells which transform mechanical energy to electrical impulse, which transmitted to the brain where they are decoded and interpreted as sound

Echo

Defn: echo is the reflected sound when then encounter an obstacle. Since the sound waves goes and bounce back it distance becomes 2d.

Diagram:



Hence speed (v) of sound associated with echo is calculated by

v = 2d/t

Nb:

i. Always echo reaches the ear more than 0.1s
ii. At 25^0C the speed of sound in air is 340m/s
iii. **From**: v = 2d/t
 Then: 2d = v x t = 0.1 x 340
 d = 17m
 Therefore: minimum distance an obstacle kept is 17m for echo to be heard

Reverberation

Defn: reverberation is reechoed of sound

Example,

A gun was fired and the echo from a cliff was heard 8s later. How far was the gun from the cliff?

Data given

Time taken by echo, t = 8s

Wave velocity in air, v =

Distance moved by sound, 2d = ?

Solution

From: d = v x t

2d = 1500 x 8

2d = 2800m

d= 1400m

Example, : NECTA 2000, QN: 04

(a) Define an echo
(b) Name any two factors that affect the speed of sound in air
(c) Explain briefly why sound produced in hall with many people is heard more clearly than when the hall has few people?
(d) A person standing 99m from the foot of mountains claps his hands and hears an echo 0.6 second later. Calculate the speed of the sound in the air

Solution

(c) When a hail has many people, most of the sound (including echoes) is absorbed by clothes and skins of the audience, thus echoes do not occur

 Data given

 Wave distance, d = 99m

 Echo time, t = 0.6s

 Sound speed, v = ?

 Solution

 From: v = 2d/t

 v = 2d/t = (2 x 99)/0.6 = 198/0.6 = 330

 v = 330m/s

Uses of Echo

Under water echo is used

i. To find depth of ocean/ocean
ii. To detect the submarines
iii. To detect large groups of fish
iv. To detect the wrecked ships
v. To detect the dangerous rocks

Musical Sounds

By den: Musical sound is the sound musical scale (combination of frequencies) that appealing the human ear

Noise

By den: Noise is the random and non-structured sound musical scale (combination of frequencies) that not appealing to the human ear

Properties of Musical Sounds

The follows is the properties used to describe musical sounds, include

i. Loudness
ii. Pitch
iii. timbre

Loudness

By den: Loudness is the intensity of the sound as perceived by the human ear. The large the amplitude, the louder the sound

Pitch

By den: Pitch is a property of sound to which sound can be ordered to scale from high to low. The higher the frequency, the higher the pith produced.

Timbre

By den: Timbre is the quality/colour of sound produced by an instrument. For Example, different instrument produce different sound

Musical Instruments

By den: Musical instruments are a device constructed/modified for making music

Category of Musical Instrument

It categories into three groups include

i. String instrument
ii. Percussion instrument
iii. Wind instrument

String Instrument

String instrument is the instrument produced sound by stretched plunked/bowed/struck string. Example, guitar is plunked, violin is bowed and piano is struck

Percussion Instrument

Percussion instrument is the instrument produced sound by struck with implement/shaken/rubbed or scrapped. Example, **drum**, **cymbals**, **tambourine**, **marimba** and **xylophone**.

Wind Instrument

Wind instrument is the instrument produced sound by blowing. Example, **recorders**, **flutes**, **vuvuzela** and **trumpets**

Stationary Waves

A stationary wave is the result when two wave waves travel in opposite direction with the same speed and frequency superposed

Diagram: crest and trough meet

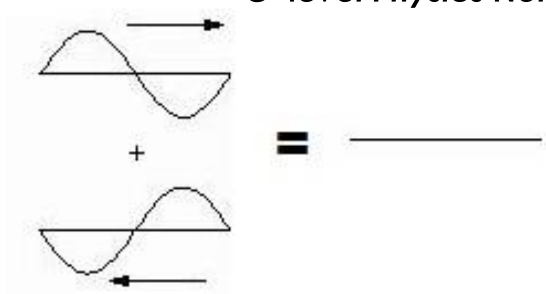
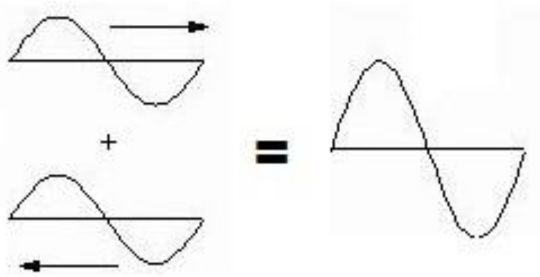


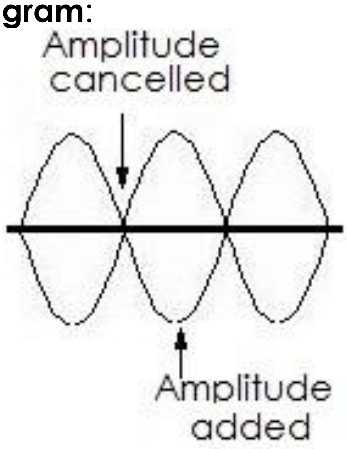
Diagram: crest/trough and crest/trough meet



NB:

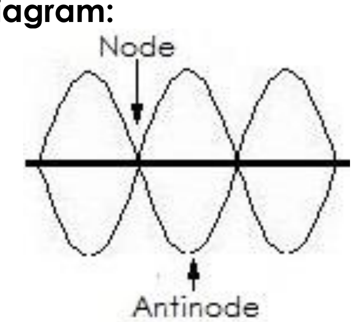
i. In string waves their amplitude are alternate between adding together and cancelling

Diagram:



ii. When adding together producing maximum displacement (amplitude) called **antinodes**
iii. When cancel out producing zero displacement (amplitude) called **nodes**

Diagram:



iv. distance between adjacent antinodes is equal to half wave length, $L = \lambda/2$
v. distance between adjacent nodes is equal to half wave length, $L = \lambda/2$

vi. distance between a nodes and an adjacent antinodes equal to one quarter, $L = \lambda/4$

Fundamental Frequency
Fundamental frequency is the lowest frequency of a vibrating object

Fundamental Note
Fundamental note is the note respond to Fundamental frequency

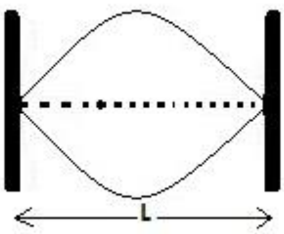
Fundamental Harmonic
A harmonic is defined as an integer (whole number) multiple of the fundamental frequency

Fundamental Overtones
Fundamental overtones is any frequency higher than the fundamental frequency

NB:

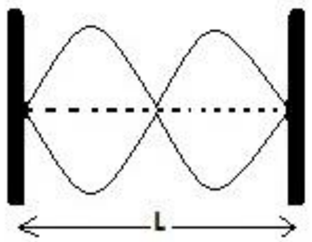
i. The fundamental note is equal to first harmonic
ii. The second harmonic is equal to first overtone
iii. Stationary wave in string have certain fixed wavelength

Consider the diagram below
Diagram: fundamental note



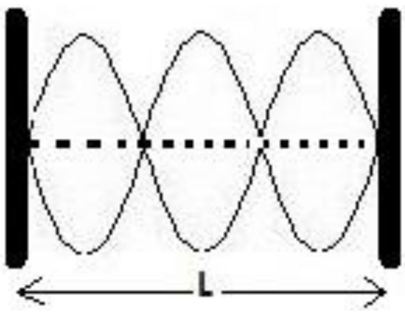
From: $L = \lambda/2$
Also: $\lambda = 2L$
From: $V = \lambda f_1$
Then: $V = 2Lf_1$

Diagram: second harmonic



From: $L = 2\lambda/2$
Also: $\lambda = 2L/2$
From: $V = \lambda f_2$
Then: $V = (2Lf_2)/2 = Lf_2$

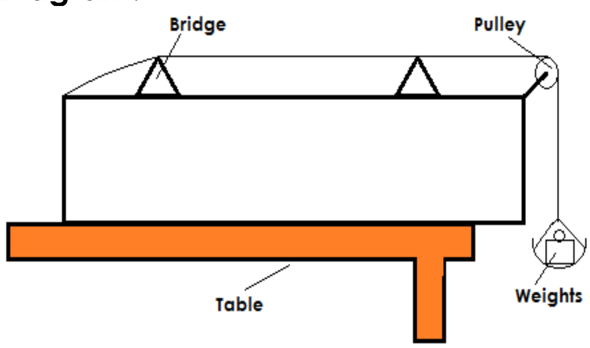
Diagram: third harmonic



From: $L = 3\lambda/2$
Also: $\lambda = 2L/3$
From: $V = \lambda f_3$
Then: $V = (2Lf_3)/3$

Generally
From: $V = (2Lf_3)/3$
Three represent the third series of harmonic therefore the formula modified to
$$V = (2Lf_n)/n$$
Where:
$n = n^{th}$ harmonic
f = frequency
v = wave velocity
L = length of string
f_n = frequency of n^{th} harmonic
f_1 = frequency of 1^{th} harmonic
f_2 = frequency of 2^{nd} harmonic
f_3 = frequency of 3^{rd} harmonic

Sonometer
Sonometer is an instrument used to study properties of stationary wave
Diagram:



Factors Affect the String Frequency
There are three factors that affect the frequency of vibrating wire, include

i. Length of wire, L

ii. Tension of the wire, T
iii. Mass per unit length, μ

Length of Wire
The frequency is inversely proportional to the length of wire
$f \propto \frac{1}{L}$ - - - - - 1

Tension of the Wire
The frequency is directly proportional to the square root of wire tension
$f \propto \sqrt{T}$ - - - - - 2

Mass per Unit Length
The frequency is directly proportional to the square root of mass per unit length
$f \propto \sqrt{\frac{1}{\mu}}$ - - - - - 3

Combine three equations
$f \propto \frac{1}{L}\sqrt{\frac{T}{\mu}}$ - Remove proportionality constant
$f = k\frac{1}{L}\sqrt{\frac{T}{\mu}}$
Where: $K = \frac{1}{2}$
Then: $f = \frac{1}{2} \, x \, \frac{1}{L}\sqrt{\frac{T}{\mu}}$

$$\boldsymbol{f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}}$$

From: $V = (2Lf_n)/n$ make f subject
$f = \frac{vn}{2L} = \frac{1n}{2L} \, x \, V$

By compassion
$$\mathbf{v = \sqrt{\frac{T}{\mu}}}$$
Modify formula
$$\boldsymbol{f_n = \frac{n1}{2L}\sqrt{\frac{T}{\mu}}}$$
Since: $\mu = \frac{m}{L}$ - substitute in equation above
$$\boldsymbol{f_n = \frac{n1}{2L}\sqrt{\frac{LT}{m}}}$$
Where:
n = n^{th} harmonic
f_n = frequency of n^{th} harmonic

Example,
A string has a length of 75cm and a mass of 8.2g, the tension in the string is 18N. Calculate the 1^{st} harmonic and 3^{rd} harmonic

Data given
Length of string, L = 75cm = 0.75m
Mass of string, M = 8.2g = 0.0082kg
Tension of string, T = 18N
1^{st} harmonic, f_1 = ?
3^{rd} harmonic, f_3 = ?

Solution
From: $f_n = \frac{n1}{2L}\sqrt{\frac{LT}{m}}$
1^{st} harmonic, f_1 = ?
$f_1 = \frac{1 \, x \, 1}{2 \, x \, 0.75}\sqrt{\frac{0.75 \, x \, 18}{0.0082}} = 27$
$f_1 = 27$Hz

3^{rd} harmonic, f_3 = ?
$f_3 = \frac{3 \, x \, 1}{2 \, x \, 0.75}\sqrt{\frac{0.75 \, x \, 18}{0.0082}} = 27$
$f_3 = 81$Hz

Example,
The vibration length of a stretched wire is altered at constant tension until the wire oscillates in unison with a turning fork of frequency 320 Hz. The length of a wire is again altered until it oscillates in unison with a fork of unknown frequency. If the two lengths are 90 cm and 65.5 cm, respectively, determine the unknown frequency

Data given
1^{st} Length of string, L_1 = 90cm = 0.9m
2^{nd} Length of string, L_2 = 65.5cm = 0.655m
1^{st} harmonic, f_1 = 320 Hz
2^{nd} harmonic, f_2 = ?

Solution
From: $f \text{ a } \frac{1}{L}$
Then: $fL = K$
Finally: $f_1L_1 = f_2L_2$ – make f_2 subject
$f_2 = (f_1L_1)/L_1$
$f_2 = (320 \times 0.9)/0.655 = 440$ Hz
$f_2 = 440$ Hz

Example, NECTA 1995: QN 08
A Sonometer wire of length 40cm between two bridges produces a note of 512Hz when plucked at the midpoint. Calculate the length of the wire that would produce a note of 256Hz with the same tension

Data given

1^{st} Length of string, L_1 = 40cm = 0.4m
1^{st} harmonic, f_1 = 512Hz
2^{nd} harmonic, f_2 = 256Hz
2^{nd} Length of string, L_2 = ?

Solution

From: f a $\frac{1}{L}$

Then: fL= K

Finally: $f_1L_1 = f_2L_2$ – make L_2 subject

$L_2 = (f_1L_1)/f_2$

f_2 = (512 x 0.4)/256 = 0.8m

L_2 = 0.8m

Forced Vibration and Resonance

Forced Vibration

Forced vibration is the vibration in a system as a result of impulse received from another system vibrating nearby

RESONANCE

Resonance is the tendency of a system to oscillate at maximum amplitude at certain frequencies from another system. For Example, turning fork can produce resonance on a piece of wood

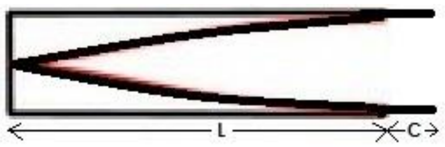
Nb:

Frequency of vibration is equal to the frequency of turning fork (the one cause resonance)

Resonance in Closed Pipe

Consider the diagram below

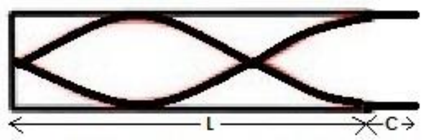
Diagram: fundamental note/ first resonance



Where:
c = end correction
L = λ/4

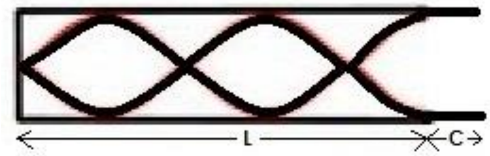
From: L = λ/4 – without end correction
L + c = λ/4 – with end correction

Diagram: second harmonic/resonance



From: L = 3λ/4 – without end correction
L + c = 3λ/4 – with end correction

Diagram: third harmonic/resonance



From: L = 5λ/4 – without end correction
L + c = 5λ/4 – with end correction

Generally

Without end correction
Ln = ((2n – 1)λ)/4

Without end correction
Ln + c = ((2n – 1)λ)/4

Where:
n = n^{th} harmonic
l_n = frequency of n^{th} harmonic

Example,

A turning fork of frequency 512 Hz is sounded at the mouth of a tube closed at one end with a movable piston. It is found that resonance occurs when the column of air is 18cm long and again when the column is 51cm long. Find wave length and velocity of sound in air

Data given

Frequency, f = 512Hz
First column length, L_1 = 18cm = 0.18m
Second column length, L_2 = 51cm = 0.51m
Wave length of sound in air, λ = ?
Velocity of sound in air, v = ?

Solution

From: L_1 = 1λ/4 - - - - 1
L_2 = 3λ/4- - - - 2

Solve simultaneous equation
Equation 2 minus equation 1

$L_2 - L_1$ = 3λ/4 - 1λ/4
$L_2 - L_1$ = 2λ/4
$L_2 - L_1$ = λ/2
0.51 – 0.18 = λ/2
0.33 = λ/2
λ = 0.33 x 2 = 0.66m
λ = 0.66m

From: v = λf
v = 0.66 x 512 = 338
v = 338m/s

Therefore the wave length of sound is 0.66m and velocity of sound in air is 338m/s

Example,

In a closed pipe, the first resonance is at 23cm and second at 73cm. determines the wave length of the sound and the end correction of pipe

Data given

First length, L_1 = 23cm = 0.23m

Second length, L_2 = 73cm = 0.73m

Wave length of sound, λ = ?

End correction of pipe, c = ?

Solution

From: $L_1 + c = 1\lambda/4$ - - - - 1

$L_2 + c = 3\lambda/4$- - - - 2

Solve simultaneous equation

Equation 2 minus equation 1

$L_2 + c – L_1 - c = 3\lambda/4 - 1\lambda/4$

$L_2 – L_1 = 2\lambda/4$

$L_2 – L_1 = \lambda/2$

$0.73 – 0.23 = \lambda/2$

$0.50 = \lambda/2$

$\lambda = 0.5 \times 2 = 1.00$m

$\lambda = 1$m

From: equation 1

$L_1 + c = 1\lambda/4$ – make c subject

$c = (1\lambda/4) - L_1$

$c = ((1 \times 1)/4) - 0.23$

$c = 0.25 - 0.23$

$c = 0.02$m

Therefore the end correction of pipe is 0.002m and wave length of sound 0.m

Example, NECTA 1997 QN: 09

(a) Identify three characteristics of sound which distinguish one note from another. Hence state the physical factors which correspondingly define the mention characteristics

(b) A resonance tube whose one end is closed and other open, resonance to a note of frequency 560Hz when the length of the air column is 15cm. determine the wave length of this sound in air. What is the shortest length of the air column which resonates in similar conditions to a note of frequency 1000Hz

Solution

(a) (i) frequency

(ii) Loudness (amplitude)

(iii) Quality of music note (Timbre)

(b) **Data given**

First Frequency, f_1 = 560Hz

First Column length, L_1 = 15cm = 0.15m

First Wave length of sound in air, λ_1 = ?

Second Frequency, f_2 = 1000Hz

Shortest length, l_2 = ?

Solution

Fist: find Wave length of sound in air, λ = ?

From: $L = 3\lambda/4$

$\lambda_1 = 4l/3 = (4 \times 0.15)/3 = 0.12$m

$\boldsymbol{\lambda_1 = 0.12}$**m**

Seconds: find Shortest length, l_2 = ?

Note: sound will travel in same speed

From: $v = \lambda_1 f_1 = 560 \times 0.12 = 67.2$m/s

Then: $\lambda_2 = v/f_2 = 67.2/1000 = 0.0672$m

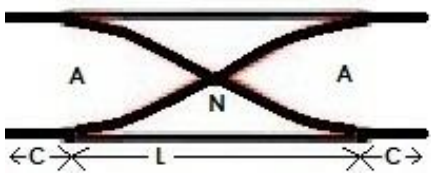
From: $L_2 = 3\lambda_2/4 = (3 \times 0.0672)/4 = 0.0504$

$\boldsymbol{L_2 = 0.0504}$**m**

Resonance in Opened Pipe

Consider the diagram below

Diagram: fundamental note/ first resonance



Where:

c = end correction

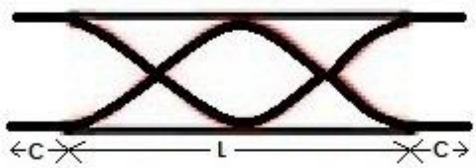
Since: opened twice end correction doubled

Then: $L = \lambda/2$

From: $L = \lambda/2$ – without end correction

$L + c = \lambda/2$ – with end correction

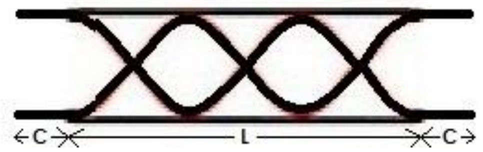
Diagram: second harmonic/resonance



From: $L = 2\lambda/2$ – without end correction

$L + c = 2\lambda/2$ – with end correction

Diagram: third harmonic/resonance



From: $L = 3\lambda/2$ – without end correction
$L + c = 3\lambda/2$ – with end correction

Generally
Without end correction
$L_n = n\lambda/2$

Without end correction
$L_n + 2c = n\lambda/2$

Where:
n = n^{th} harmonic
l_n = frequency of n^{th} harmonic

Example,
A turning fork of frequency 250Hz is used to produce resonance in an opened pipe. Given that the velocity of sound in air is 350m/s. find the length of tube which gives
a) First resonance
b) Third resonance

Data given
Sound frequency, f = 250Hz
Sound velocity, v = 350m/s
First resonance Length, L_1 = ?
Second resonance Length, L_2 = ?

Solution
From: $L_n = n\lambda/2$
Find wave length first
From: $v = \lambda f$ –make λ subject
$\lambda = v/f = 350/250 = 1.4m$

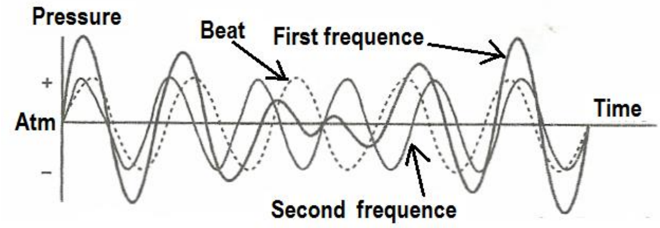
(a) First resonance Length, L_1 = ?
From: $L_1 = \lambda/2$
$L_1 = \lambda/2 = 1.4/2 = 0.7m$
$L_1 = 0.7m$

(b) Second resonance Length, L_2 = ?
From: $L_2 = 2\lambda/2$
$L_2 = 2\lambda/2 = (1.4 \times 2)/2 = 2.8/2 = 1.4$
$L_2 = 1.4m$

Beats
Beats is the fall or rise in loudness of sound when two sources of sound of nearly equal frequencies produce sound together.

Formation of Beats
Beats formed when two/more sounds instruments (e.g. forks) of nearly equal pitch are played/sounded together. As a results a regular rise and fall in the loudness occurs as the waves generated by the instruments interfere constructively and destructively respectively.

Diagram:



The Beat frequency/number is given by
$B_f = f_1 - f_2$ or $f_2 - f_1$

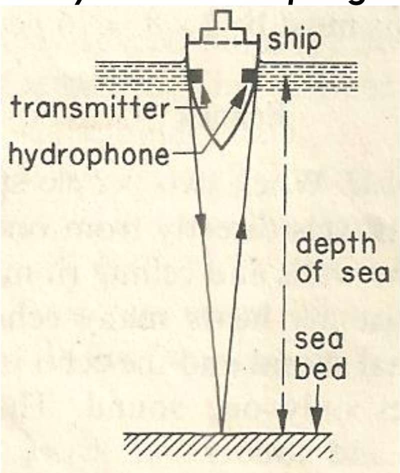
Example,
A 256Hz turning fork produces sound at the same time with a 249Hz turning fork. What is the beat frequency?

Data given
First frequency, f_1 = 256Hz
Second frequency, f_2 = 249Hz
Beat frequency, B_f = ?

Solution
From: $B_f = f_2 - f_1$
$B_f = f_1 - f_2 = 256 - 249 = 7Hz$
$B_f = 7Hz$

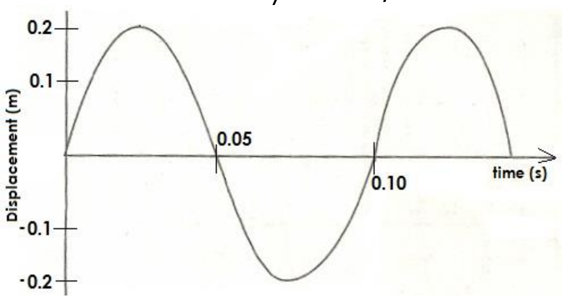
Example, : NECTA 2010, QN: 10
(a) (I) Distinguish between longitudinal wave and transverse wave
(ii) Explain how beats are formed
(b) A light wave is refracted into an optically less median. What change will occur in
(i) The frequency?
(ii) The speed?
(iii) The wavelength?
(c) (i) what is an echo
(ii) A sound is sent out from the ship and its reflection from the ocean floor returns one second later. Assuming that the velocity of sound in water is 1500m/s. how deep is the ocean?

Diagram



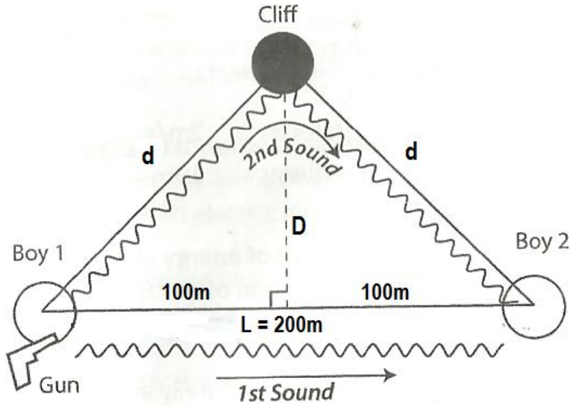
Data given
Time taken by echo, t = 1s
Wave velocity in air, v =
Distance moved by sound, 2d = ?
Solution
From: 2d = v x t
2d = 1500 x 1
2d = 1500m
d= 750m

Example, : NECTA 2011, QN: 06
(a) (i) What is a sonometer?
(ii) Briefly explain when resonance is said to occur.
(b) Two boys are stand 200m apart on one side of a high vertical cliff at the same perpendicular distance from it. When one fires a gun, the other hears the sound 0.6seconds after the flash and the second sound 0.25second after the first sound. Calculate the perpendicular distance of the boys from the cliff
(c) A diagram below illustrates part of the displacement-time graph of a wave travel with velocity of 2m/s.



Calculate.
i. The amplitude
ii. Frequency
iii. Wave length

Solution:
(b) Consider the diagram below



First sound
Distance of sound to other boy, L = 200m
Time taken to other boy, t_1 = 0.65s
Sound Speed, v = L/t_1
v = 200/0.65 = 307.69m/s
v = 307.69m/s

Second sound
Echo time, t_2 = 0.65 + 0.255 = 0.85s
Distance of echo, d = ?
From: 2d = v x t_2
2d = 307.69 x 0.85 = 261.54
d = 130.77m

Now: perpendicular distance, D = ?
From: Pythagoras theorem
$D^2 + 100^2 = d^2$
$D^2 = d^2 - 100^2 = (130.77)^2 - 100^2$
$D^2 = 17100.79 - 10000$
$D^2 = 7100.79 = (84.27)^2$
D = 84.27m

(c) **Data given**
Speed, v = 2m/s
Amplitude, A = 0.2m
Period, T = 0.1s
Frequency, f = ?
Wave length, λ = ?
Solution
i. The amplitude is 0.2m

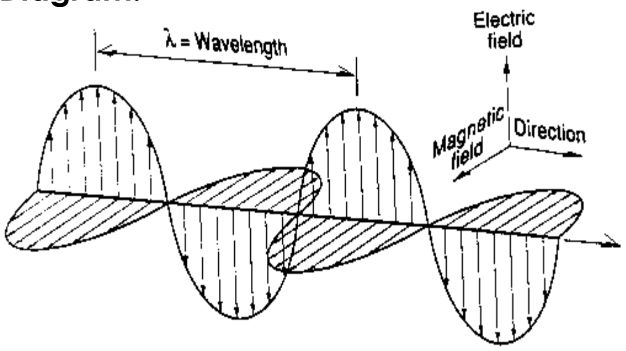
ii. Frequency, f = ?
From: f = 1/T
f = 1/T = 1/0.1 = 10
f = 10Hz

iii. Wave length, λ = ?
From: , λ = v/f
λ = v/f = 2/10 = 0.2
λ = 0.2m

Electromagnetic Waves

Electromagnetic wave is the wave travel perpendicularly to both electric and magnetic field. Include

Diagram:



Electromagnetic wave include the follows
- i. Radio wave
- ii. Microwaves
- iii. Infrared radiation
- iv. Visible light
- v. Ultraviolet rays
- vi. X–rays
- vii. Gamma rays

Nb:
- i. It produced when electrically charged particles oscillate or change energy
- ii. The greater the energy change, the higher the frequency of the resulting wave
- iii. In vacuum propagated in speed of light

Properties of Electromagnetic Waves

It is transverse waves which exhibit the following characteristics
- i. Do not require material medium for travel
- ii. It undergoes reflection, refraction, interference and diffraction
- iii. Travel at speed of 3 $\times 10^8$ m/s in vacuum
- iv. They carry no electric charge
- v. Transfer energy in form of electric & magnetic field
- vi. They obey wave equation, $v = \lambda f$

Electromagnetic Spectrum

Defn: Electromagnetic spectrum is a continuous band of all electromagnetic waves arranged in order of increasing or decrease frequencies or wavelength. It divided into seven regions or bands

Tables of Electromagnetic Spectrum

Wavelength (m)	Region	Frequency (H)
$>10^{-1}$	Radio waves	$>3 \times 10^9$
$10^{-1} - 10^{-4}$	Micro waves	$3 \times 10^9 - 3 \times 10^{12}$
$10^{-4} - 10^{-7}$	Infrared	$3 \times 10^{12} - 4.3 \times 10^{14}$
$7 \times 10^{-7} - 4 \times 10^{-7}$	Visible light	$4.3 \times 10^{14} - 7.5 \times 10^{14}$
$4 \times 10^{-7} - 10^{-9}$	Ultraviolet light	$7.5 \times 10^{14} - 3 \times 10^{17}$
$10^{-9} - 10^{-11}$	X-rays	$3 \times 10^{17} - 3 \times 10^{19}$
$<10^{-11}$	Gamma rays	$>3 \times 10^{19}$

Electromagnetic Spectrum Observation

There are two observations about electromagnetic spectrum include
- i. **It continuous**: means each band merges into next and there is no gap between their frequencies
- ii. **Some Wave length overlap**: in some case there is overlap of wave length so we have to name according to source not the wave length, for Example, **X-rays** and **Gamma rays**

Radio Waves

It has the longest wavelength in the electromagnetic spectrum

Category of Radio Wave

It divided into the following
- i. Long waves (**LW**)
- ii. Medium waves (**MW**)
- iii. Short waves (**SW**), include Very high frequency (**VHF**) and ultra high frequency (**VHF**)

Sources of Radio Waves

It produced by;
- i. Alternating electric currents flowing through in special conductor called **antennae**
- ii. Special circuits called **oscillator**
- iii. Object in space such as **planets**, **comets**, **stars** and **galaxies**

Detection of Radio Waves

Radio waves are detected using specially designed **antennae** such as those used in radios and televisions.

Uses of Radio Waves

i. Broadcasting of information by radio and television channels is achieved using radio waves.
ii. Astronomers use large radio telescopes to collect and study radio waves from distant stars and galaxies.

Microwaves

Microwaves have a short wavelength of between 10^{-4} m to about 0.1m

Sources of Microwaves

Microwaves are produced by oscillation of charges in special **antennae** mounted dishes. Micro waves are also produced in devices called **magnetrons**.

Detection of Microwaves

Micro wave can be detected by using special receiver which converts radio wave energy to sound called **RADAR** (**R**adio **D**etection and **R**anging)

Uses of Microwaves

i. Microwaves are used in cooking. In a microwave oven, microwave pass through the food and are absorbed by the food molecules.
ii. Radar system used microwave for detection of position, speed, and other characteristics of remote objects.
iii. Are used in long-distance communication because they are not affected by clouds or other atmospheric condition.

Infrared Waves

Infrared radiation has frequency of between 10^{12} and 10^{14} Hz. It has heating effect

Sources of Infrared Waves

It produced by vibration of atoms and molecules due to their thermal energy. All hot bodies emit infrared radiation

Detection of Infrared Waves

It detected by **black bulb thermometer**, **photographic films**, **Thermistor** and **phototransistors.**

Uses of Infrared Waves

i. It is used to cook food in convectional ovens
ii. It is used in **remote control**, **night vision device**, **fibre-optic telecommunication** and **security system**
iii. Used in infrared lasers that produce infrared beams that can be used to read information on compact discs.
iv. Used in the chemical industry to determine molecular structure and composition of substances by studying their infrared emission or absorption.
v. Used in the medical field to locate diseased tissues (these areas emit abnormal heat compared to the other areas) and injury by analysing the body tissue and body fluid.
vi. Used for military purposes where infrared imaging devices are used to locate enemy troops in the dark, detect hidden mines, arm caches, to guide anti-aircraft missiles, etc.
vii. Infrared radiation is used to de-ice the wings of aircraft
viii. In industries they are used for welding plastics, drying prints, curing (process of hardening) coatings etc.
ix. Used in locating missing people and people trapped under collapsed buildings (Infrared imaging devices are used)
x. Used to locate overheating in electric system

Visible Light

Visible light is the range of electromagnetic wave frequencies to which human eyes are sensitive

Sources Of Visible Light

It produced by electrons transitions within an atom (anything that's hot enough to glow). The sun emits 50% of visible light

Detection of Visible Light

It detected by eyes, photographic films and photocells

Uses of Visible Light

Visible light has very many uses

i. Photography
ii. Vision
iii. Photosynthesis

Ultraviolet Light

It has short wavelength than visible light

Sources of Ultraviolet Light

i. It produced by electrons transitions within an atom but more energetically
ii. Sun emit ultraviolet radiation which absorbed by ozone layer
iii. Electric arc used for welding emit ultraviolet radiation

Detection of Ultraviolet Light

It can detect by

i. Photographic film (ultraviolet light does not allowed to pass through across ordinary glass until fitted with quartz materials)
ii. Fluorescent materials which absorb and re-emit ultraviolet light

Uses of Ultraviolet Light

i. It stimulates of production of vitamin D in human skin
ii. It used in treatment of skin conditions such as **psoriasis**
iii. It is used as germicidal agent. Sterilization of food and purification of air and water
iv. It used to detect forget document and fake currencies. E.g. **bank**
v. It is used extensively in astronomical observation

NB:

Ultraviolet light can cause damage of skin, eyes, immune system (mutation) when prolonged exposure

X-Rays

X-rays Is the electromagnetic wave with short wavelength and very high frequency produced b when fast-moving electrons hit a metal target. It also called **ionization radiation** because if encounter an atom cause loss of electrons

Sources of X-Rays

It produced when electron accelerated in very high velocity hit a metal target x-rays

Tube

Detection of X-Rays

It can detect by the following methods

i. By using photographic plate
ii. By using x-ray film in a cassette
iii. By using rare earth element screens

Properties of X-Rays

i. travel in straight line at the velocity of light
ii. they cannot be deflected by electric or magnetic field
iii. they can produce fluorescence
iv. they affect photographic film
v. they penetrate matter but depend on density of matter
vi. they ionize gases
vii. can be diffracted by crystals

Uses of X-Rays

i. x-ray photography for diagnosis of denser tissue like bones
ii. it use in treatment of cancer
iii. used in industry to detect flaws in metal casting and welded joint such as in the aeroplane structure or building structure
iv. they used in airports and seaport for non-invasive security search
v. they are used in the study of the arrangement of atoms in solid
vi. used to produce images of very small object

Gamma Rays

Gamma ray is more energetically among electromagnetic wave. Also can cause **ionization**

Sources of Gamma Rays

i. It produced in space such as **solar flares**, **supernovae**, **neutron star**, **black holes** and **active galaxies**. All gamma ray from space absorbed by earth's atmosphere

ii. It produced by **radioactive decay of atoms** (natural radioactivity)
iii. It produced by **nuclear fission** (in atomic bombs and nuclear reactors)

Detection of Gamma Rays

It can detect by the following methods

i. Photographic films
ii. Geiger-Muller tube
iii. Cloud chamber

Uses of Gamma Rays

i. X-ray photography for diagnosis of denser tissue like bones
ii. It use in treatment of cancer
iii. It used in agriculture to obtain new plant varieties which are disease-resistance and give more yield

Example, NECTA 1995: QN 07

(a) Explain why radio waves are similar to light waves but not sound waves
(b) A radio station transmits a signal of wave 1500m. Calculate the frequency of this signal

Data given

Wave length, $\lambda = 1500m$

Wave Velocity, $v = 3 \times 10^8$ m/s

But: Frequency, $f = ?$

From: $V = \lambda f$

Then: $f = V/\lambda$

$f = 3 \times 10^8 / 1500 = 200000$ Hz $= 200$ KHz

$f = 200$ KHz

Example, NECTA 1998: QN 04

(a) What is diffraction of wave?
(b) Illustrate how plane water wave fronts are diffracted on passing through a narrow gap
(c) (i) Is it possible for light to be diffracted on passing through an open window?
(ii) Give an explanation on your answer above

Example, NECTA 1998: QN 08

(a) What is the fundamental frequency of a vibrating string?
(b) Sonometer consists of a taut steel wire fixed between two bridges 100cm apart. Defining the first harmonic, second harmonic, third harmonic and fourth harmonic, explain how overtones can be obtained

Electromagnetism

Defn: Electromagnetism is the effect produced by the interaction of an electric current with a magnetic field

We have already discuss in magnetism that electricity in solenoid produce magnetism, vice versa is the true in this topic we will see how magnet produce electricity

Direction of Current And Magnetic Field

Direction is governing by

i. Right hand grip rule
ii. Maxwell's right hand screw rule

Right Hand Grip Rule

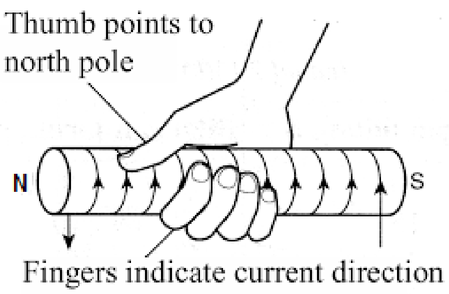
It concerning the direction of current and magnetic field in conductor and direction of current and magnetic north pole in solenoid

For solenoid

The law for solenoid States that

"***Wrapping right hand around a solenoid your fingers point the direction of current and the thumb point direction of magnetic north pole***"

Diagram:

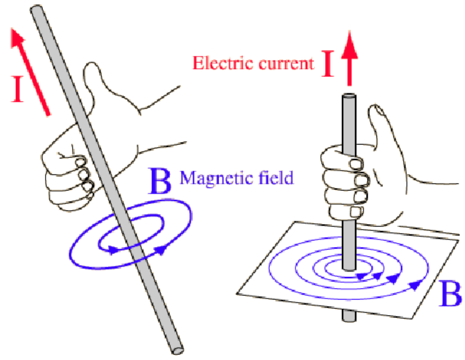


For conductor

The law for conduct States that

"***Wrapping right hand around a conductor your fingers point the direction of magnetic and the thumb point direction of current***"

Diagram:

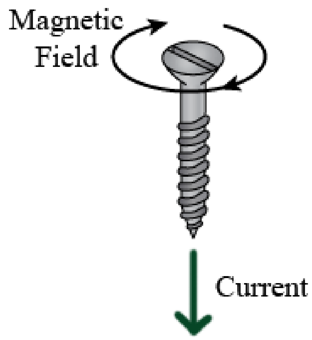


Maxwell's Right Hand Screw Rule

The law States that

"**When screw rotate advanced it moves in the direction of current and rotate in the direction of magnetic field**"

Diagram:

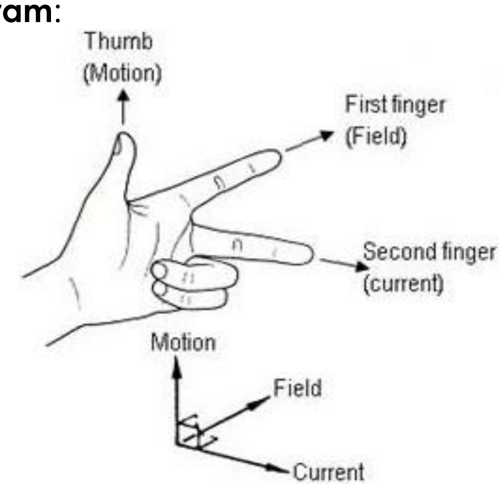


Fleming's Left Hand Rule

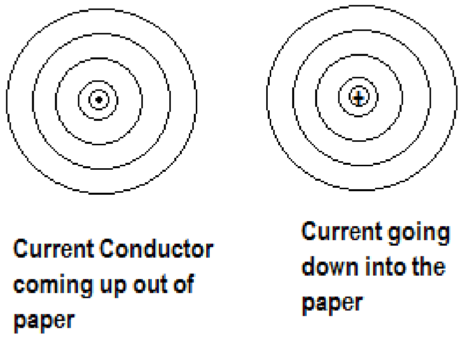
It describe the direction of force produced by conductor carrying current, which state that

"***The right hand is held with the thumb, first finger and second finger of left hand mutually perpendicular to each, The Thumb represents the direction of force/Motion of the conductor, The First finger represents the direction of the magnetic Field and the Second finger represents the direction of the Current***"

Diagram:



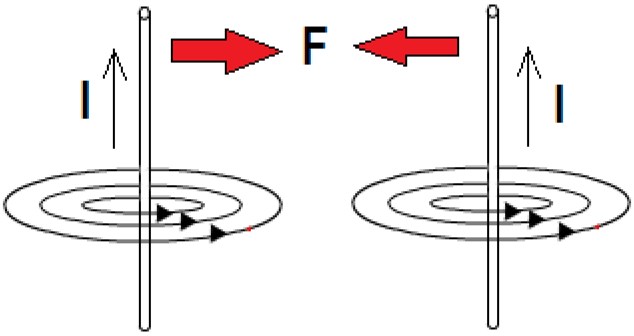
Where:



Force in Parallel Conductor

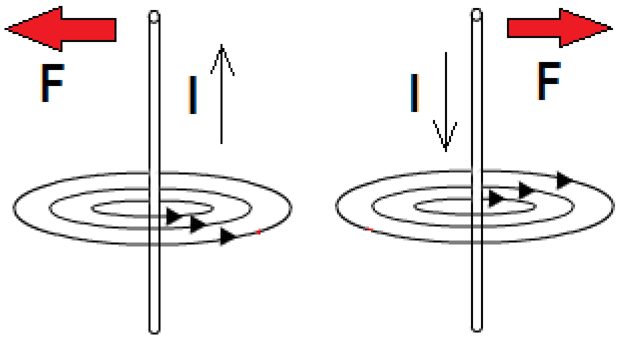
When the current pass through a two conductors in the same direction the conductors are attracted to each other

Diagram:



When the current pass through a two conductors in the opposite direction the conductors are repulsed to each other

Diagram:



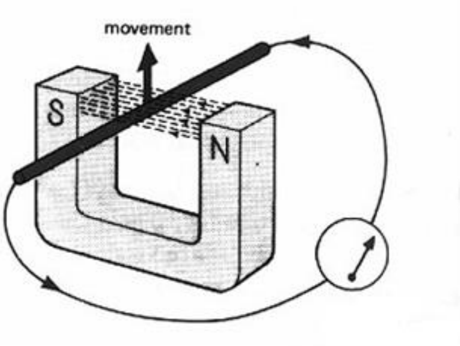
Electromagnetic Induction

Defn: Electromagnetic induction is the production of electromotive force whenever there is change in the magnetic flux (lines) linking a conductor

Or

Defn: Electromagnetic induction is the production of an electromotive force across a conductor when it is exposed to a varying magnetic field

Diagram:



NB:

i. Magnetic flux is the line
ii. Electromotive produced is called **induced electromotive force**
iii. Current produced is called **induced current**
iv. The conductor should moves in perpendicular to magnetic field
v. No current when conductor moves parallel to magnetic field

Laws Of Electromagnetic Induction

We have two laws associated with electromagnetic induction include

i. Lenz's law
ii. Faraday's law

Lenz's Law

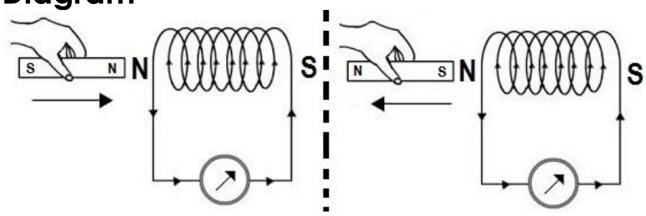
It describe the direction of induced e.m.f, which state that

"The direction of induced e.m.f is such that the resulting induced current flows in such a direction that oppose the change that cause it"

NB:

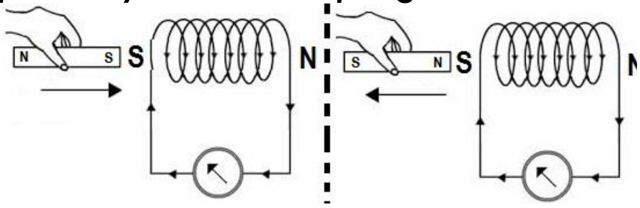
i. When North Pole approach and South Pole withdrawing the current moves in the same direction

Diagram



ii. When North Pole withdrawing and South Pole approach the current moves in the same direction

Diagram



Faraday's Law
It divided into two laws of electromagnetic induction include
1. Faraday's first law
2. Faraday's second law

Faraday's First Law
It state that

"**Whenever there is change in magnetic flux linked with a closed circuit e.m.f induced**"

Faraday's Second Law
It describe the magnitude of induced e.m.f, which state that

"***The induced e.m.f in a conductor in a magnetic field is directly proportional to the rate of change of the magnetic flux linking the conductor***"

Nb:
Faraday's law can be combined and states as one as follows

"**Whenever there is change in magnetic flux linked with a closed circuit e.m.f induced whose magnitude *is directly proportional to the rate of change of the magnetic flux linking the conductor***"

Factor Affects Induced E.M.F Magnitude
Magnitude of Induced e.m.f depend on the follows factor
1. The strength of magnetic field
2. The rate of change of magnetic flux (speed of motion)
3. Cross section Area of the conductor
4. Number of turns (N)

The Strength of Magnetic Field
In electromagnetic induction, when strong magnetic it resulting high strength of magnetic field which induced high magnitude of induced e.m.f

The Rate of Change of Magnetic Flux
Increase in motion (speed) result high the rate at which magnetic flux change in which produce high magnitude of induced e.m.f

Cross Section Area of the Conductor
Increase in Cross section Area of the conductor results high magnitude of induced e.m.f

Number of Turns (N)
Increase in Number of turns results high magnitude of induced e.m.f

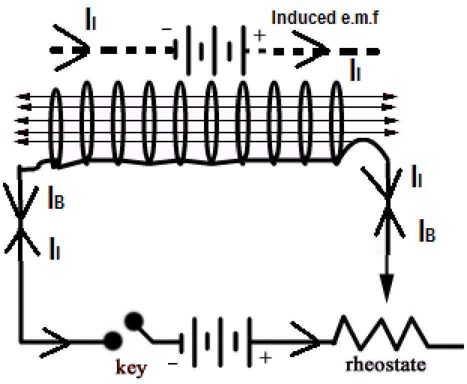
Self-Induction
Defn: Self-induction is the phenomenon in which a change in electric current in a coil produces an induced e.m.f in the coil itself

Or

Defn: self-induction is the production of e.m.f in a conductor/solenoid as a result of varies current in the same conductor/solenoid

NB:
1. If current increased results increase in induced current (back e.m.f) which subtract the original current result the resultant current be smaller than original current

   Diagram:



From Ohm's law of complete circuit

$E = I(R + r)$

$I = E/(R + r)$

But: $E_t = E - E_b$

Then: $I = (E - E_b)/(R + r)$

Where:

I = current of power supply

E = E.m.f of power supply

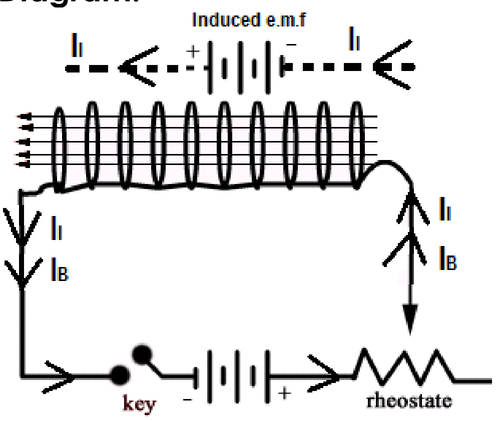
Eb = back E.m.f produced by coil

R = external resistance

r = internal resistance

ii. If current decreased results decrease in induced current (back e.m.f) which add to the original current result the resultant current be larger than original current

Diagram:



From Ohm's law of complete circuit

$E = I(R + r)$

$I = E/(R + r)$

But: $E_t = E + E_b$

Then: $I = (E + E_b)/(R + r)$

Where:

I = current of power supply

E = E.m.f of power supply

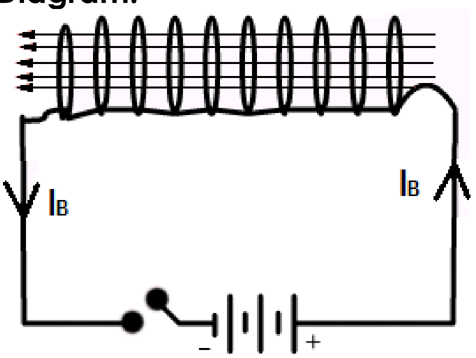
Eb = back E.m.f produced by coil

R = external resistance

r = internal resistance

iii. In constant current no induced current

Diagram:



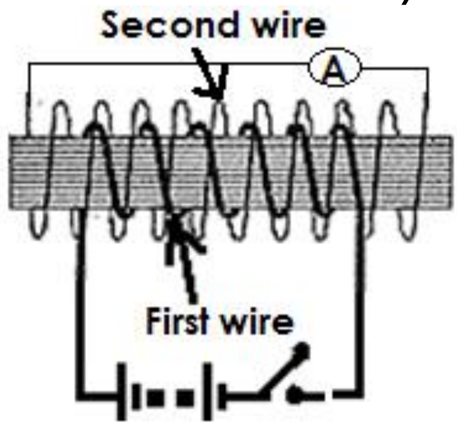
iv. Back e.m.f is the voltage induced in the coil due to variation of electric current flowing in the same coil

v. Self-induction can be minimized by using non-**inductive coil**

Non-Inductive Coil

Defn: non-inductive coil is a doubly wounded turns of wires

Diagram



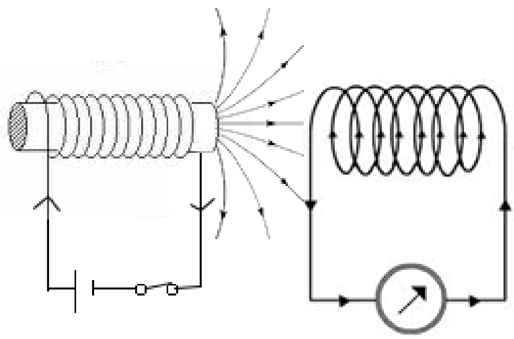
How Minimized Self Induction

If the electric current flowing through the first coil wire, the second coil wire cancels out by induce in the opposite direction the electric current which deflected by ammeter or galvanometer thus self-induction minimized

Mutual Induction

Defn: mutual induction is the production of e.m.f in one conductor or solenoid as a result of changing current in another conductor or solenoid

Diagram:



NB:

i. The coil or solenoid with vary current is called **primary coil**

ii. The coil or solenoid with induced current is called **secondary coil**

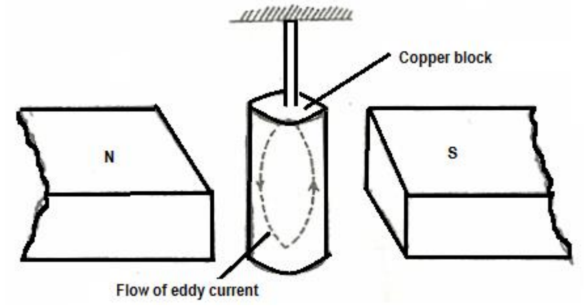
Mechanism

Primary coil produces magnetic flux which change magnetic flux in secondary coil to produce electromotive force

Eddy Current

Defn: Eddy current Are induced current loops circulating within a conductor

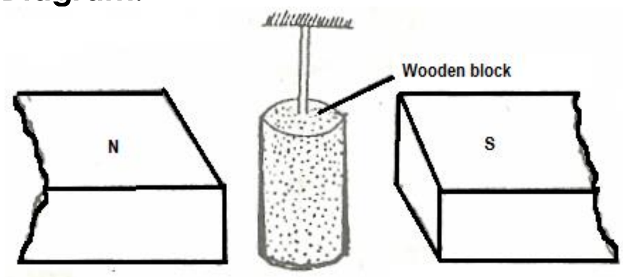
Diagram:



Damping of Eddy Current

Eddy current can be minimized by insulator materials in which have high resistance in which eddy current cannot make loops circulation within a conductor

Diagram:



Methods Used To Minimize Eddy Current

Therefore Eddy current can be minimized by the following methods

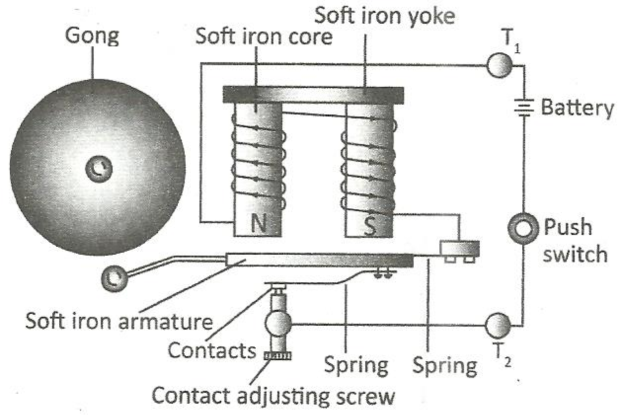
i. **Laminated core**: this is reasons why all instrument uses principle of electromagnetic limited like motor armature, dynamos armature, transformer coil wrapped by insulator sheet
ii. **Magnetic material with high resistivity** e.g. ferrite

Advantage Of Eddy Current

i. Useful in heating metals
ii. Useful in electrical damping
iii. Crack detection
iv. Measurement of material thickness
v. Measurement of coating thickness
vi. Measurement of conductivity

Electric Bell

Consider the diagram below



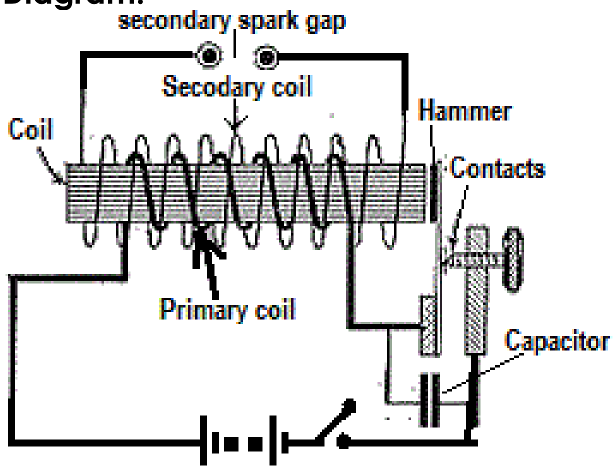
Mechanism

Induced magnetism on soft iron attract iron the armature vibrates and hammer attached to it strikes the gong which open the circuit which incomplete the circuit by contacts cause soft iron to lost magnetism where spring pullback to platinum contacts to complete circuit. This cycle of events is repeated automatically

Induction Coil

Defn: induction coil is an electrical device consisting of two coils (primary and secondary coil) where secondary coil wound over primary coil on an iron core. Also called **spark coil**

Diagram:



NB:

i. It used to produce high voltage alternating current (a.c) from low voltage direct current (d.c)
ii. Primary coil is made by tens or hundreds of turns of coarse wire
iii. secondary coil is made by thousands of turns of fine wire
iv. secondary coil is wound top of primary coil

v. due to large number of secondary coil very large induced e.m.f about hundreds of kilovolts (KV) is produced
vi. due to change of current caused by platinum contacts in primary coil very large induced e.m.f about hundreds of kilovolts (KV)is produced
vii. Capacitor is in parallel with the make-and-break contacts
viii. If capacitor not introduced, the secondary voltage is much less and sparking occurs between the platinum contacts

Mechanism

When switch closed to complete the circuit, the primary coil produce magnetic field (magnetism on soft iron) which cause secondary to induce high voltage due to large number of turns, Induced magnetism on soft iron attract iron hammer which open the circuit which incomplete the circuit by open the gap in platinum contacts cause soft iron to lost magnetism where spring pullback to platinum contacts to complete circuit. This cycle of events is repeated automatically

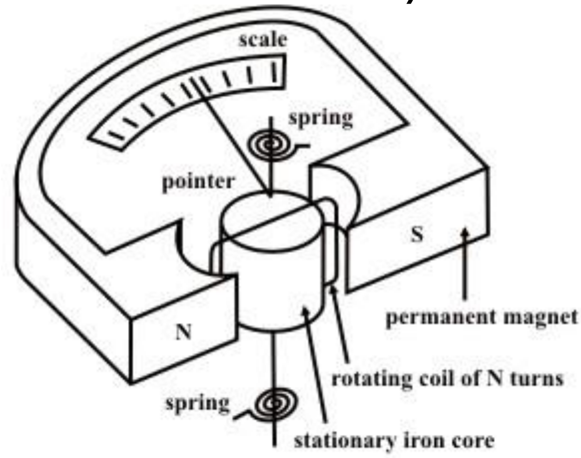
Application of Induction Coil

i. it used in ignition system of internal combustion engines
ii. a smaller version of it is used to trigger the flash tubes used in cameras and strobe lights
iii. it also used in wireless telegraphy

Moving Coil Galvanometer

It consists of a rectangular coil over soft iron cylindrical core such that are free to rotates about a vertical axis which suspended by spring which provide a restoring couple/force, the point which connected to soft iron cylindrical core and powerful permanent magnet which calved spherical poles N and S

Diagram:



Mechanism

i. When the current pass through a coil the soft iron magnetized which may repel or attracted by permanent magnet results turning effect on the coil
ii. The turning effect is linear scale over which the pointer moves

Nb:

i. The galvanometer whose scale graduated to measure current in mill amperes is called **millimeter**
ii. Galvanometer can measure small current i.e. in the order of mill amperes. This is caused by the low resistance of a coil
iii. It measure only directly current

Characteristics of Highly Sensitive Galvanometer

i. Magnetic flux density (B) must be large
ii. Number of turn (N) must be large
iii. Area of coil (A) must be large
iv. Tensional constant (C) must be small

Factors Affect Galvanometer Sensitivity

i. Magnetic flux density (B) must be large or magnetic strength
ii. Number of turn (N) must be large
iii. Area of coil (A) must be large
iv. Tensional constant (C) must be small or power of hair spring

Magnetic strength

The stronger magnetic used, the higher sensitivity and vice versa

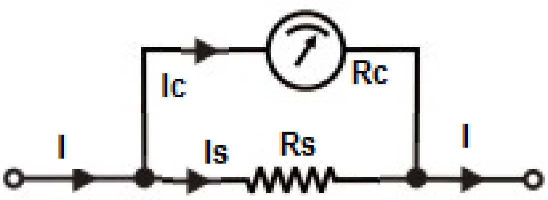
Number of turn

Increase the Number of turn the higher sensitivity and vice versa

Area of coil (A) must be large
The large the area of coil the higher sensitivity and vice versa

Power of hair spring
The less powerfully of a hair spring, the higher sensitivity and vice versa

Moving Coil Ammeter
Ammeter is device which measure current in amperes. It constructed by modification of moving coil galvanometer by connecting a low resistance called **shunt** parallel to the coil of galvanometer in order to measure current in amperes. **Note**: Rc>Rs
Diagram:

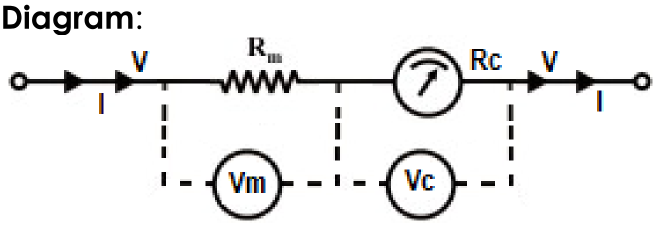


Mechanism
When the large current is passed a small current is flows through the galvanometer coil (Rc) where the rest current flows through shunt (RS)

Mathematically
1. Potential difference across galvanometer coil and shunt are equal **(Vc = Vs = V)**
   But: V = IR
   Vc = Vs
   Ic x Rc = Is x Rs
2. Since they parallel to each other, **I = Is + Ic**

Example,
Suppose the galvanometer coil, Rc = 10Ω and the full scale deflection current, Ic = 15mA. If it is to be converted so that it gives a full scale deflection current, I = 1.5A. Find the value of shunt
Data given
Galvanometer coil, Rc = 10Ω
Coil current, Ic = 15mA = 0.015A
Total current, I = 1.5A
Shunt current, Is = I – Ic = 1.5 – 0.015 = 1.485A
Shunt, Rs= ?
Solution
From: Vc = Vs
Ic x Rc = Is x Rs – make Rs subject
Rs = (Ic x Rc)/Is
Rs = (0.015 x 10)/1.485
Rs = 0.15/1.485
Rs = 0.10Ω

Moving Coil Voltmeter
It constructed by modification of moving coil galvanometer by connecting a high resistance called **multiplier** series to the galvanometer coil in order to measure potential difference in volts. **Note**: Rc<Rm
Diagram:



Mechanism
When the voltage (V) is passed, a small voltage is flows through the multipliers (Vm) where the rest current flows through galvanometer coil (Vc)

Mathematically
1. current across galvanometer coil and multiplier are equal **(Ic = Im = I)**
   But: I = V/R
   Vm/Rm = Vc/Rc
   Vm x Rc = Vc x Rm
2. Since they series to each other, **V = Vm + Vc**

Example,
Suppose the galvanometer coil resistance is 10Ω, the full scale deflection current is 15mA and the instrument is to be converted to measure a full scale deflection potential difference of 3V. Calculate the resistance of multiplier
Data given
Galvanometer coil, Rc = 10Ω
Coil current, Ic = 15mA = 0.015A
Coil voltage, Vc = Ic x Rc = 10 x 0.015 = 0.15V
Total voltage, V = 3V

Multiplier voltage, Vm = V–Vc = 3 – 0.15 = 2.85V

Multiplier resistance, Rm= ?

Solution

From: Ic = Is

Vm x Rc = Vc x Rm– make Rm subject

Rm = (Rc x Vm)/Vc

Rm = (10 x 2.85)/0.15

Rm = 28.5/0.15

Rm = 190Ω

Example, : NECTA 2001 QN: 6

(a) State any characteristics of a highly sensitive galvanometer

(b) (i)what is eddy current?

(ii) Explain two advantage of eddy current

(c) Explain how a moving coil galvanometer can be converted into an ammeter and into a voltmeter

Example, : NECTA 2004 QN: 10

(a) List down two (2) factors that affect the magnitude of induced e.m.f in a moving coil galvanometer

(b) (i) State the laws of electromagnetic induction

(ii) Explain how eddy current are produced

(iii) How can eddy current minimized

(c) A moving coil galvanometer of 30Ω resistance which carries a maximum current of 15mA can be converted into an ammeter

i. How can the galvanometer be made to give ampere readings?
ii. If the device is to give a 1.5A full scale deflection what value resistance will be required?

Data given

Galvanometer coil, Rc = 30Ω

Coil current, Ic = 15mA = 0.015A

Total current, I = 1.5A

Shunt current, Is = I – Ic = 1.5 – 0.015 = 1.485A

Shunt, Rs= ?

Solution

From: Vc = Vs

Ic x Rc = Is x Rs – make Rs subject

Rs = (Ic x Rc)/Is

Rs = (0.015 x 30)/1.485

Rs = 0.45/1.485

Rs = 0.303Ω

Generator

Defn: generator is device consist a coil rotating in an external magnetic field to produce electricity

Types of Generator

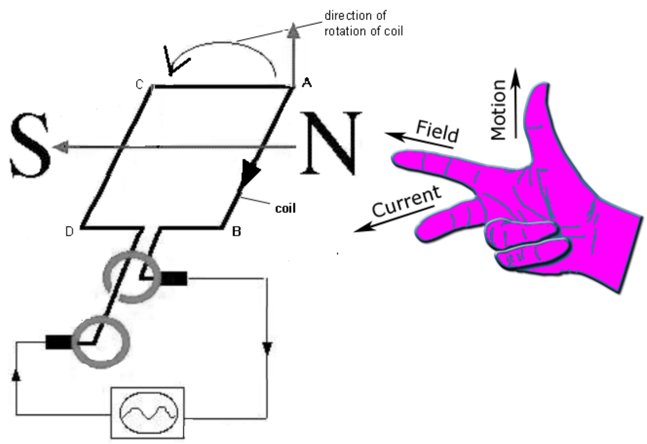
It divided into two according to kind of current produce

i. Alternating current generator
ii. Direct current generator

Alternating Current Generator

Defn: a.c generator is device consist a coil rotating in an external magnetic field to produce alternating current. Also is called **alternator**

Diagram:



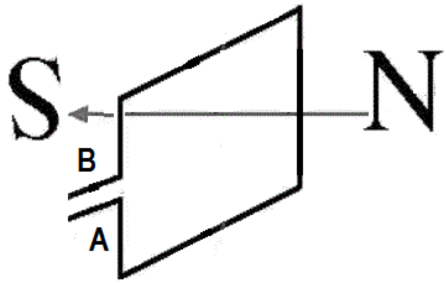
NB:

i. It uses principle of faraday's law of induction
ii. Coil spinning at constant rate in magnetic field to induce oscillating e.m.f
iii. Armature (part of spinning coil) made by soft iron core with wound turns of insulated wire
iv. Armature revolve freely around a strong magnetic field on an axis
v. Two slip rings are connected to the ends of the armature where two carbon brushes rest on it
vi. The magnetic field should cut the coil

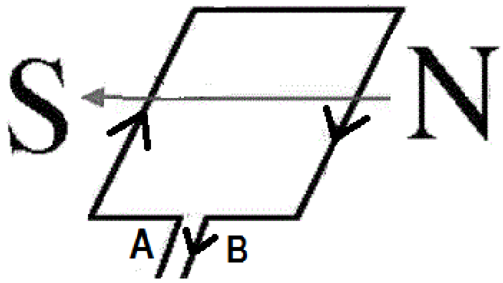
Mechanism of Alternator

i. When the coil vertical at 360^0 or 0^0 no e.m.f produced due to no cutting of the magnetic field on the coil

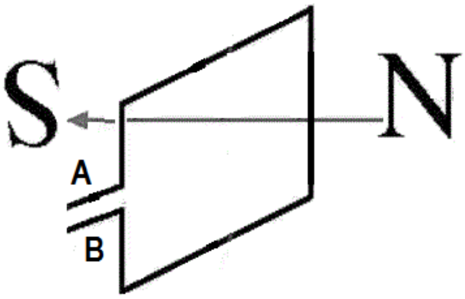
   Diagram:



ii. When the armature is rotate at 90^0 (parallel to magnetic field) the motion/force of coil is perpendicular to the magnetic field hence maximum e.m.f is induced (maximum positive)
Diagram:

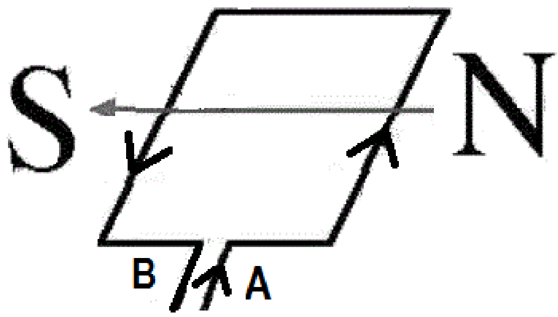


iii. When the coil vertical (at 180^0) no e.m.f produced due to no cutting of the magnetic field on the coil
Diagram:

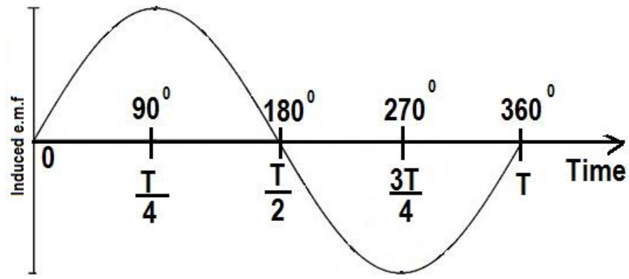


iv. When the armature is rotate after 180^0, starting from vertical position and the side of loop interchange which cause the loop of current to change

v. When the armature is rotate at 270^0 (parallel to magnetic field) the motion/force of coil is perpendicular to the magnetic field hence minimum e.m.f is induced (maximum negative)
Diagram:



vi. This cycle of events is repeated automatically hence electricity is produced
Diagram:

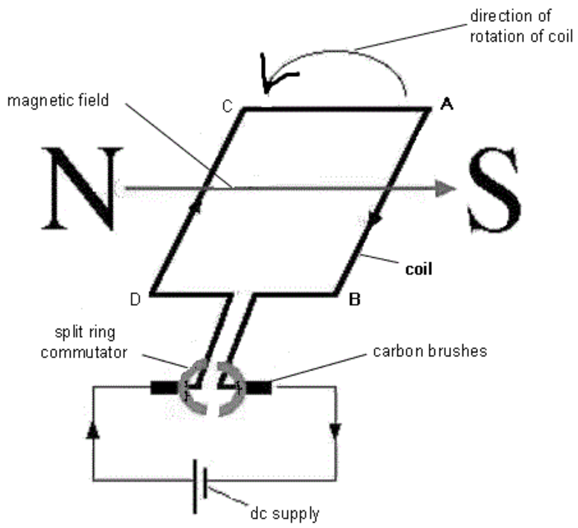


NB:

i. The number of cycle produce per second is called **frequency of a.c**
ii. The induced current is called **a.c current**
iii. The induced e.m.f is called **a.c e.m.f**

Direct Current Generator

Defn: d.c generator is device consist a coil rotating in an external magnetic field to produce direct current.
Diagram:



In d.c generator the slip rings in a.c generator by replacing the half commutator to prevent reverse of current. It half commutator is called **commutator segment** which insulated from other half commutator

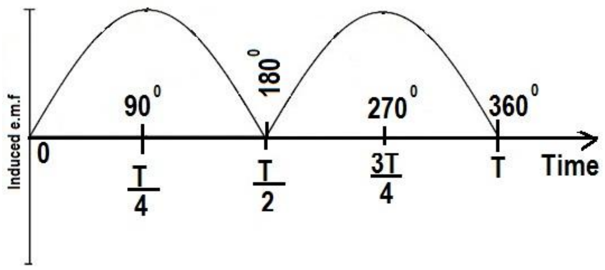
Mechanism of D.C Generator

i. When the coil vertical no e.m.f produced due to no cutting of the magnetic field on the coil
ii. When the armature is rotate at 90^0 (parallel to magnetic field) the motion/force of coil is perpendicular to

the magnetic field hence maximum e.m.f is induced (maximum positive)

iii. When the coil vertical (at 180^0) no e.m.f produced due to no cutting of the magnetic field on the coil
iv. When the armature is rotate after 180^0 , starting from vertical position and the side of commutator segment interchange the loop which cause the loop of current remain in the same direction
v. This cycle of events is repeated automatically hence electricity is produced

Diagram



Advantage of alternator

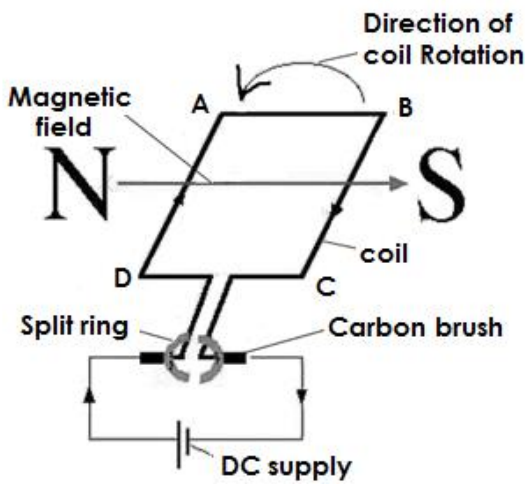
i. Commutator are complex and costly to construct d.c generator, therefore many d.c generator are a.c generator with rectifiers

   Defn: Rectifiers is the device used to flow current only in one direction. We will study further in electronics
ii. Transformer works on a.c current

Electric Motor

Defn: is an electric device used to convert electrical energy to mechanical energy

Diagram



Main Parts of Electric Motor

i. Carbon brushes
ii. Commutator split ring
iii. Magnetic field
iv. Rectangular coil of wire

Rectangular coil of wire

Rectangular coil of wire formed by winding several turns of wire on a soft iron core

Magnetic field

Magnetic field is the magnetic formed by two unlike poles of permanent magnet

Commutator split ring

It formed by divided copper ring into two equal halves. It used to reverse direction of flowing electric current through the coil by changing the contact

Carbon brushes

It forms connection by power supply and rectangular coil

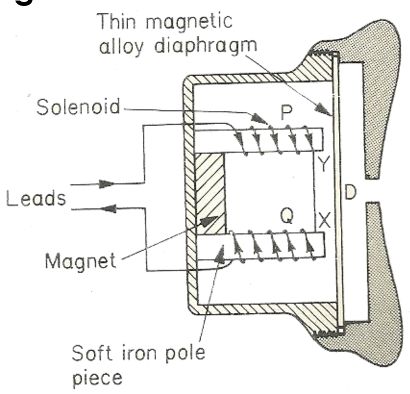
Mechanism of Electric Motor

i. when the switch is closed electric current flowing horizontal coil magnetic field produced
ii. interaction magnetic field bar magnet will creates magnetic couple i.e. north pole of the coil face north pole of the bar magnet while south pole of the coil face south pole of the bar magnet
iii. the coupling of the magnetic field cause the coil to rotate since Like poles repel each other and unlike poles attract
iv. When coil reached in vertical position (rotate at 90^0) the commutator loose contact with carbon brush but the momentum carried by the coil takes it part to the vertical position
vi. When the armature is rotate after 180^0 , starting from vertical position the side AD and BC change position and the side of commutator segment interchange the loop which cause the loop of current remain in the same direction
vii. This cycle of events is repeated automatically hence motor rotates in the same direction

Telephones Receiver (Ear-Peace)

Defn: *is an electric device used to convert varying electrical energy to sound energy*. The purpose of ear piece is to the reverse of microphone. **Microphone** is the electric device used to convert sound energy to varying electrical energy

Diagram:



Main Parts Of Telephones Ear-Peace

i. Permanent magnet
ii. Insulated wire (solenoid)
iii. Magnetic allow diaphragm
iv. Lead wire used for connection

Permanent magnet

It is placed between two solenoids

Solenoid

It kept by insure that the same pole facing in the same direction

Magnetic allow diaphragm

It formed by impregnated iron fillings on a piece of paper

Lead wire

It used for connection from source of varying electric current to each solenoid

Mechanism Of Telephones Ear-Peace

i. When one speak through the microphone in one line of a telephone the sound energy is converted into electrical energy entering the ear piece of another line through lead wire
ii. The sound makes a diaphragm(a kind of small tight drum skin stretched across the narrow end of the hone) vibrates
iii. The vibration move a coil near a magnet, converting the mechanical sound energy into a varying/fluctuating electric current
iv. The electric current travels through lead wire
v. At the receiving end similar equipment reverses the process. The electric current flows into a coil placed near a magnet, making the coil move back and forth and pushing another diaphragm
vi. The diaphragm stretched over a second horn, recreates the original sound

Nb:

The narrowing shape of the diaphragm helps to amplify the sound

Magnetic Relay

Defn: Magnetic relay is an electric device which is used to control one circuit when an electric current is flowing in the other circuit

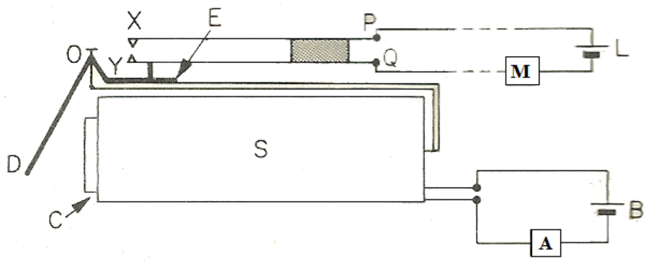
Or

Magnetic relay is switch used to control large current in the secondary current when small electric current flowing in the primary circuit

Main Parts of Magnetic Relay

i. Solenoid
ii. Contact
iii. Insulating block
iv. Spring
v. Soft iron armature

Diagram:



Mechanism of Magnetic relay

i. When an electric current from battery B is flowing in the solenoid S, the core C becomes magnetized and attracts iron armature lever D pivoted at O cause part E to move upward
ii. This close a gap between two spring-loaded Y and X which joined to

battery L and allow electrical current to flow to the other electrical equipment

Uses of Magnetic relay

i It is used in telephone exchange system during dialing of numbers

ii Switching on or off heavy current in most electronics devices

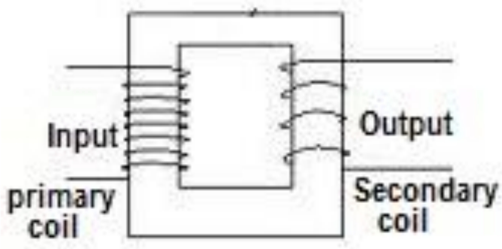
Mechanism of Telephone exchange system

i. When an electric current from battery B when dialing from telephone A in solenoid S , the core C becomes magnetized and attracts iron armature lever D pivoted at O cause part E to move upward
ii. This close a gap between two spring-loaded Y and X which joined to battery L and allow electrical current to flow to the distance telephones exchange M
iii. Thus a message sent by operating A is passed to M

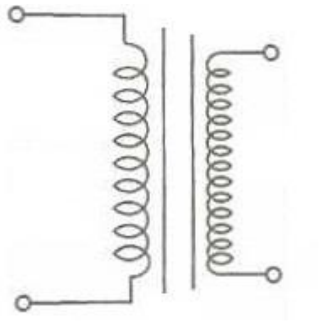
Transformer

Defn: transformer is the device uses mutual induction to convert a.c voltage to large or low **or** Transformer is an electrical device that transfers energy between two or more circuits through electromagnetic induction. The coil connected to the source is called **primary coil** and the coil e.m.f induced is called **secondary coil**

Diagram:



Its symbol



Types of Transformer

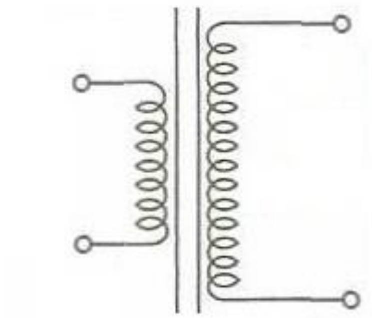
They are two types includes

i. Step up transformer
ii. Step down transformer

Step Up Transformer

Step up transformer is the transformer used to convert from low a.c voltage to high a.c voltage

Diagram



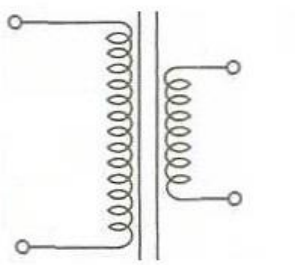
NB:

i. Primary coil is made by turns of coarse wire while secondary coil is made by turns of fine wires
ii. Primary coil is made by less turns of coarse wire while secondary coil is made by higher turns of fine wires

Step Down Transformer

Step down transformer is the transformer used to convert from high a.c voltage to low a.c voltage

Diagram



NB:

i. Secondary coil is made by turns of fine wire while primary coil is made by turns of coarse wires
ii. secondary coil is made by less turns of fine wire while primary coil is made by higher turns of coarse wires

Transformer Equation
From the factor affect induced e.m.f (faraday's law)
For primary coil
Np α Vp– removes proportionality constant
Np= K Vp- - - - - - - - 1

For primary coil
Ns α Vs– remove proportionality constant
Ns = K Vs - - - - - - - - 2

Divide equation 1 to equation 2
Np/Ns = (K Vp)/(K Vs)
Np/Ns = Vp/Vs

Suppose no loss in power
Pp = Ps
But: p = IV
Then: Ip x Vp = Is x Vs – make Vp/Vs subject
Vp/Vs = Is/Ip
Therefore: Vp/Vs = Is/Ip = Np/Ns
Vp/Vs = Is/Ip = Np/Ns

Where:
Np = number of turn in primary coil
Ns = number of turn in secondary coil
Vp = potential difference in primary coil
Vs =potential difference in secondary coil
Ip = current in primary coil
Is =current in secondary coil
Pp = power in primary coil
Ps =power in secondary coil

Transformer Efficiency
Defn: Transformer efficiency is the ratio of secondary coil power to primary coil power express as a percentage
Mathematically:
Eff = $\left(\frac{Ps}{Pp}\right) x\ 100\%$

But: Ps = Is x Vs
Pp = Ip x Vp
Then: Eff = (Ps/Pp) x 100%
Eff = $\left(\frac{\text{Is x Vs}}{\text{Ip x Vp}}\right) x\ 100\%$

Eff = $\left(\frac{\text{Is}}{\text{Ip}}\right)\left(\frac{\text{Vs}}{\text{Vp}}\right) x\ 100\%$
But: Ns/Np = Vs/Vp
Then: Eff = $\left(\frac{\text{Is}}{\text{Ip}}\right)\left(\frac{\text{Ns}}{\text{Np}}\right) x\ 100\%$
Eff = $\left(\frac{\text{Is x Ns}}{\text{Ip x Np}}\right) x\ 100\%$

Example,
A transformer is used to step down 240V mains supply to 12V for laboratory use. If the primary coil has 600 turns, determine the number of turns in the secondary coil
Data given
Number of turn in primary coil, Np = 600 turns
Potential difference in primary coil, Vp = 240V
Potential difference in secondary coil, Vs = 12V
Number of turn in secondary coil, Ns = ?
Solution
From: Np/Ns = Vp/Vs – make Ns subject
Ns = (Vs x Np)/Vp
Ns = (12 x 600)/240
Ns = 7200/240 = 30
Ns = 30 turns

Example,
A current of 0.6A is passed through a step up transformer with a primary coil of 200 turns. A current of 0.1A is obtained in the secondary coil. Determine the number of turns in the secondary coil and the voltage across if the primary coil is connected to 240V mains.
Data given
Number of turn in primary coil, Np= 200 turns
Potential difference in primary coil, Vp = 240V
Current in primary coil, Ip = 0.6 A
Current in secondary coil, Is = 0.1A
Number of turn in secondary coil, Ns = ?
Potential difference in secondary coil, Vs= ?
Solution
Number of turn in secondary coil, Ns = ?
From: Np/Ns = Is/Ip – make Ns subject
Ns = (Ip x Np)/Is

Ns = (0.6 x 200)/0.1
Ns = 120/0.1 = 1200
Ns = 1200 turns

Potential difference in secondary coil, Vs= ?
From: Np/Ns = Vp/Vs – make Vs subject
Vs = (Vp x Ns)/Np
Vs = (240 x 1200)/200
Vs= 288000/200 = 1440
Vs = 1440V

Example,
A step up transformer has 10000 turns in the secondary coil and 100 turns through the primary coil. An a.c of 5A flow in the primary coil when connected to a 12V a.c supply, Calculate
a) the voltage across secondary coil
b) current in secondary coil if transformer efficiency is 90%

Data given
Number of turn in primary coil, Np= 100 turns
Number of turn in secondary coil, Ns = 10000
Potential difference in primary coil, Vp = 12V
Current in primary coil, Ip = 5 A
Transformer efficiency, Eff = 90%
Potential difference in secondary coil, Vs= ?
Current in secondary coil, Is = ?

Solution
a) Potential difference in secondary coil, Vs= ?
   From: Np/Ns = Vp/Vs – make Vs subject
   Vs = (Vp x Ns)/Np
   Vs = (12 x 10000)/100
   Vs = 120000/100 =1200
   Vs = 1200V

b) Current in secondary coil, Is = ?
   From: Eff=$\left(\frac{\text{Is x Vs}}{\text{Ip x Vp}}\right) x\ 100\%$- make Ps subject

   Is =$\frac{\text{Eff x Ip x Vp}}{\text{Vs x 100\%}}$ = $\frac{\text{90 x 5 x 12}}{\text{1200 x 100\%}}$
   Is = 5400/120000 = 0.045
   Is = 0.045A

Radioactivity

Defn: Radioactivity is the process whereby atom disintegrates (emit radiation)

Or

Defn: radioactivity is the process in which an unstable atomic nucleus loses energy by emitting radiation in the form of particles or electromagnetic wave.

NB:

i. Radioactivity also called **radioactive decay**
ii. Disintegrated atom is called **parent nuclide**
iii. New formed is called **Daughter nuclide**

Terms Used

Matter

Defn: Matter is the anything that occupies space and has weight. For Example, **water**, **iron**, **meat**, **wood** etc

Elements

Defn: Element is a pure substance that is made up of only one kind of atom and cannot be broken down into simpler parts by a chemical means. For Example, helium (**H**), hydrogen (**He**), iron (**Fe**) etc

Atom

Defn: Atom is the smallest particle of an element that has all the chemical characteristics of the element. For Example, helium (**H**), hydrogen (**He**), iron (**Fe**) etc

Molecules

Defn: a molecule is a group of atoms. For Example, water molecule (H_2O), hydrogen molecules (H_2)

Strong Force

Defn: *Strong force is the force hold protons and neutrons present in the nucleus oppose and overcome repulsion between protons*

Binding Energy

Defn: *binding energy is energy hold protons and neutrons present in the nucleus oppose and overcome repulsion between protons*

Nuclear Binding Energy

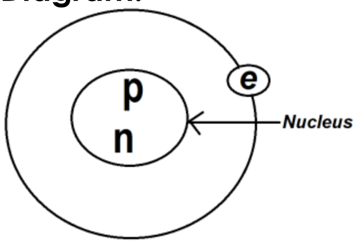
Defn: *binding energy is energy required to break apart, split or break down the nucleus of the atom to its components (protons and neutrons)*

Structure of Atom

According to Rutherford atom

"***Atom has a structure like a small solar system, in which the planet is electron and the place* of the sun is taken by a small heavy positive charged particle called nuclear (Protons and Neutrons)"**

Diagram:



Where:

p = protons

n = neutrons

e = electrons

Therefore Atoms are made up by subatomic (three types) of particles namely

i. Protons
ii. Neutrons
iii. Electrons

PROTONS

Defn: Protons is the positive charged particle located at nucleus. It denoted by small letter **p**. its charge and his mass is **+1.6 x** $\mathbf{10^{-19}}$C and **1.6726 x** $\mathbf{10^{-27}}$kg respectively

Neutrons

Defn: Neutrons is the neutral charged particle located at nucleus. It denoted by small letter **n**. its charge and his mass is **0**C and 1**.6749 x** $\mathbf{10^{-27}}$kg respectively

Electrons

Defn: Electrons is the negative charged particle revolves around the nucleus. It denoted by small letter e. its charge and his mass is -1.6 x 10^{-19}C and 9.1094 x 10^{-31}kg respectively

Properties of Subatomic Particles

Particle	Symbol	Charge (C)	Mass (Kg)
Proton	P	+1.6 x 10^{-19}	1.6726 x 10^{-27}
Neutron	N	0	1.6749 x 10^{-27}
Electron	E	-1.6 x 10^{-19}	9.1094 x 10^{-31}

Atomic Number

Defn: *Atomic number is the number of proton particle in nucleus of a particular element*. It denoted by capital letter Z

Mathematically: **Z = ∑p**

Mass Number

Defn: Mass number is the sum of protons and neutrons particles. Also is called atomic mass/weight. It denoted by capital letter A

Mathematically: **A = Z + N**

Nb:

i. Magnitude of protons and electrons particles is equal
ii. Mass/weight of atom located at nucleus
iii. In given atom/elements (X) mass number (A) located as superscript while atomic number (Z) located as subscript. i.e. $^{A}_{Z}X$

Isotopy

Defn: *Isotopy is the existences of atoms with the same atomic number but differ in atomic mass*. Elements which can form isotopy is called **isotopic elements**

Isotopes

Defn: isotopes are the atoms of the same element having the same atomic number but different mass number

Isotopic Elements and Their Isotopes

Elements	Z	Isotopes	A
Hydrogen	1	Hydrogen - 1	1
		deuterium	2
		tritium	3
Carbon	6	Carbon - 12	12
		Carbon - 13	13
		Carbon - 14	14
Oxygen	8	Oxygen - 16	16
		Oxygen - 17	17
		Oxygen - 18	18
Chlorine	17	Chlorine - 35	35
		Chlorine - 37	37
Uranium	92	Uranium - 234	234
		Uranium - 235	235
		Uranium - 238	238
lead	82	lead - 202	202
		lead - 206	206
		lead - 207	207
		lead - 208	208

Nb:

i. The different isotopes always differ by one neutron ($1^{1}_{0}n$)
ii. Isotopes of particular element/atom; the largest the mass number (A) the heaviest of element and vice versa

Isobars

Defn: isobar is the different elements having the same mass number but different atomic number. For Example,
$^{n}_{m}Y$ and $^{n}_{d}X$

Isotones

Defn: isobar is the different elements having the same number of neutrons. For Example,
$^{14}_{6}C$ and $^{16}_{8}O$

Charge of Atom

Atom consist two charge includes

i. Positive charge (protons)
ii. Negative charge (electron)

Positive Charge

Positive charge is the charge found at nucleus generated by protons charge

Negative Charge

Negative charge is the charge found at electron orbit/shell

Derivation Of Charge Of Atom

Atomic number = Z
Charge of atom = Q
Each electron Charge, e = -1.6 x 10^{-19} C
Each proton Charge, p = +1.6 x 10^{-19} C
Since:

1particle of atom have 1.6 x 10^{-19} C charge

Mathematically: 1p = e - - - - - - - - 1

Some particle of atom has Q charge

Mathematically: Zp = Q - - - - - - - - - -2

Divide: equation (1) and (2)

1p/Zp = e/Q

1/Z = e/Q

Q = Ze

Therefore charge of atom whether nucleus/positive charge or electrons negative charge can be calculated by above formula

Nb:

i. Negative Charge and positive charge of particular element or atom are equal in magnitude
ii. Charge of atom can be calculated by the same formula since are equal in magnitude
iii. Neutron and protons particles of atom never change(remains constant)
iv. Electrons particle can be lost, added or shared by another atom
v. If atom lost electron particle the atom become net positive charged which called **Cation**
vi. If atom added electron particle the atom become net negative charged which called **Anion**

Example,

One isotope of chlorine has the symbol $^{37}_{17}\text{Cl}$

i. Calculate the number of neutrons in this isotope
ii. Calculate the charge in coulombs on the nucleus of this isotope

Data given:

Atomic mass, A = 37

Atomic number, Z = 17

Electron charge, e = -1.6 x 10^{-19} C

Proton charge, p = +1.6 x 10^{-19} C

Neutrons, N = ?

Protons charge, Q =?

Solution

i. **From**: A = Z + N – make N subject

N = A – Z = 37 – 17 = 20

N = 20

ii. **From**: Q = Ze

Q = Z x e = 17 x 1.6 x 10^{-19}

Q = 27.2 x 10^{-19} = 2.72 x 10^{-18}

Q = 2.72 x 10^{-18}C

Example,

Tin (Sn) has a total of twenty-five isotopes; the lightest is represented by the symbol$^{108}_{50}\text{Sn}$. Given that all twenty-five isotopes of tine exist, write down the symbol for the heaviest tin **isotopes**

Data given

Mass number, A = 108

Atomic number, Z = 50

Twenty-five tin, $^{A}_{Z}\text{Sn}$ = ?

Solution

Since the different isotopes always differ by one neutron (1^{1}_{0}n)

$^{A}_{Z}\text{Sn} = {}^{108}_{50}\text{Sn} + 24^{1}_{0}\text{n} = {}^{108+24}_{50}\text{Sn} = {}^{132}_{50}\text{Sn}$

$\mathbf{^{A}_{Z}Sn = {}^{132}_{50}Sn}$

Therefore heaviest isotope of tin will be $^{132}_{50}\text{Sn}$

Stable Atom

Defn: *Stable atom is the atom whereby its binding energy is strong enough to hold nucleus of an atom together*. Stability of atom decrease as the atomic number increase

Unstable Atom

Defn: *unstable atom is the atom whereby its binding energy is not strong enough to hold nucleus of an atom together*.

Types of Radioactivity

There are two types includes

i. Natural radioactivity
ii. Artificial radioactivity

Natural Radioactivity

Defn: natural radioactivity is the spontaneous disintegration of unstable atoms (nuclei). For Example, unstable isotopes such that **carbon-14** and heavy elements such as **lead** and **uranium** etc

Nb:

i. Materials exhibit radioactivity is called **radioactive material**
ii. In the periodic table all elements above lead exhibit natural radioactivity

iii. Example, of **radioactive material** are thorium (Th), uranium (U) , Radon (Rn) , Radium (Ra), Polonium (Po) etc

How Natural Radioactivity Occurs?

Natural radioactivity occur when atomic nucleus has many number of protons in the nucleus, due to law of charge like charge repel therefore repulsion force is large enough to overcome strong force (bonding energy) resulting unstable atomic nucleus disintegrate (decay) into smaller nuclei (**daughter nuclide)** which are smaller and more stable than **parent nuclide**

Nuclear Radiation

Defn: nuclear radiation is the energy or particles or electromagnetic waves emitted by unstable atom

Types of Radiation

There are three includes

i. Alpha (α) particle
ii. Beta (β) particle
iii. Gamma (γ) rays

Alpha Particle (α)

Defn: Alpha particle is the particle emitted by radioactive material which is equivalent to helium nucleus particle (^4_2He)

$\boldsymbol{\alpha = {}^4_2He}$

Effect on Nucleus

When a radioactive nucleus emits an alpha particle its atomic number decrease by two and mass number decrease by 4. The effect tend to form other element

Chemically

$${}^{A}_{Z}\mathrm{X} \xrightarrow{\text{yields}} {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$$

NB:

i. ${}^{A}_{Z}\mathrm{X}$ Is parent nuclide
ii. ${}^{A-4}_{Z-2}\mathrm{Y}$ is daughter nuclide
iii. The parent nuclide can give more than one daughter nuclide

Example,

Uranium-238 undergoes an alpha decay to produce thorium-234

Solution

$${}^{238}_{92}\mathrm{U} \xrightarrow{\text{yields}} {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

Example,

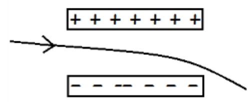
Radium-222 undergoes an alpha decay to produce radon-218

Solution

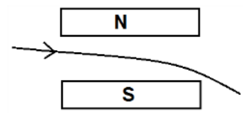
$${}^{222}_{88}\mathrm{Ra} \xrightarrow{\text{yields}} {}^{218}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$$

Properties of Alpha Particles

i. It is helium in nature
ii. It has positively charged
iii. it has relative charge of 2+
iv. Low kinetic energy electrons
v. Very Low penetration since it the heaviest particle
vi. It can be stopped/shielding by a **few cm of air**, **thin sheet of paper**, **skin**, **clothes** etc
vii. Cause some material to fluorescence i.e. to give out light
viii. It affect/blackens photographic plate (film)
ix. It heaviest particle due to its biggest mass and charge
x. Very high ionizing power since it the heaviest particle
xi. It emitted up to speed of 0.1C where C = 3 x 10^8 m/s
xii. Deflected toward negative plate



xiii. Deflected toward south pole



Beta Particle (β)

Beta particle is the particle emitted by radioactive material which is equivalent to electrons ($^{\;0}_{-1}e$)

β = $\boldsymbol{{}^{\;0}_{-1}e}$

Effect on Nucleus

When a radioactive nucleus emits beta particle its atomic number decrease by one and mass number remain constant. The effect tend to form other element

Chemically

$${}^{A}_{Z}\mathrm{X} \xrightarrow{\text{yields}} {}_{Z-1}^{\;\;A}\mathrm{Y} + {}^{\;0}_{-1}\mathrm{e}$$

Example,

Carbon-14 undergoes beta decay to produce nitrogen-14

Solution

$^{14}_{6}C \xrightarrow{\text{yields}} {}^{14}_{7}N + {}^{0}_{-1}e$

Example,

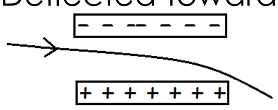
Iodine-131 emits beta particles to produce xenon-131

Solution

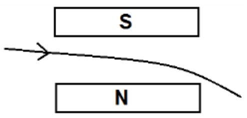
$^{131}_{53}I \xrightarrow{\text{yields}} {}^{131}_{54}Xe + {}^{0}_{-1}e$

Properties of Beta Particles

i. It is electrons in nature
ii. It has relative charge of -1
iii. It has negatively charged particle
iv. high kinetic energy electrons
v. Moderate penetration due to its low mass
vi. It can stopped by a few mm of metals like **aluminium**, **Plastic**, **glass**, **light metals** etc
vii. Moderate ionizing power due to its low mass
viii. It emitted up to speed of 0.9C where C = 3 x 10^8 m/s
ix. It affect/blackens photographic plate (film)
x. Cause some material to fluorescence i.e. to give out light
xi. smaller mass and charge than the alpha particle
xii. Deflected toward positive plate



xiii. Deflected toward north pole



Gamma Rays (γ)

Gamma ray is the ray emitted by radioactive material which equivalent to electromagnetic wave. it released during emission of an alpha or a beta particle (γ). It also called **gamma radiation**

Effect on Nucleus

When a radioactive nucleus emits an alpha particle its atomic number and mass number remain constant. The effect tend to form other element

Chemically with beta particle

$^{A}_{Z}X \xrightarrow{\text{yields}} {}_{Z-1}^{A}Y + {}_{-1}^{0}e + \gamma$

Chemically with alpha particle

$^{A}_{Z}X \xrightarrow{\text{yields}} {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \gamma$

Example,

Cobalt-60 by emitting a beta particle to produce nickel-60 and gamma rays

Solution

$^{60}_{27}Co \xrightarrow{\text{yields}} {}^{60}_{28}Ni + {}_{-1}^{0}e + \gamma$

Example,

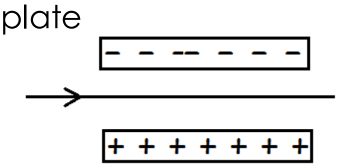
Iodine-131 emits beta particles to produce xenon-131 and gamma rays

Solution

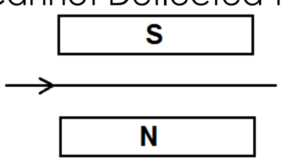
$^{131}_{53}I \xrightarrow{\text{yields}} {}^{131}_{54}Xe + {}_{-1}^{0}e + \gamma$

Properties of Gama Rays

i. It electromagnetic wave in nature
ii. They neutral in charge
iii. Have zero relative charge
iv. very high frequency electromagnetic radiation
v. Very highly penetrating since have no mass
vi. Can be stopped by a **thick layer of steel** or **concrete**, **Dense metal**, **concrete**, but even a few cm of dense lead doesn't stop all of it
vii. The lowest ionizing power since have no mass
viii. It have no mass since is ray(radiation)
ix. It emitted with speed of 3 x 10^8 m/s
x. It affect/blackens photographic plate (film)
xi. Cause some material to fluorescence i.e. to give out light
xii. Cannot Deflected toward negative plate



xiii. Cannot Deflected toward south pole



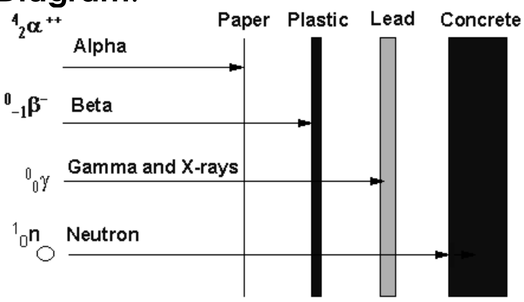
Different Between Alpha Particles, Beta Particles and Gamma Rays

i. Alpha particles has positive charge, Beta particles has negative charge wile Gamma rays has no charge

ii. Alpha particles has Low kinetic energy electrons, Beta particles has high kinetic energy electrons while Gamma rays has high kinetic energy electrons than Alpha particle and Beta particle

iii. Alpha particles has Very Low penetration power, Beta particles has Moderate penetration power while Gama rays have Very highly penetrating power

Diagram:



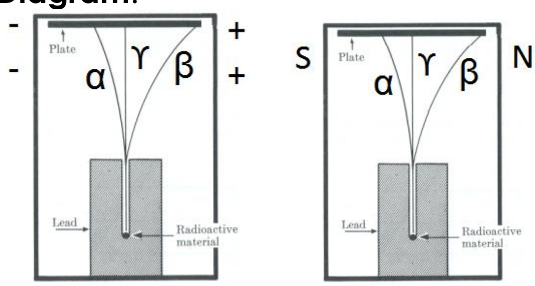
iv. Alpha particles has biggest mass and charge, Beta particles has smaller mass and charge than the alpha particle While Gama rays have no mass and no electric charge

v. Alpha particles has Very high ionizing power, Beta particles has Moderate ionizing power While Gama rays has lowest ionizing power

vi. Alpha particles is particle, Beta particles is a particle While Gama rays is electromagnetic wave

vii. Alpha particles Deflected toward negative plate, Beta particles Deflected toward positive plate while Gama rays is not deflected

Diagram:



viii. Alpha particles Deflected toward South Pole, Beta particles Deflected toward North Pole while Gama rays is not deflected

Laws of Radioactive Decays

There are three laws of radioactive decay which states that

i. "***when radioactive material decayed by emission of alpha particle its mass number and atomic number decrease by 4units and 2units respectively***"

$${}^{A}_{Z}X \xrightarrow{\text{yields}} {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

ii. "***when radioactive material decayed by emission of beta particle its mass number remain constant/unchanged while atomic number increase by 1units***"

$${}^{A}_{Z}X \xrightarrow{\text{yields}} {}_{Z+1}^{A}Y + {}^{0}_{-1}e$$

iii. "***when radioactive material decayed by emission of gamma ray neither mass number and atomic number change***"

$${}^{A}_{Z}X \xrightarrow{\text{yields}} {}^{A}_{Z}Y + \gamma$$

Example,

Radioactive uranium ${}^{238}_{92}U$ emits an α-particle to become thorium. Thorium emits a β-particle to become praseodymium which then emits another β-particle. What are atomic number, mass number and number of final atom produced?

Solution

Radioactivity takes three stages

First stage

$${}^{238}_{92}U \xrightarrow{\text{yields}} {}^{234}_{90}Th + {}^{4}_{2}He$$

Mass number= 234

Atomic number= 90

Second stage

$${}^{234}_{90}Th \xrightarrow{\text{yields}} {}^{234}_{91}Pr + {}^{0}_{-1}e$$

Mass number= 234

Atomic number= 91

Third stage

$${}^{234}_{91}Pr \xrightarrow{\text{yields}} {}^{234}_{92}X + {}^{0}_{-1}e$$

Mass number= 234

Atomic number= 92

Uranium has atomic number 92 therefore the final product is uranium

Example,

i. Define the terms isotope
ii. Uranium $^{238}_{92}\mathrm{U}$ decay to polonium $^{222}_{84}\mathrm{Po}$ by α-particle emission at each stage via $^{234}_{x}\mathrm{Th}$, $^{230}_{y}\mathrm{Ra}$ and $^{226}_{z}\mathrm{Rn}$. Following this stage $^{224}_{84}\mathrm{Po}$ decayed to $_{86}^{q}\mathrm{Rn}$ by β-particle only
   (a) Write balanced equation of the stage decay process from $^{238}_{92}\mathrm{U}$ to $^{226}_{z}\mathrm{Rn}$ and determine value of x, y, z and q
   (b) Identify isotopes and isobars

Solution (ii)

(a) Radioactivity takes five stages

$$^{238}_{92}\mathrm{U} \xrightarrow{\alpha} {}^{234}_{x}\mathrm{Th} \xrightarrow{\alpha} {}^{230}_{y}\mathrm{Ra} \xrightarrow{\alpha} {}^{226}_{z}\mathrm{Rn} \xrightarrow{\alpha} {}^{222}_{84}\mathrm{Po} \xrightarrow{\beta} {}_{86}^{q}\mathrm{Rn}$$

First stage

$$^{238}_{92}\mathrm{U} \xrightarrow{\alpha} {}^{234}_{x}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

92 = x + 2

X = 90

Second stage

$$^{234}_{90}\mathrm{Th} \xrightarrow{\alpha} {}^{230}_{y}\mathrm{Ra} + {}^{4}_{2}\mathrm{He}$$

90 = x + 2

X = 88

Third stage

$$^{230}_{88}\mathrm{Ra} \xrightarrow{\alpha} {}^{226}_{z}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$$

88 = x + 2

X = 86

Fourth stage

$$^{226}_{86}\mathrm{Rn} \xrightarrow{\alpha} {}^{222}_{84}\mathrm{Po} + {}^{4}_{2}\mathrm{He}$$

Fifth stage

$$^{222}_{84}\mathrm{Po} \xrightarrow{\beta} {}_{86}^{q}\mathrm{Rn} + {}_{-1}^{0}\mathrm{e} + {}_{-1}^{0}\mathrm{e}$$

$$^{222}_{84}\mathrm{Po} \xrightarrow{2\beta} {}_{86}^{q}\mathrm{Rn} + 2{}_{-1}^{0}\mathrm{e}$$

222 = q + 2x0

222 = q + 0

q = 222

(b) Isotopes is Radon; $^{226}_{86}\mathrm{Rn}$ and $^{222}_{86}\mathrm{Rn}$
   Isotopes is $^{222}_{84}\mathrm{Po}$ and $^{222}_{86}\mathrm{Rn}$

Example, NECTA 2013 QN: 5 (c)

A uranium nucleus, U-238 with atomic number 92, emits two α-particles and two β-particles and finally forms a thorium (Th) nucleus. Write the nuclear equation for this process

Solution

$$^{238}_{92}\mathrm{U} \rightarrow 2{}^{4}_{2}\mathrm{He} \rightarrow 2{}_{-1}^{0}\mathrm{e} \rightarrow {}^{234}_{90}\mathrm{Th}$$

Application of Natural Radioactivity

i. **In hospital (medicine)**
   a. Used to sterilize hospital equipment
   b. Used to trace and treat maligned growth. E.g. **cancer** and **tumors**
   c. to measure correct patient dosages of radioactive pharmaceuticals
   d. Used as a tracer to diagnose pernicious anemia
   e. Used in molecular biology and genetics research.

ii. **In industry**
   a. Used to revel/detect and remove overflows in metal and plastics
   b. Used to measure thickness and density of material
   c. Used to making of preservation
   d. To test aeroplane jet engine turbines for structural integrity
   e. To ensure the right fill level for packages of food, drugs, and other products. (The products in these packages do not become radioactive.)
   f. To measure and control the thickness or density of metal and plastic sheets
   g. Used in many smoke detectors for homes and businesses
   h. to measure levels of toxic lead in dried paint samples
   i. to ensure uniform thickness in rolling processes like steel and paper production
   j. to help determine where oil wells should be drilled
   k. Used to analyze metal alloys for checking stock, scrap sorting

iii. **In agriculture**
   a. It is used to kill weeds
   b. Used to check cracking in pipes used for irrigation purpose
   c. Used to produce varieties of plants which are harder and more resistance to disease

d. Helps in research to ensure that potential new drugs are metabolized without forming harmful by-products
e. Radioactive phosphorous is mixed in phosphate fertilizer to determine the amount of phosphorous absorbed by the plant
f. to measure and control the liquid flow in water pipelines for irrigation
g. to measure and control the liquid flow in oil pipelines
h. to gauge the moisture content of soil in the road construction and building industries
i. to measure the moisture of materials stored in soils
j. To measure amount of moisture content store in grains and control pests

iv. **In transport**
a. Used to inspect passenger's luggage before boarding the plane
b. Used to inspect airline luggage for hidden explosives

v. **Science Field**
a. Important aid to biomedical researchers studying the cellular functions and bone formation in mammals
b. Used in research in red blood cell survival studies
c. to tell researchers whether oil wells are plugged by sand
d. Used in biological research, agriculture, pollution control, and archeology
e. Used to analyze electroplating solutions

Artificial Radioactivity
Defn: artificial radioactivity is the emitting of radiation due to bombarding small and stable nuclei by high energetically particles. It also called **induce radioactivity**

How Artificial Radioactivity Occurs?
Artificial radioactivity is archived by neutron disturbance even if is the neutral in charge is given maximum kinetic energy toward stable atomic nucleus. After bombarded stable atomic nucleus become unstable results disintegration. Protons never used

Method Of Induce Radioactivity
There are two methods includes
i. Neutron activation
ii. Photonuclear reaction

Neutron Activation
Neutron activation is the process whereby neutron radiation induce radioactivity in materials

Example,
Stable cobal-59 undergo neutron radiation to emit cobalt-60
$^{59}_{27}\text{Co} + {}^{1}_{0}\text{n} \xrightarrow{\text{yields}} + {}^{60}_{27}\text{Co}$

Photonuclear Reaction
Photonuclear reaction is the reaction whereby radioactive induced by bombarding the target nucleus with high energy X-rays or gamma rays

Example,
In each of the nucleus reaction listen below what is the atomic number, mass number and a name of the particle produced?
i. Born $^{10}_{5}\text{Bo}$ bombarded with a neutron gives lithium $^{7}_{3}\text{Li}$ particle
ii. aluminium $^{27}_{13}\text{Al}$ bombarded by α-particle to give silicon $^{30}_{14}\text{Si}$ particle
iii. sodium $^{23}_{11}\text{Na}$ bombarded by α-particle to give aluminium $^{27}_{13}\text{Al}$ particle
iv. chlorine $^{35}_{17}\text{Cl}$ bombarded with proton gives sulphur $^{35}_{16}\text{S}$ particle

Solution
i. $^{10}_{5}\text{Bo} + {}^{1}_{0}\text{n} \rightarrow {}^{7}_{3}\text{Li} + {}^{a}_{b}\text{X}$

Mass number	Atomic number
10 + 1 = 7+ a	5 + 0 = 3 + b
11 = 7+ a	5 = 3+ b
a = 4	b = 2

Particle is alpha (helium)

ii. $^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{14}\text{Si} + {}^{a}_{b}\text{X}$

Mass number	Atomic number
27 + 4 = 30+ a	13 + 2 = 14 + b

31 = 30 + a 15 = 14 + b
a = 1 b = 1
Atom produced is proton

iii. $^{23}_{11}\text{Na} + ^{4}_{2}\text{He} \rightarrow ^{26}_{13}\text{Al} + ^{a}_{b}\text{X}$

Mass number	Atomic number
23 + 4 = 26+ a	11 + 2 = 13 + b
27 = 26 + a	13 = 13 + b
a = 1	b = 0

Atom produced is neutron

iv. $^{35}_{17}\text{Cl} + ^{0}_{1}\text{p} \rightarrow ^{35}_{16}\text{S} + ^{a}_{b}\text{X}$

Mass number	Atomic number
35 + 0 = 35+ a	17 + 1 = 16 + b
35 = 35 + a	18 = 16 + b
a = 0	b = -2

Atom produced is two electrons

Application of Artificial Radioactivity
i. Neutron activation is one of the most sensitive and accurate methods of **trace-element analysis**
ii. Neutron activation is uses nuclear reactors for nuclear energy generation
iii. Neutron activation is uses nuclear reactors for making nuclear bombs

Hazards/Effect of Nuclear Reaction
It can cause the follows
i. Skin burning and Redding when exposed in radiation
ii. Death by killing human body cell
iii. Cancerous tumors
iv. Genetic mutation

Precaution to Be Taken From Hazard
i. Limiting the time of exposure
ii. Increase the distance from the source of radiation
iii. Using materials such water, concrete or lead to absorb the radiation
iv. Hold radioactive material by using mechanical tong
v. keep out of the environment which radioactive material

Types of Nuclear Reaction
There are two types includes
i. Nuclear fission
ii. Nuclear fusion

Nuclear Fission
Defn: nuclear fission is the process whereby unstable nucleus of an atom split into two or more smaller nuclei.

Example,
$$^{236}_{92}\text{U} \xrightarrow{\text{yields}} ^{94}_{36}\text{Kr} + ^{140}_{56}\text{Ba} + 2^{1}_{0}\text{n}$$

NB:
i. Nucleus fission of heavy element is a highly exothermic reaction thus why used as a source of energy
ii. If neutron bombarded with atom the decay will continue until stable atom form since neutron decrease to Finnish. This chain is called **chain reaction**

Example,
$$^{99}_{41}\text{Nb} \xrightarrow{\beta} ^{99}_{42}\text{Mo} \xrightarrow{\beta} ^{99}_{44}\text{Ru}$$
$^{236}_{92}\text{U}$ (Stable)
$$^{133}_{51}\text{Sb} \xrightarrow{\beta} ^{133}_{52}\text{Te} \xrightarrow{\beta} ^{133}_{53}\text{I} \xrightarrow{\beta} ^{133}_{54}\text{Xe} \xrightarrow{\beta} ^{133}_{55}\text{Cs}$$

(Stable)

Application of Nuclear Fission
i. It is used in nuclear power plants to generate electricity
ii. It is used in making nuclear bombs

Nuclear Fusion
Defn: nuclear fusion is the process whereby lighter nuclei joining together to form heaver nucleus.
Example,
Nuclear fusion of deuterium and tritium yield helium, neutron and heat energy
$$^{2}_{1}\text{H} + ^{3}_{1}\text{H} \xrightarrow{\text{yields}} + ^{4}_{2}\text{H} + ^{1}_{0}\text{n} + \text{H}$$

Nb:
i. Nucleus fusion of heavy element than iron or nickel is endothermic reaction
ii. Nucleus fusion of lighter element is exothermic reaction
iii. Nucleus fusion occur naturally in stars
iv. Nucleus fusion occur artificial in human enterprises

Application of Nuclear Fusion
i. It is used in nuclear power plants to generate electricity

ii. It is used in making nuclear bombs. For Example, hydrogen bomb

Carbon – 14 Dating

Defn: is the scientific method which is used to determine age of dead living and non-living organism

Half-life of Radioactive Nucleus

Defn: half-life is the time required for one half of the nuclei present to decay. It represent by symbol ($t_{\frac{1}{2}}$)

Nb:

Each radioactive material has its own half-life

Activity

Defn: activity is the rate of disintegration of radioactive material with time

Or

Defn: activity is the number of atoms decayed per unit time

Activity also called count rate. SI unit of activity is count rate per second, **c.p.s**

Mathematically

Activity, A = $\frac{number\ of\ atom\ decayed, -\Delta N}{time\ taken,\ \Delta t}$

A = $\frac{-\Delta N}{\Delta t}$

Nb:

i. Negative means as time goes number of atom decrease
ii. Activity is directly proportional to the original number of atoms presents

Mathematically

Activity, A α original of atoms presents, N

A α N – removal proportionality constant

A = kN

But: A = $\frac{-\Delta N}{\Delta t}$

$\frac{-\Delta N}{\Delta t}$ = kN

Where:

K = λ = proportionality/decay constant

$\frac{-\Delta N}{\Delta t}$ **= λN**

But: decay constant, λ is given by

λ = $\frac{ln\,2}{t_{\frac{1}{2}}} = \frac{\log_e 2}{t_{\frac{1}{2}}}$, where e = 2.718

λ = $\frac{ln\,2}{t_{\frac{1}{2}}} = \frac{0.6932}{t_{\frac{1}{2}}}$

λ = $\frac{0.6932}{t_{\frac{1}{2}}}$

Radioactive Decay Equation

It relates original, **No** number of atoms, number of atoms remain which not decayed, **N**, time for disintegrate, t and half time, $t_{\frac{1}{2}}$

Initial of No, at t = 0 after zero half-life, $t_{\frac{1}{2}}$ No will remain undecayed

N = No = $\frac{No}{1} = \frac{No}{2^0}$ **= No**$(\frac{1}{2})^0$

Second of No, at t = $t_{\frac{1}{2}}$ after one half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{2}$

N = $\frac{No}{2} = \frac{No}{2^1}$ **= No**$(\frac{1}{2})^1$

Third of No, at t = $2t_{\frac{1}{2}}$ after two half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{4}$

N = $\frac{No}{4} = \frac{No}{2^2}$ **= No**$(\frac{1}{2})^2$

Fourth of No, at t = $3t_{\frac{1}{2}}$ after three half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{8}$

N = $\frac{No}{8} = \frac{No}{2^3}$ **= No**$(\frac{1}{2})^3$

Fifth of No, at t = $4t_{\frac{1}{2}}$ after four half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{16}$

N = $\frac{No}{16} = \frac{No}{2^4}$ **= No**$(\frac{1}{2})^4$

Nth of No, at t = $nt_{\frac{1}{2}}$ after nth half-life, $t_{\frac{1}{2}}$ will remain undecayed will be No$(\frac{1}{2})^n$

N = $\frac{No}{2^n}$ = No$(\frac{1}{2})^n$

N = No $(\frac{1}{2})^n$

But: From our relation above it seems n equal to ratio of time taken, **t** by original atom, **No** to the half-life, $t_{\frac{1}{2}}$, therefore

n = $\frac{t}{t_{\frac{1}{2}}}$

Modify the equation

N = No $(\frac{1}{2})^{\frac{t}{t_{\frac{1}{2}}}}$

Where:

t = time taken by original atom

$t_{\frac{1}{2}}$ = half-life taken after each activity

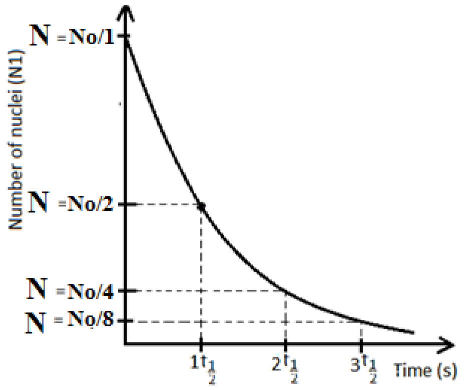
No = original atom

N = number of atom remain undecayed

Radioactive Decay Curve

Defn: radioactive decay curve is the exponential curve drawn with number of atoms on the vertical axis and time for disintegration on the horizontal axis

Diagram:



Initial of No, at t = 0 after zero half-life, $t_{\frac{1}{2}}$ No will remain undecayed

$\mathbf{N = No = \frac{No}{1} = \frac{No}{2^0} = No(\frac{1}{2})^0}$

Second of No, at t = $t_{\frac{1}{2}}$ after one half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{2}$

$\mathbf{N = \frac{No}{2} = \frac{No}{2^1} = No(\frac{1}{2})^1}$

Third of No, at t = $2t_{\frac{1}{2}}$ after two half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{4}$

$\mathbf{N = \frac{No}{4} = \frac{No}{2^2} = No(\frac{1}{2})^2}$

Fourth of No, at t = $3t_{\frac{1}{2}}$ after three half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{8}$

$\mathbf{N = \frac{No}{8} = \frac{No}{2^3} = No(\frac{1}{2})^3}$

Fifth of No, at t = $4t_{\frac{1}{2}}$ after four half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $\frac{No}{16}$

$\mathbf{N = \frac{No}{16} = \frac{No}{2^4} = No(\frac{1}{2})^4}$

Nth of No, at t = $nt_{\frac{1}{2}}$ after nth half-life, $t_{\frac{1}{2}}$ will remain undecayed will be $No(\frac{1}{2})^n$

$N = \frac{No}{2^n} = No(\frac{1}{2})^n$

$\mathbf{N = No\ (\frac{1}{2})^n}$

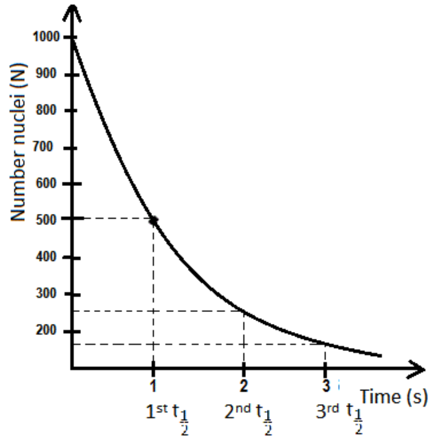
Nb:

i. Half-life is the same for isotope
ii. Half-life is independent to physical state, temperature and pressure
iii. Radioactive isotope never decay to zero value

For Example,

Isotope has a half-life of 1min and 1000 nuclei initially present, after 1min will decay to 500 nuclei, next 1min will decay to 250 nuclei, and next 1min will decay to 125 nuclei and so on

Graphically



Example,

A sample of a radioactive contains 120 nuclei. Calculate the number of half-life it takes for the sample to decay so that there are only 15 nuclei left undecayed

Data given

Initial mass, No = 120 nuclei

Final mass, N = 15 nuclei

Number of half-lives, n = ?

Solution

From: No/N = 2^n

120/15 = 2^n

8 = 2^n

$2^3 = 2^n$

n = 3

Example,

The half-life of iodine-131 is 8 days. A sample contains 800g of iodine-131. How much of the sample will remaining undecayed after 40 days

Data given

Initial mass, No = 800 nuclei

Half-life, $t_{\frac{1}{2}}$ = 8 days

Time taken, t = 40 days
Final mass, Nn = ?
Solution

From: $No/N = 2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$ - make N subject

$N = No/2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

$N = 800/(2^{(\frac{40}{8})}) = 800/(2^5)$

N = 800/32 = 25

N = 25g

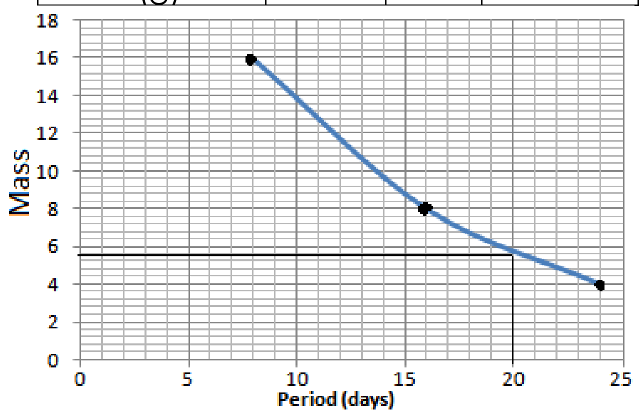
Therefore 25g will undecayed after 40 days

Example,
The half-life of iodine-131 is 8 days. A sample contains 16g of iodine-131

i. Draw a graph to represents
ii. From the graph determine mass of the sample which will remain undecayed after 20 days

Solution
i. Table of value

Period (days)	8	16	24
Mass (g)	16	8	4



ii. From the Table above 5.6g will remain undecayed after 20 days

Example, : NECTA 2001, QN: 08
(a) Define the term (i) half-life (ii) atomic number
(b) Name the three fundamental particles of which atoms of an element are composed. How these particles are distributed in atom of an element whose atomic number is 3 and mass number is 7
(c) A radioactive nucleus is denoted by the symbol $^{226}_{88}X$. Write down the composition of the nucleus at the end of the following stages of disintegration
i. Emission of alpha (α) particle
ii. Emission of beta (β) particle
iii. Emission of gamma (γ) radiation

Solution
i. $^{226}_{88}X \xrightarrow{\text{yields}} {}^{222}_{86}X + {}^{4}_{2}H$ (α particle)
ii. $^{222}_{86}X \xrightarrow{\text{yields}} {}^{222}_{87}X + {}^{0}_{-1}e$ (β particle)
iii. $^{222}_{87}X \xrightarrow{\text{yields}} {}^{222}_{87}X + \gamma$ (γ particle)

Example,
The half-life of $^{214}_{83}B$ is 20min. what fraction of a sample of this radioactive remain after 2 hours?
Data given
Half-life, $t_{\frac{1}{2}}$ = 20min
Time taken, t = 2 hrs = 120 min
Sample fraction, No/N =?
Solution

From: $No/N = 2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

$No/N = 2^{\left(\frac{120}{20}\right)} = 2^6 = 64$

No/N = 64 – inverse both sides

$\mathbf{N/No = \frac{1}{64}}$

Example,
The half-life of thorium - 234 is 24 days. The physics department of the West Indies in Jamaica bought a sample of this thorium from England on the day of dispatch its activity was 4 x 10⁵c.p.s

i. What was the activity of source when it arrived in Jamaica 72 days later?
ii. What safety precaution should be suppliers have taken to ensure that of dude workers would be harmed

Data given
Half-life, $t_{\frac{1}{2}}$ = 24 days
Time taken, t = 72 days
Initial sample, No = 4×10^5c.p.s
Sample remained undecayed, N = ?
Solution

From: $No/N = 2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

$4 \times 10^5/N = 2^{\left(\frac{72}{24}\right)} = 2^3 = 8$

$4 \times 10^5/N = 8$ – inverse both sides

$N/4 \times 10^5 = \frac{1}{8}$

N = 4 x 10^5 x $\frac{1}{8}$ = 5 x 10^4

N = 5 x 10^4 c.p.s

Example,

The half-life of a radioactive element is 10 min. calculate how long it will take for 90% of a given mass of element to decay

Data given

Half-life, $t_{\frac{1}{2}}$ = 10 min

Initial sample, No = 100%

Element decayed, Nd = 90%

Sample remained undecayed, N = 10%

Time taken, t = ?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

100/10 = $2^{\left(\frac{t}{10}\right)}$

10 = $2^{\left(\frac{t}{10}\right)}$ - apply log both sides

Log10 = log$2^{\left(\frac{t}{10}\right)}$

Log10 = $\frac{t}{10}$ log2

$\frac{t}{10}$ = Log10/log2 = $\log_2 10$ = 3.32

t = 3.32 x 10

t = 33.2 min

Example, : NECTA 2014

a) What is meant by half-life of a radioactive element?

b) A radioactive element was an initial count rate of 1200 counts per minutes measured by a scale and this falls to 150 counts per minute in 15hours

   i. Determine half-life of the element

   ii. If the initial number of an atom in another sample of this element is 3 x 10^{20}. How many atoms will have decayed in 25 hours?

(i) Data given

Time taken, t = 15Hrs

Initial elements, No = 1200 c.p.m

Elements undecayed, N = 150 c.p.m

Half-life, $t_{\frac{1}{2}}$ = ?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

1200/150 = $2^{\left(\frac{15}{t_{\frac{1}{2}}}\right)}$

8 = $2^{\left(\frac{15}{t_{\frac{1}{2}}}\right)}$ - apply log both sides

Log 8 = log$2^{\left(\frac{15}{t_{\frac{1}{2}}}\right)}$

3Log2 = $\frac{\mathbf{15}}{\boldsymbol{t_{\frac{1}{2}}}}$ log2

3= $\frac{15}{t_{\frac{1}{2}}}$

$t_{\frac{1}{2}}$ = $\frac{15}{3}$ = 5

$\boldsymbol{t_{\frac{1}{2}}}$ = 5 Hrs

(ii) Data given

Time taken, t = 25Hrs

Initial elements, No = 3 x 10^{20}c.p.m

Half-life, $t_{\frac{1}{2}}$ = 5Hrs

Elements undecayed, N = ?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

3 x 10^{20}/N = $2^{\left(\frac{25}{5}\right)}$ = 2^5 = 32

3 x 10^{20}/N = 32 – inverse both sides

N/3 x 10^{20}= $\frac{1}{32}$

N = 3 x 10^{20} x $\frac{1}{32}$ = 2.5 x 10^{19}

N = 9.375 x 10^{18} c.p.s

But:

Decayed atom = initial – undecayed atom

Nd = 3 x 10^{20} – 9.375 x 10^{18}

Nd = 2.90625 x 10^{20} c.p.s

Law of Radioactive Decay

It states that

"***Count Rate is direct proportional to the number of undecayed atoms in the sample***"

Mathematically:

C α N – removal proportionality constant

C = kN – make k subject

K = C/N

So: Co/No = C/N = C/N= K

For: Co/No = Cn/Nn – make NO/N

Finally: Co/C = No/N

Since: No/Nn = 2^{n}

Co/C = No/N = $2^{\mathbf{n}}$

Example, : NECTA 2003 QN: 8

(a) Write two properties of (i) X-rays (ii) gamma rays

(b) (i) Give any four uses of cathode ray oscilloscope (CRO)
(ii) State two ways in which x-rays differ from gamma rays

(c) A particular radioactive has a half-life of 2.0 hours. A sample gives a count of 2400 per second at 11:00 a.m. when will the count have dropped to approximately 300 per second in the same counting system?

Data given
Initial count rate, Co = 2400/s
Final count rate, C = 300/s
Half-life, $t_{\frac{1}{2}}$ = 2.0 hrs

Solution
1st find number of half-life, n = ?
From: Co/C = 2^n
2400/300 = 2^n
8 = 2^n
$2^n = 2^3$
n = 3
2nd find time taken for decaying, t = ?
From: n = $\left(\frac{t}{t_{\frac{1}{2}}}\right)$
3 = $\left(\frac{t}{2}\right)$
t = 6hrs
Therefore:
Time will be (11:00a.m + 6hrs) 5:00p.m

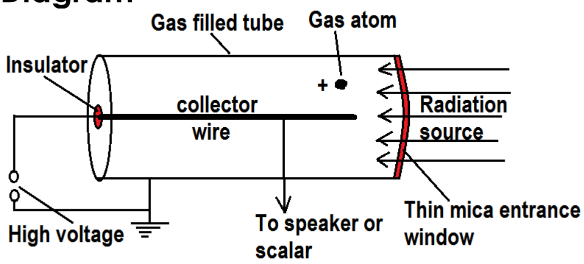
Example, : NECTA 2013 QN: 5(b)
A certain radioactive material has a half-life of 2 minutes. If the initial count rate is 256 per minutes
i. How long does it take to reach a count rate of 32 per minutes
ii. What fraction of the original number of atoms is left undecayed?

Data given
Initial count rate, Co = 256/m
Final count rate, C = 32/m
Half-life, $t_{\frac{1}{2}}$ = 2 min

Solution
i. 1st find number of half-life, n = ?
From: Co/C = 2^n
256/32 = 2^n
8 = 2^n
$2^n = 2^3$
n = 3
2nd find time taken for decaying, t = ?
From: n = $\left(\frac{t}{t_{\frac{1}{2}}}\right)$
3 = $\left(\frac{t}{2}\right)$
t = 6 minutes

ii. Undecayed = original – decayed
Undecayed = 256 – 32 = 224
Undecayed = 224
To gen fraction divide by original both
Fraction undecayed = 224/256 = 7/8
Fraction undecayed = 7/8

Detection of Nuclear Radiations
Nuclear radiation is detected by its ability of ionize atom/molecules of gas passed through the detector, we have about many device but the first-three is the common detector includes
i. Geiger Muller tube (GM tube)
ii. Spark counter
iii. Cloud chamber
iv. Photographic plate (film)
v. Bubble chamber
vi. Gold leaf electroscope

Geiger Muller Tube
Defn: Geiger Muller tube is the device which detect radiation by ionization of noble gas such as argon in a closed tube
Diagram


Composition of Gm Tube
i. Hollow tube consist noble gas coated metallic film maintained at a high negative voltage relative to the collector
ii. Mica thin window at one end where radiation allowed passing through mica during detection
iii. A collector wire at the centre of tube

Mechanism of Gm Tube
When radiation pass through a thin mica window the noble gas (argon) in the tube ionize which loose electron, electron

accelerate toward collector. The current produced cause the speaker to click or scale to count

Background Count Rate

Defn: Background count rate is the reading recorded by scale count or speaker even through there is no source of radioactive material hold near mica window of G.M.T

Source of Background Count Rate

i. Earth's radioactive impurities
ii. Residue of nuclear radiation present in G.M.T
iii. Cosmic rays escape from outer space through ozone layer

Nb:

In calculation Background count rate is treated as zero. i.e. not allowed (it subtracted from recorded count rate)

Example,

A Geiger Muller tube connected to rate meter is hold near a radioactive source, the corrected count rate(allowing for Background count rate is 400 c.p.s. 40 min the corrected count rate is 25c.p.s. what is the half-life of the source?

Data given

Time taken, t = 40 min

Initial count rate, No = 400 c.p.m

Final count rate, N = 25 c.p.m

Half-life, $t_{\frac{1}{2}}$ =?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

400/25 = $2^{\left(\frac{40}{t_{\frac{1}{2}}}\right)}$

16 = $2^{\left(\frac{15}{t_{\frac{1}{2}}}\right)}$ - apply log both sides

Log 16 = log$2^{\left(\frac{40}{t_{\frac{1}{2}}}\right)}$

4Log2 = $\frac{40}{t_{\frac{1}{2}}}$ log2

4= $\frac{40}{t_{\frac{1}{2}}}$

$t_{\frac{1}{2}} = \frac{40}{4} = 10$

$t_{\frac{1}{2}}$ **= 10 min**

Example,

A rate meter records a background count rate of 2 c.p.s, when a radioactive source is held near the count rate is 162 c.p.s. if the half-life of the source is 5 min. what will the recorded count rate be 20 min?

Half-life, $t_{\frac{1}{2}}$ = 5 min

Time taken, t = 20 min

Background count rate, Nb = 2 c.p.s

Initial count rate, No = (162 – 2) = 160 c.p.s

Final count rate, N = ?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

160/N = $2^{\left(\frac{20}{5}\right)}$ = 2^4 = 16

160/N = 16 – inverse both sides

N/160 = $\frac{1}{16}$

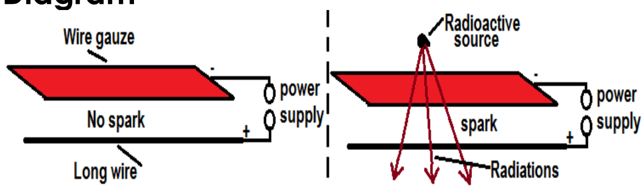
N = 160 x $\frac{1}{16}$ = 10 c.p.s

N = 10 c.p.s

Spark Counter

Defn: Spark counter is the device used to detect the presence of radiation based on their ability to ionize dry air molecules by producing sparks

Diagram



Composition of Spark Counter

i. Piece of wire gauze
ii. Long wire
iii. Power supply with voltage below level required to cause a spark

Mechanism Of Spark Counter

When radiation pass through dry air cause dry air to ionize which increase conductivity of dry air allowing electrons to pass through them to form sparks

Nb:

The number of sparks produced depends in the types of radiation emitted

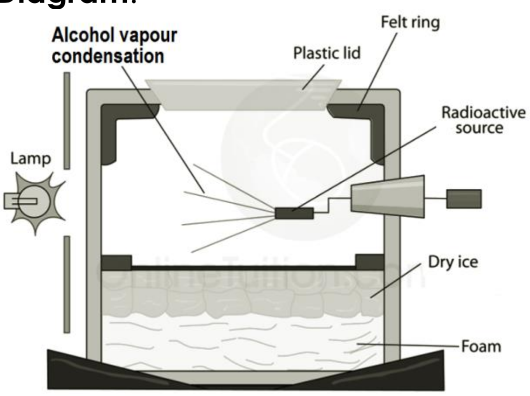
i. When Alpha (α) particles are emitted the largest number of sparks are produced due to highest ionization effect
ii. When Beta (β) particles are emitted the least number of sparks are produced due to moderate ionization effect
iii. When Gamma (γ) rays are emitted the few number of sparks are produced due to lowest ionization effect

Wilson Cloud Chamber

Defn: Wilson Cloud chamber is a device used to detect presence of radiation by producing tracks of light

It sealed environment containing a supersaturated vapour of water, alcohol or any other compound that can be kept near its condensation point by regulating the temperature of the chamber. Supersaturated vapour of water refers to a vapour of a compound (water) that has a higher (partial) pressure than the vapour pressure of that compound (water).

Diagram:



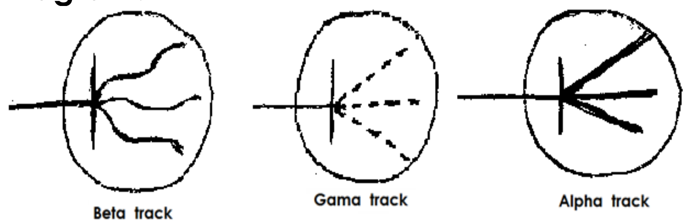
Composition of Cloud Chamber

i. **Felt ring soaked in alcohol**: to supply alcohol vapour to the chamber
ii. **Radioactive source**: produce radiation and cause ionization of vapour
iii. **Dry ice**: uses to cool the alcohol vapour until it is saturated
iv. **Alcohol vapour condensation**: to form liquid droplets around the ionized molecule
v. **Lamp**: uses to light track which cause to view it clear
vi. **Foam**: support dry ice
vii. **Plastic lid**: the eyepiece

Mechanism of Cloud Chamber

When radiation pass through Supersaturated vapour, it ionize supersaturated vapour which cause condensation of supersaturated vapour which leaves trail of charge particles by tracking of tiny droplets in the Supersaturated vapour. It detects alpha and beta particles. Each radiation has unique shape

Diagram:



Thinner and Wave — least track — thick and straight

Example,

A snap shot photograph of a cloud chamber shows 40 tracks well defined alpha particle track. A second snap shot taken 2 min later shows only 10 tracks. What is the half-life of the alpha source?

Data given

Time taken, t = 2 min
Initial track, No = 40 tracks
Final track, N = 10 tracks
Half-life, $t_{\frac{1}{2}}$ = ?

Solution

From: No/N = $2^{\left(\frac{t}{t_{\frac{1}{2}}}\right)}$

40/10 = $2^{\left(\frac{2}{t_{\frac{1}{2}}}\right)}$

4 = $2^{\left(\frac{15}{t_{\frac{1}{2}}}\right)}$ - apply log both sides

Log 4 = log$2^{\left(\frac{2}{t_{\frac{1}{2}}}\right)}$

2Log2 = $\frac{2}{t_{\frac{1}{2}}}$ log2

$2 = \frac{2}{t_{\frac{1}{2}}}$

$t_{\frac{1}{2}} = \frac{2}{2}$ = 1 min

$\boldsymbol{t_{\frac{1}{2}}}$ **= 1 min**

Photographic Film

The energy carried by radioactive emitted cause **healing effect**. When exposed to light (or other forms of electromagnetic radiation such as X-rays), it forms a latent (invisible) image. Chemical processes can then be applied to the film to create a visible image, in a process called **film developing**.

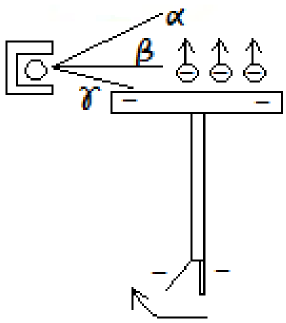
Bubble Chamber

Bubble chamber is similar to a cloud chamber but bubbles are formed in a liquid along the path of the radiation. It detect alpha and beta particles

Gold Leaf Electroscope

When radiation allowed passing through charged electroscope the air surrounding leave ionized results electroscope collapse due to concentration of electrons when air surrounding ionize

Diagram:



Different Between X-Rays and Gamma Rays

i. x-rays are caused by energy transition in electron **while** gamma rays are caused by nuclear reaction within the nuclear
ii. metal (e.g. tungsten) used to produce x-rays not decaying **while** metal used to produce gamma rays decaying
iii. wavelength of x-rays determined by nature of target and operating voltage **while** gamma rays depending on the nuclear for their wavelength
iv. x-rays are emitted by stable atoms of heavy nucleus **while** gamma rays formed nucleus of energetically unstable to became stable

Example,

A patient suffering from cancer of thyroid glands is given a dose of radioactive iodine 131, with a half-life of 8 days, to combat diseases. He is temporarily radioactive and his nurse must be changed regularly to project them. If his radiation is initially 4 times the acceptable level, how long is it before the special nursing radiations can be dropped

Data given

Initial dose level, Co = 4x

Final dose level, C = x

Half-life , $t_{\frac{1}{2}}$ = 8 days

Solution

1st find number of half-life, n = ?

From: $Co/C = 2^n$

$4x/x = 2^n$

$4 = 2^n$

$2^n = 2^2$

n = 2

2nd find time taken for decaying, t = ?

From: $n = \left(\frac{t}{t_{\frac{1}{2}}}\right)$

$2 = \left(\frac{t}{8}\right)$

t = 16 days

Thermionic Emission

Defn: Thermionic emission is the discharge of electrons from the surfaces of heated materials.

Or

Defn: Thermionic emission is the phenomena of metals to emit electrons when they are heated

Or

Defn: Thermionic emission is the thermally induced flow of charge carriers from a surface or over a **potential-energy barrier**

Why Thermionic Emissions Occur?

This occurs because the thermal energy given to the carrier overcomes the work function of the material

Work Function

Defn: work function is the minimum thermodynamic work (i.e. energy) needed to remove an electron from a substance to a point in the vacuum immediately outside the substance surface.

Nb:

Final electron position is far from the surface on the atomic scale, but still too close to the substance to be influenced by ambient electric fields in the vacuum

What Occur After Thermionic Emissions?

After emission, a charge that is equal in magnitude and opposite in sign to the total charge emitted is initially left behind in the emitting region. But if the emitter/Metal/ cathode is connected to a battery, the charge left behind is neutralized by charge supplied by the battery as the emitted charge carriers move away from the emitter/Metal/ cathode, and finally the emitter/Metal/ cathode will be in the same state as it was before emission.

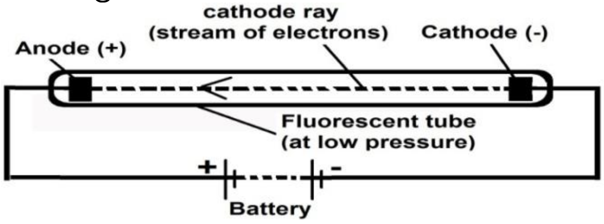
Types of Thermionic Emission

We will discuss two thermionic emission include

i. Cathode rays
ii. X- rays

Cathode Rays

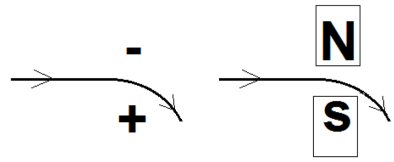
Defn: Cathode rays are a stream of fast-moving electrons from cathode to anode.



Properties of Cathode Rays

Cathode rays have the following properties:

i. They travel in straight lines.
ii. They carry negative charges.
iii. They cause fluorescence (glow) when they strike materials.
iv. They have energy and momentum.
v. They are deflected by electrical (toward positive charge) and magnetic fields (toward South Pole).
   Diagram:

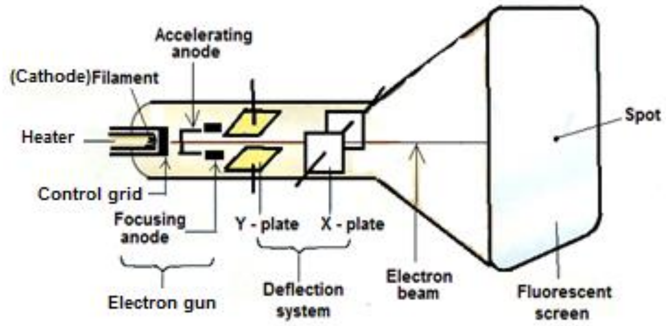


vi. Cathode rays can ionize gas atoms if the potential difference is large and the gas pressure is not high.
vii. They can penetrate thin sheets of paper or metal foils depending on their energy.
viii. They affect photographic plates.
ix. They produce X-rays when stopped suddenly

The Cathode-Ray Tube (CRT)

The cathode ray tube (CRT) is evacuated vacuum tubes containing electron gun used accelerates and deflect the electron beam(s) onto the phosphorescent screen to create the image

Diagram:



Why Cathode-Ray Tube Evacuated?

Cathode-Ray Tube evacuated to minimize air or electric resistance in order to make electrons travel without colliding with other particles

What happens if CRT not vacuums?

If gas is maintained in the tube (at atmospheric or high pressure), the tube will behave like an open circuit (insulator), when p.d across strong enough will cause an electric spark which will ionize the air and make it conduct electricity and then there is no production of cathode rays thus the fluoroscope screen will not form image

Components of the Cathode-Ray Tube

It consists three system include

1. Electron Gun
2. Deflection system
3. Fluorescent Screen

1. **Electron Gun**

It consist **Heate**r, **cathode**, **control grid**, **accelerating anode** and **focusing accelerating anode**.

(a) **Heate**r

It heating element used to heat cathode to high temperatures from 800°C to several thousand degrees Celsius either directly by an electric current or indirectly

(b) **Cathode**

This is a metal filament such as tungsten heated by electron gun resulting metal electrons attains enough kinetic energy than a Work Function of a metal and escape the cathode by thermionic emission

(c) **control grid**

The control grid functions as a "**gate**" to control the number of electrons in the beam reaching the anode. A more negative voltage on the grid will repel the electrons back toward the cathode so fewer get through to the anode. A less negative, or positive, voltage on the grid will allow more electrons through grid

(d) **accelerating anode**

This is a metal disk maintained at a high positive voltage of 5 000 V to 50 000 V used to pull electrons from cathode to focusing anode

(e) **Focusing anode**

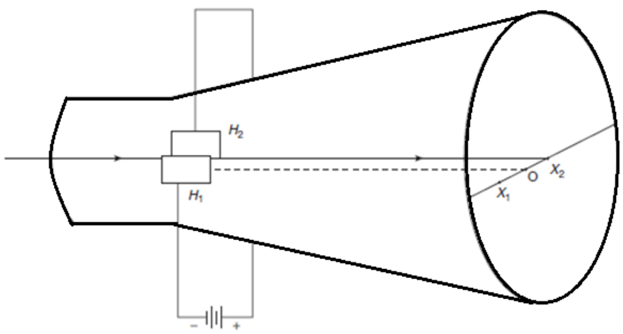
This is a metal disk maintained at a high positive voltage of 5 000 V to 50 000 V used to pull electrons received from accelerating anode to deflection system up to fluoresce screen

2. **Deflection system**

It consists **horizontal (x) deflection plates** and **vertical (y) deflection plates**

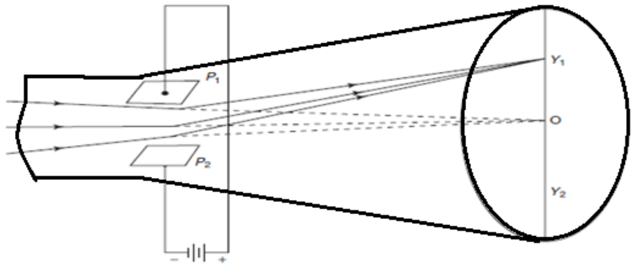
(a) **Horizontal (X) Deflection Plates**

Are metal plates carrying equal but opposite charges (signal). They are used to deflect the electron beam horizontally (left or right). The beam is attracted to the positive plate and repelled from the negative plate



(b) **Vertical (Y) Deflection Plates**

Are metal plates carrying equal but opposite charges (signal). They are used to deflect the beam vertically (up or down)



NB: The horizontal and vertical deflection plates can direct the beam towards any point on the screen. In some devices, the electrically charged plates are replaced by poles of electromagnets.

3. **Fluorescent Screen**

This is the display component of the CRT where image displayed. It is phosphor coated so that it emits light wherever the electrons strike it

NB:

i. The horizontal and vertical deflection plates can direct the beam towards any point on the screen. In some devices, the electrically charged plates are replaced by poles of electromagnets.
ii. The deflection plates move the electron beam to different points on the screen resulting in the formation of an image for a short time about (20^{-1} sec) or 0.05 Hz

Operation of the Cathode-Ray Tube

Cathode is heated indirectly by a heater (electric gun) until thermal electron emission. The electrons emits is controlled by grid towards anode. After travelling through the hole in the anode the electrons hit the luminescent screen, causing them to slow down and excite the phosphor in the screen to fluorescence

Applications of the Cathode-Ray Tube

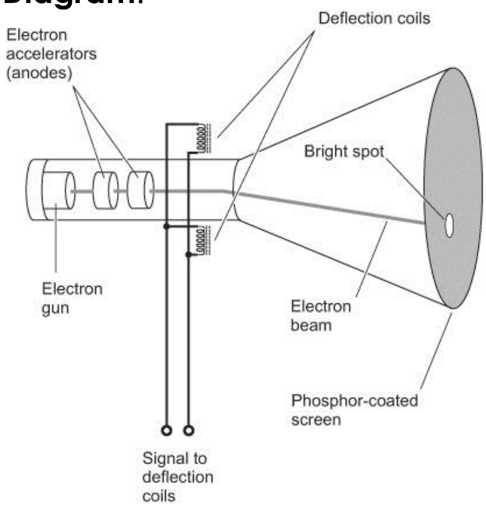
The cathode-ray tube is used in

i. computer display (Monitor)
ii. Televisions (TV)
iii. cathode-ray oscilloscopes (CRO)

Televisions (TV)

It may be black and white television or coloured television

Diagram:



Operation of black and white television

The signal is first amplified and then applied to the vertical deflection plates to deflect the beam vertically. At the same time, a voltage is applied to the horizontal deflection plates thus causing the beam to be deflected horizontally. The image is formed on the screen by varying the brightness at thousands of points on the screen. The brightness of a point on the screen depends on the number of electrons that strike it

Operation of coloured television,

The signal is first amplified and then applied to the vertical deflection plates to deflect the beam vertically. At the same time, a voltage is applied to the horizontal deflection plates thus causing the beam to be deflected horizontally. The image is formed on the screen (**phosphors of primary colour**: **red**, **green** and **blue**). The image is formed by varying the intensity of the electron beam that strikes the different phosphors

Nb:

i. The intensity of the electron beam can be varied by changing the voltage on the grid located between the cathode and the anode
ii. The grid has a negative charge and so repels the electrons coming from the cathode

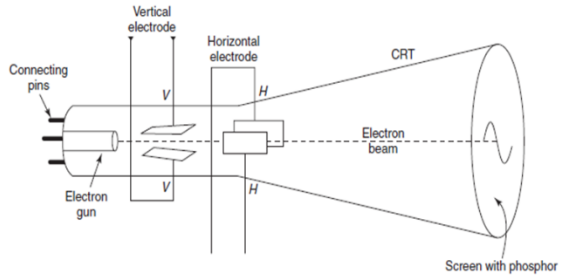
iii. By changing the grid's voltage it allows more or fewer electrons to pass on to the anode and ultimately to the screen
iv. Some colour televisions use a single electron gun whereas others use three
v. The process where plate voltage(signal) converted to image on fluorescent screen is called **scan**
vi. The horizontal and vertical motion of electrons towards fluorescent screen is called **scanning**

The Computer Displays
Computer displays work in the same way as the television

The Cathode-Ray Oscilloscope (CRO)
The cathode-ray oscilloscope is typically used to display signals in wave forms. It operates in a way similar to a television

Operation of Cathode-Ray Oscilloscope
The signal is first amplified and then applied to the vertical deflection plates to deflect the beam vertically. At the same time, a voltage is applied to the horizontal deflection plates thus causing the beam to be deflected horizontally at a uniform (constant) rate. The signal applied to the vertical plates is thus displayed on the screen as a function of time. The horizontal axis serves as a uniform time scale. The screen of the CR0 is covered with a grid to facilitate measurements.

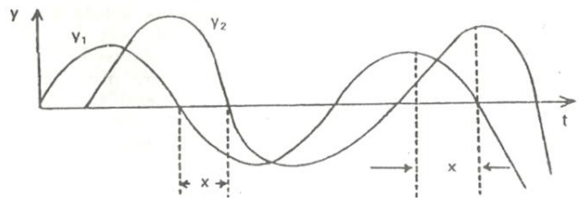
How CRO Make Wave Form?
i. To cause a wave-form pattern to be traced on the screen the bright spot must be moved horizontally at a uniform rate while simultaneously a varying p.d. (a.c. signal) under study is applied to the Y-plates to cause vertical deflections
ii. The horizontal uniform motion of the bright spot on the screen is achieved by applying a p.d, to the X-plates with a sweep generator of time base circuit. The p.d. builds up uniformly with time to a maximum and then flies back to repeat the process regular intervals. At low frequencies, this makes a trace of a moving bright spot which at high frequencies owing to persistence of vision, become a continuous bright line
iii. The combination of the X-plate sweep and the Y-plate signals enables the spot to trace a wave-form
iv. The vertical displacement gives the magnitude of the voltage signal and the shape of the wave form depicts the signal variation with time.



Uses of Cathode-Ray Oscilloscope (CRO)
i. **Measuring frequencies**
By using an oscilloscope which has a calibrated time - base, the frequency of an a.c. signal can be measured. The horizontal distance occupied by one cycle of the waveform on the screen scale multiplied by the calibration scale sec/m (or ms/cm) gives the period, T, from which the frequency f, of the waveform can he obtained using the relation
T = horizontal distance (m) x scale (sec/m)
T = m x (sec/m) = (m x sec)/m
T = sec
f = 1/T

ii. **Measuring Voltages**
The unknown voltage, **v** of an a.c. signal can be measured by connecting it to the Y-plates and switching off the time base. The vertical line on the screen is then centered and its length, **L** measured. By proportion, the peak-to peak voltage which is twice the peak voltage can be found
V = L/2

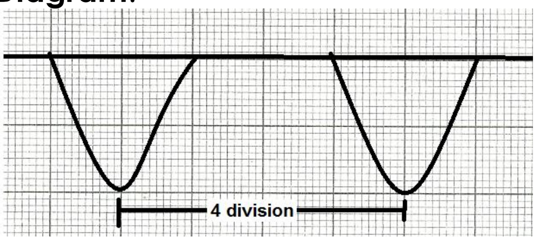
iii. **Measuring phase differences**
The phase different between any two waves forms can be measure by using a double beam oscilloscope
Diagram:



When the beams are displayed simultaneously on the screen and superposed over each other, the horizontal distance x cm, between their peaks can be used to calculate their phase difference

$\phi = \frac{2\pi}{\lambda} x$

iv. **Measuring small time intervals**
A cathode ray oscilloscope can be used to determine the time interval between two pulses, even though the time interval is very small
Diagram:



From the figure above If the time base is set to 2 ms/div, the time interval between the 2 pulses can be calculated as follow:
t = 4 x 2ms = 8 ms = 0.008s.
Time interval = division x time base

v. **Comparison of frequencies**
Comparison of frequencies f_1 and f_2 of two waves - forms is also possible by measuring the corresponding horizontal distances d_1 and d_2

$\frac{f_1}{f_2} = \frac{T_2}{T_1} = \frac{d_2}{d_1}$

X-Rays

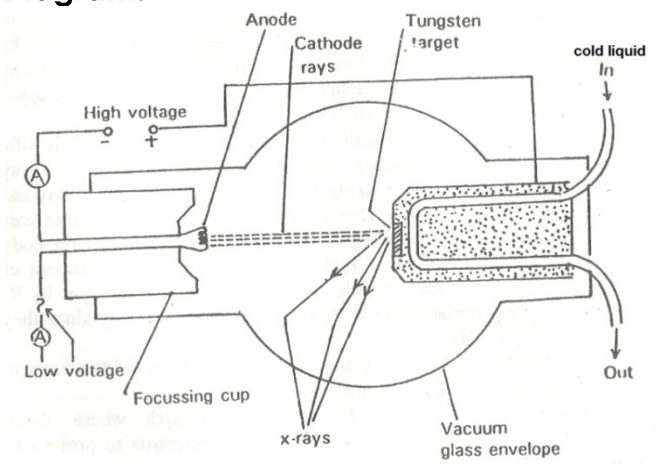
Defn: X-rays are rays produced when fast moving electron strikes a target. Its electromagnetic radiation similar to light but with much higher frequency (3 x 10^{17} - 3 x10^{19}) Hz and short wavelength that ranges from 6 x 10^{-11}m to 10^{-9}m.

The X-Ray Tube

The X-Ray Tube is the highly evacuated glass bulb contains cathode and anode made of platinum and tungsten or heavy metal of high melting point

Production of X-Rays

X-rays are produced when filament or a cathode which emits fast-moving electrons into a vacuum; fast-moving electrons accelerate from cathode to strike a target with an anode which some of kinetic energy converted to X-rays
Diagram:



Nb:
i. In production of x – rays there two include circuit of low (**secondary circuit**) and circuit of high voltage (**primary circuit**)
ii. Circuit of low voltage used to heat cathode
iii. circuit of high voltage used to make high tension for voltage for produce fast moving electrons between the electrode anode and cathode
iv. cold in used to cool tungsten target

Types of X-Rays

There are two types of X-rays includes
i. Soft X-rays
ii. Hard X-rays

Soft X-Ray

Soft X-ray is the kind of X-ray produced by lower accelerating potential with longer wavelength, lower range of frequency. They have less energy and less penetrating power

Hard X-Ray

Hard X-ray is the kind of X-ray produced by high accelerating potential with short wavelength, higher range of frequency.

They have high energy and more penetrating power

Properties of X-Rays

viii. travel in straight line at the velocity of light
ix. they cannot be deflected by electric or magnetic field
x. they can produce fluorescence
xi. they affect photographic film
xii. they penetrate matter but depend on density of matter
xiii. they ionize gases
xiv. can be diffracted by crystals

Application/Uses of X-Rays

1. **In the medical field soft X-rays are used**
   i. To detect broken or fractured bones or some disease in soft tissue
   ii. To treatment cancer
2. **Crystallography**: experimental study of the arrangement of atoms in solid (study of arrangement of crystals)
3. **Astronomy**: X-rays emitted by celestial objects are used in observational astronomy
4. **X-ray microscopic analysis**: involves the use of electromagnetic radiation in the soft X-ray band to produce image of very small objects
5. **X-rays fluorescence**: technique in which X-rays are generated within a specimen and detected. The outgoing energy of the identify the composition of the sample
6. **Security installation**: it used for non-invasive security searches at airports and seaports
7. **Industries**: it used to inspect metal-casting and welded joints for hidden faults

Effect of X – Rays to Human Beings

i. Destroy body cells and can cause cancer
ii. Can cause mutation due to destroy of genitals

NECTA 1997 Qn: 12

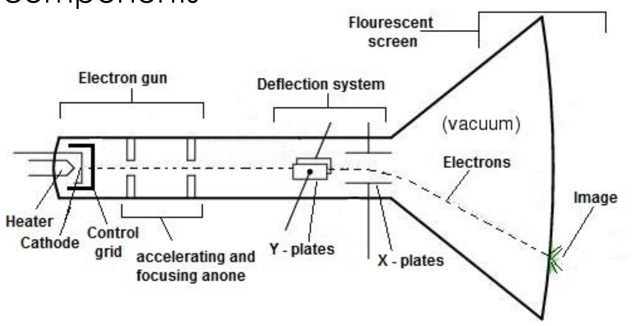
(a) State one way in which cathode rays differ from electromagnetic waves and describe an experiment which illustrates this difference
(b) Draw a labelled diagram of a longitudinal section view of the cathode ray oscilloscope tube showing its main features

Solution

(a) Their difference

Cathode rays	**electromagnetic waves**
Cathode rays are deflected by magnetic or electric field	electromagnetic waves are not deflected by magnetic or electric field
Cathode rays have negative charge	electromagnetic waves have no charge

(b) Diagram of CRO with its main components



NECTA 2002 Qn: 11

(a) (i) What are the two types of X – rays?
(ii) X – Rays are said to have harmful effect to human beings when used for a long time. Explain the effect that X – rays cause to human beings
(b) Describe how X – rays are produced in X – ray tube
(c) Show the three main parts of cathode ray oscilloscope on a well labelled diagram

NECTA 2003 Qn: 08

(a) Write two properties of
(i) X rays (ii) cathode rays
(b) (i) give any four uses of cathode ray oscilloscope (CRO)
(ii) State two ways in which x – rays differ from gamma rays
(c) A particular radioactive has a half-life of 2.0 hours. A sample gives a count rate of 2400 per second at 11:00 am.

When will the count have dropped to approximately 300 per second in the same counting system?

NECTA 2004 Qn: 11

(a) Explain briefly the following
(i) Thermionic emission
(ii) The production of a stream of electrons in cathode ray oscilloscope (C.R.T)
(iii) The principle of transistor

(b) What method in a device using the thermionic emission principle ensures that the electrons produced
(i) Do not accumulate at the source?
(ii) Reach their range undeviated?
(iii) Travel without meet other forms of particles on their way to the target?

(c) Using block diagram for n-p-n transistor, show how a transistor can be used in a simple circuit as
(i) An amplifier (ii) A switch

NECTA 2007 Qn: 11

(a) (i) explain why cathode ray tube (CRT) are evacuated
(ii) What happens to the CRT when a gas is maintained?
(iii) If gas is maintained in a CRT, will the image be formed onto the screen? Explain

(b) In the production of X – rays what are role of:
(i) Low voltage
(ii) High voltage?
(iii) Tungsten target?

(c) How is hard X – rays produced?
(i) Discus the differences between conductors and semiconductors
(ii) Use the following information to calculate the current gain of a C – E amplifier

$I_B \times 10^{-6}$ A	100	200	300	400	500
$I_C \times 10^{-3}$ A	5	10	15	20	25

NECTA 2009 Qn: 11

(a) (i) Define thermionic emission
(ii) What is X – rays?
(iii) Mention two uses of X – rays

(b) With the aid of a diagram, explain how X – rays are produced

(c) Draw a well labelled diagram of a cathode ray oscilloscope.

Electronics

Defn: *Electronics is a branch of physics that deals with the emission and effects of electrons in materials.*

NB:

i. The various electronic components connected to each other to form systems or circuits called **Electronic systems (Electronic circuits)**
ii. An electronic circuit is used to perform a wide variety of tasks. The main uses of electronic circuits are:
   a. Conversion (ac to dc) and distribution of electric power.
   b. Controlling and processing of data

Electronic Component

Defn: *An electronic component is any basic discrete device or physical entity in an electronic system used to affect electrons or their associated fields*. For Example, **power sources**, **resistors**, **capacitors**, **diodes**, **transistors**, and **integrated circuits** etc.

Types of Electronic Components

They are two types of Electronic components includes

i. Passive Electronic components
ii. Active Electronic components

Passive Electronic Components

Defn: *Passive components are Electronic components that consume energy but do not produce energy*. Passive components include power sources (battery or generator), resistors, capacitors and inductors.

Nb:

i. They do not have the ability to produce ***gain***, that is, to increase the power or amplitude of a signal.
ii. They also do not have ***directionality***, that is, they operate in the same way regardless of the direction of the current flowing through them.

Active Electronic Components

Defn: *Active components are Electronic components that have direction and/or the capacity to produce gain*. They include semiconductor devices such as **diodes**, **transistors** and **integrated circuits**

Insulators

Defn: *An electrical insulator is a material or object which resists the flow of electrical charges through it.* Insulator has infinite resistance and zero conductances. For Example, s **glass**, **mica**, **paraffin**, **hard rubber** and also many plastics

Why resists the flow of electrical charges?

i. It has not free electrons which are responsible to call/pass through electrical charge
ii. The electrons in the material including the outermost ones are strongly bound to the atoms.

Conductors

Defn: *Conductors is a material or object which allows the flow of electrical charges through it*. For Example, s **all metals** and **some non-metals** such as **graphite** (carbon)

Semiconductors

Defn: *A semiconductor is a material where its electrical conductance intermediate between conductance of insulator and conductor.* For Example, s **silicon**, **germanium**, **cadmium sulphide** and **gallium arsenide**

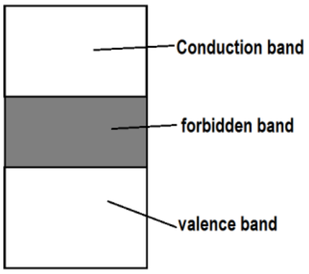
Nb:

i. A semiconductor behaves as an insulator at very low temperature
ii. Has a significant electrical conductance at room temperature, however, much lower than that of a conductor

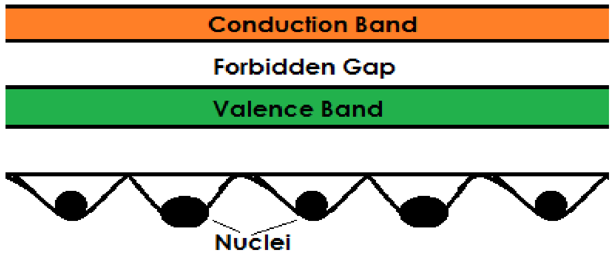
Energy Bands

The energy-band structure (or simply band structure) of a solid is the series of "**allowed**" and "**forbidden**" energy bands that it contains

Diagram:



Crystal diagram



We have about three bands in which a band electrons posse's energy called **energy level**

i. Conduction band
ii. Band gap (forbidden band)
iii. Valence band

Conduction Band

The conduction band is the range of electron energy, higher than that of the valence band, sufficient to make the electrons free to accelerate under the influence of an applied electric field and thus constitute an electric current

Band Gap

Band gap is an energy range in a solid where no electron states can exist. Also called an **energy gap**

Valence Band

The valence band is the highest range of electron energies where electrons are normally present at the absolute zero temperature

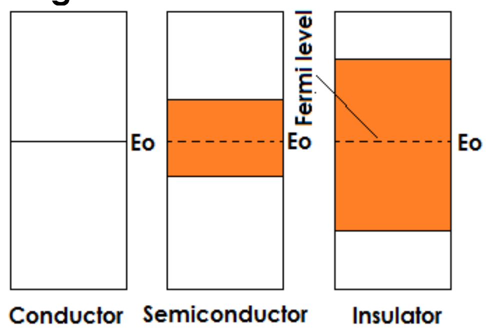
NB:

i. When the band gap energy is met, the electron is excited into a free state, and can therefore participate in conduction.
ii. The band gap determines how much energy is needed from the sun for conduction, as well as how much energy is generated.
iii. A hole is created where the electron was formerly bound. This hole also participates in conduction.
iv. In semiconductors and insulators, there is a band gap (forbidden band) above the valence band
v. No conduction occurs In metals, the valence and conduction bands overlap
vi. For insulators, the forbidden energy gap is large

The Fermi Level

Defn: Fermi level is the top of the available electron energy levels at absolute zero (0 Kelvin) temperatures

Diagram:



NB:

i. For insulators and semiconductors, the Fermi level lies in the gap between the valence and conduction bands. At low temperatures, no electrons are available for conduction
ii. Since the valence and conduction bands overlap in conductors, the Fermi level can lie in the conduction band.

How Semiconductor Conducts Electricity

As the temperature is increased, some of the electrons in the valence band acquire thermal energy that is greater than the forbidden gap energy and move to the conduction band. Therefore, the material becomes a conductor. When an electron moves out of a valence band it leaves behind a small space called a **hole** (it carries a positive electric change). Electrons and holes in the conduction and valence bands, respectively, are referred to as **free charge carriers**.

Temperature effect On Metal conductivity

Increase in temperature tends to increases the random motion of electrons;

it reduces the electrical conductivity of metals

Types of Semiconductors

There are two types, includes

i. Intrinsic semiconductors
ii. Extrinsic semiconductors

Intrinsic Semiconductors

Defn: an intrinsic semiconductor is the semiconductor that has number and type of free charge carriers itself

Extrinsic Semiconductors

Defn: *an extrinsic semiconductor is the semiconductor that their number and type of free charge carriers presents modified by doping with impurity*

Difference between conductors from semi-conductor

conductor	semi-conductor
The charger carriers are free electron	Their charger carriers are both holes and electron
The conductivity decrease with increasing in temperature	Their conductivity increase with increasing temperature
There is no forbidden gap i.e. valance and conduction bond overlapped	There is forbidden gap btn valance and conduction bond

Difference btn intrinsic from extrinsic semi-conductor

intrinsic	extrinsic
Is the pure form of semi-conductor	Is an impure form of semiconductor
It has equal number of holes and electron	It has unequal number of holes and electron
It has conductivity depends on temperature only	It has conductivity depend on both temperature impunities
It has low conductivity	It has high conductivity

Doping

Defn: *Doping is the adding of impurity to modify the conductivity of an atom into their crystal lattices.*

Terms Used In Doping

i. **Acceptor atoms** are atoms which receive electrons from other atoms
ii. **Donor atoms** are atoms which supply electrons to other atoms
iii. **Dopant** is the element/impurity which added to modify the conductivity of an atom

NB:

i. Conductivity of intrinsic semiconductor increase as temperature increases
ii. Heavily doping a semiconductor increases its conductivity. Thus why heavily doped **silicon** is often used as a replacement for metals
iii. **Silicon** and **Germanium** are the best semiconductors as they are used to make the most common electronic devices/components such as transistors and diodes

Types of Doped Semiconductor

Doping produces two types of semiconductors, namely

i. N-type semiconductor
ii. P-type semiconductor

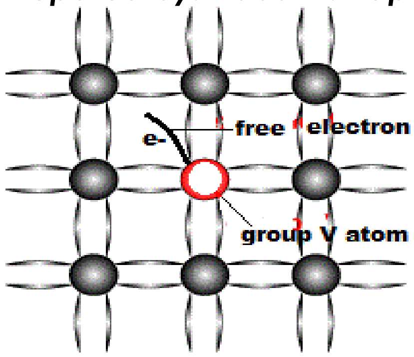
N-Type Semiconductor

Defn: *N-type semiconductor is the type of semiconductor with electron carriers*. The purpose of n-type doping is to produce an abundance of mobile or carrier electrons in the material

Mechanism of Doping

Consider the silicon with four valences (**with four electrons in their outer most shell**) combine with Dopant of **more than four electrons** they will share the four valences results the extra electron from Dopant (group V) remaining as extra (free electrons). This extra electron is only weakly bound to the atom and can easily be excited into the conduction band, since the silicon atoms with five valence atoms have an extra electron to "**donate**", they are called **donor atoms**

Diagram of silicon after doping



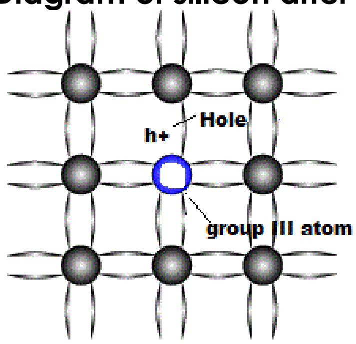
P-Type Semiconductor

Defn: *P-type semiconductor is the type of semiconductor with holes carriers*. The purpose of n-type doping is to produce an abundance of holes in the valence band.

Mechanism of Doping

Consider the silicon with four valences (**with four electrons in their outer most shell**) combine with Dopant (group III) of **less than four electrons** in their outer most shell they will share the three electrons results the semiconductor with less electrons (holes) to attain stable, since the silicon atoms with three valence atoms have an less electron to "**acceptor**", they are called **acceptor atoms**

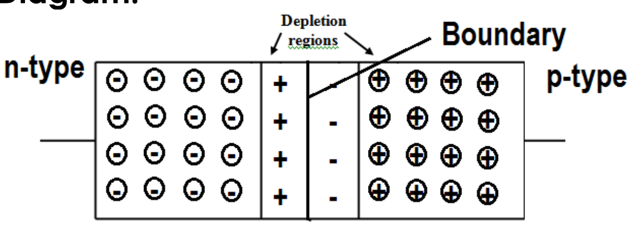
Diagram of silicon after doping



The P-N Junction

Defn: p-n junction is made by combining a p-type semiconductor and an n-type semiconductor in a single continuous crystal.

Diagram:



Terms Used In P-N Junction

i. **diffusion of charge** is spread out of charge (holes and electrons) which can result repelling and attraction of charge
ii. **Barrier potential** is the maximum voltage at the junction when there is no further diffusion of charge
iii. **Deplection layer** is an electric field at the junction of the pn junction when barrier potential is reached

Mode of Action of P-N Junction

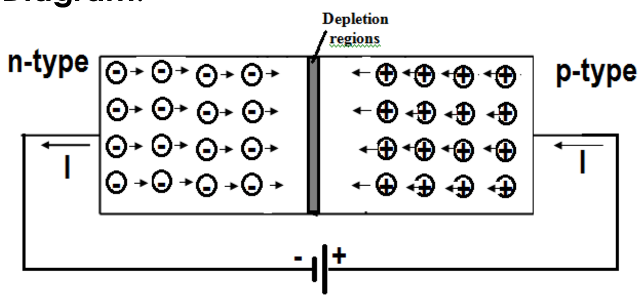
There are two modes of action of P-N junction, these are

i. Forward – bias
ii. Reverse- bias

Forward- Bias of P-N Junction

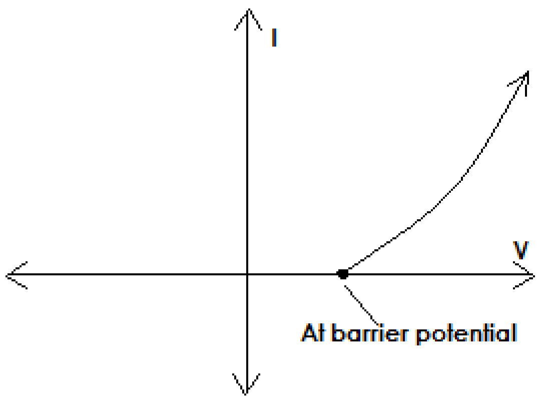
Consider the diagram in the circuit shown below

Diagram:



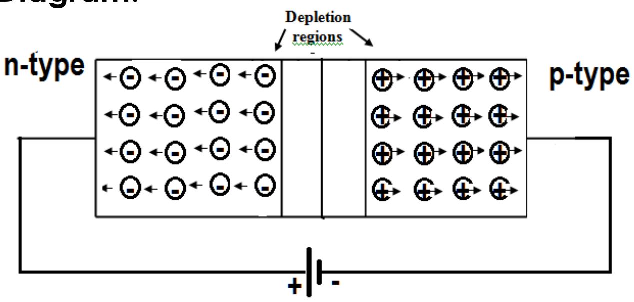
i. The flow of electrons from the N- side to the P- side of a junction and holes from P- side to the N- side increases across boundary where reduced depletion layer results/allow recombination of electron and holes
ii. The potential barrier is reduced
iii. The resistance of the junction to the current flowing is reduced
iv. Then the P-N junction is said to be forward biased

Graph of voltage against current for forward



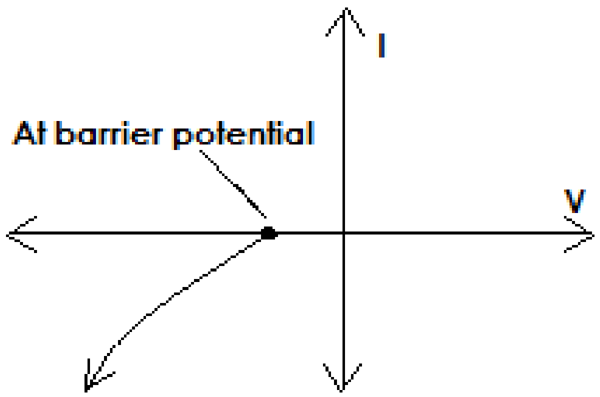
When the voltage of the battery is greater than barriers potential minority charge carries are repelled and large electric current flowing

Reverse - Bias P-N Junction
Consider the diagram in the circuit shown below
Diagram:



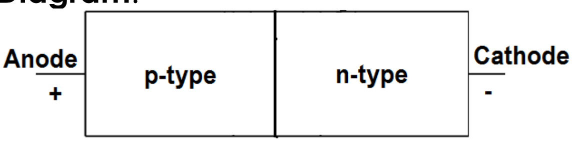
i. The depletion layer is widened.
ii. The rate of diffusion/recombination of electrons with holes is reduced
iii. The potential barrier is increased.
iv. The resistance to the flow of current becomes large

Graph of voltage against current for reverse



When the voltage of the battery is greater than barriers potential minority charge carries are repelled and very small or no electric current is flowing

Diodes
Defn: *diode is an electrical device that allows current to move through it in one direction*.
Diagram:



Symbol:

Nb:

i. The n-region is called the **cathode**
ii. The p-region is the **anode**
iii. When the junction is reverse-biased, the diode blocks the voltage
iv. When the junction is forward-biased, the diode conducts
v. The magnitude of the current through the diode depends on the current in the external circuit

Types of Diode
There are different types of diodes used in electronic circuits. The following are the most common ones:
i. Semiconductor diode
ii. Metal semiconductor diode
iii. Light-emitting diode
iv. Zener Diode

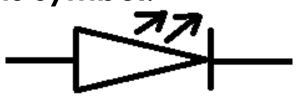
Semiconductor Diode
Most semiconductor diodes are made up of silicon or germanium.

NB:
The main uses of semiconductor diode is rectification

Metal Semiconductor Diode
These types of diodes are formed by the deposition of a metal on the surface of a metal conductor.

Nb:
The metal-semiconductor diode is used for very fast switching and microwave applications.

Light-Emitting Diode
A light-emitting diode (LED) is a semiconductor diode that emits light when an electrical current is applied in the forward direction of the diode.
Its symbol:



NB:
i. LEDs are made from a variety of semiconductor materials depending on the wavelength of the light required
ii. The most commonly used materials for visible LEDs are gallium phosphide and gallium arsenic phosphide

iii.. LEDs have a wide range of applications, from simple indicator lamps and huge display screens to optical fiber communication links

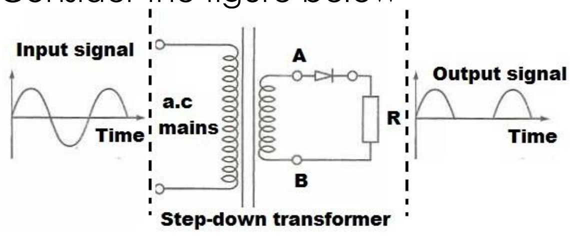
Zener Diode
Zener diodes are specially manufactured diodes designed to be operated in the reverse breakdown voltage. Every Zener diode is manufactured for a specific reverse breakdown voltage called the **Zener voltage**.
Its symbol:

NB:
Zener diodes are used as voltage regulator devices. It allow required voltage to pass through

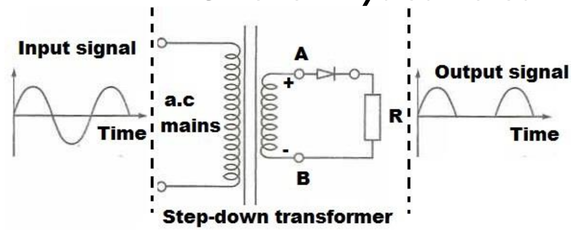
Rectifiers
Defn: Rectifier is the process of converting alternating current to direct current
Or
Defn: Rectifier is the process of obtaining direct current from alternating current.

Rectification Ways
Rectification can be done in two ways includes
i. Half-wave rectifiers
ii. Full -wave rectifiers

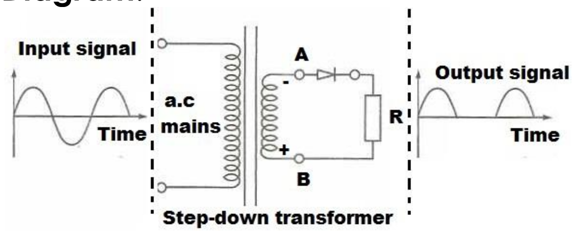
Half-Wave Rectifiers
Consider the figure below



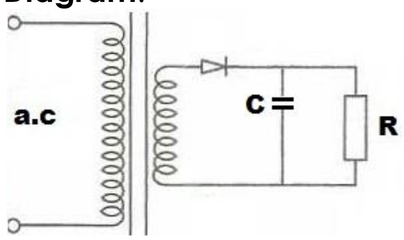
Mechanism
i. During the first half-cycle of the sinusoidal wave form, A is positive and B is negative. The diode is forward-biased and current flows around the circuit formed by the diode
Diagram:



ii. During the second half-cycle, A is negative and, B is positive. The diode is reverse-biased therefore no current flows in the circuit
Diagram:

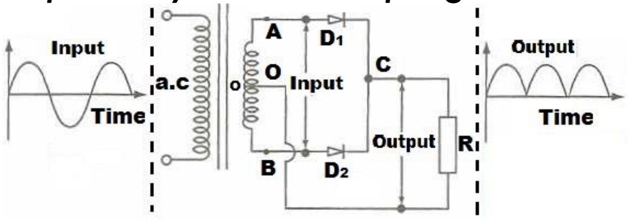


NB:
i. The diode conducts on every half-cycle
ii. The rectified voltage is d.c and is always positive in value
iii. If the diode is reversed, then the output voltage is negative
iv. The voltage is not steady and needs to be **smoothed** (by putting a large capacitor, C in parallel with the load) for it to be useful
Diagram:



v. The capacitor is charged during the positive half-cycle of the a.c. and discharges through the load in the negative half-cycle

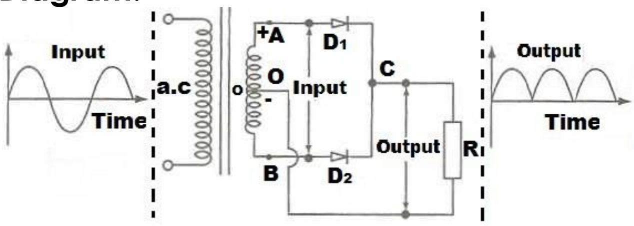
Full -Wave Rectifiers
In this circuit both halves of the a.c. cycle are transmitted but in the same direction. One way of achieving this is to have a transformer whose output has a Centre tap, that is, its output can be taken at two points one being half the other
Diagram:



Mechanism

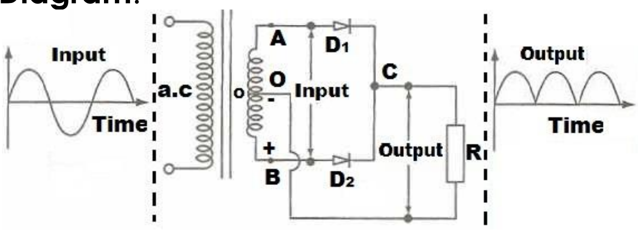
i. In the positive half-cycle, point A is positive with respect to O. Diode D_1 conducts but diode D_2 is reverse-biased. The current passes through D_1, C, Rand back to O

Diagram:



ii. In the negative half-cycle, point B is positive with respect to O. Diode D_2 conducts but diode D_1 is reverse-biased. The current passes through D_2, C, R and back to O

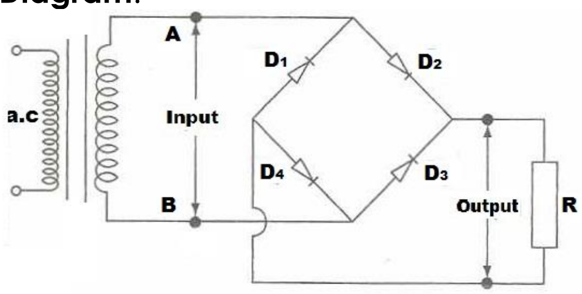
Diagram:



iii. The direction of the current through R is the same as in the first half-cycle

Another method of achieving full-wave rectification is by using a bridge rectifier

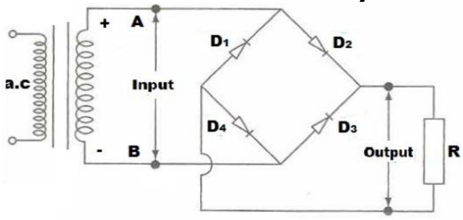
Diagram:



Mechanism

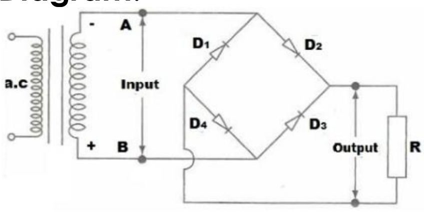
i. In the first half-cycle, point A is positive so that diode D_2 and are forward-biased and D_1 and D_3 are reverse-biased. Diode D_2 conducts and the current flows from A via D_2, R, D_4 and back to the source at B.

Diagram:



ii. In the second half-cycle, B is positive and so diode D_3 is forward-biased and D_4 and D_2 are reverse- biased. Diode D_3 and D_1 conducts and current flows from B via D_3, R, D_1, and back to the source at A.

Diagram:



iii. The current through R is in the same direction in both half-cycles

iv. The output is the same as that for the other full-wave rectifier

Transistors

Defn: Transistor is a semiconductor device used to amplify or switch electronic signals and electrical power.

Terminal of Transistor

It composes semiconductor material with at least three terminals for connection includes

i Emitter (E)
ii Collector (C)
iii Base (B)

Emitter (E)

Defn: Emitter is terminal used to remove charge from transistor

Collector (C)

Defn: Collector is terminal used to receive charge repelled from emitter terminal

Base (B)

Defn: Base is terminal between emitter terminal and collector terminal

Nb:

i Some transistors are packaged individually but most are found in integrated circuits (more than one transistor) ii Base terminal is thin and lightly doped

Types of Transistors

There are two broad categories of transistors include;

i. Bipolar transistors
ii. Field-effect transistors (FETs)

Bipolar Transistors

Defn: Bipolar transistors Is the transistor in which require a biasing input current at their control leads. It require both positive (holes) and negative (electrons) carriers to operate

Field-Effect Transistors

Defn: Field-effect transistors Is the transistor in which require a biasing input only a voltage and practically no current. It require only one charge carrier

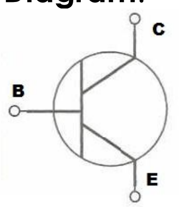
NB:

i According to our course we will study only bipolar transistor
ii Always emitter and base form reverse bias
iii Always collector and base form forward bias

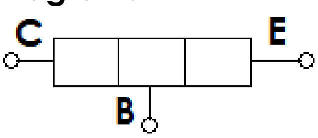
Bipolar Transistors

Bipolar transistors are three-terminal devices that act as electrically controlled switches or as amplifier controls. A bipolar transistor consists of a pair of p -n junction diodes that are joined back-to-back (sandwich form). The leads (regions) are labeled base (B), collector (C) and emitter (E)

Symbol Diagram:



Block Diagram:



Types of Bipolar Transistors

There are two types of bipolar transistors includes

i. n-p-n transistor
ii. p-n-p transistor

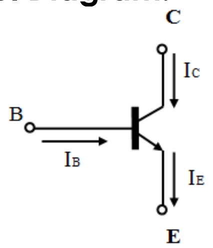
Nb:

i In transistor whether PNP or NPN, **emitter and base form forward bias** while **collector and base form reverse bias**

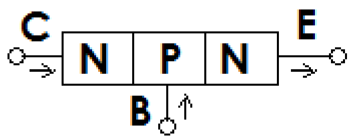
N-P-N Transistor

Defn: n-p-n transistor is the kind of transistor in which current emitter (I_e) point out.

Symbol Diagram:



Block Diagram:



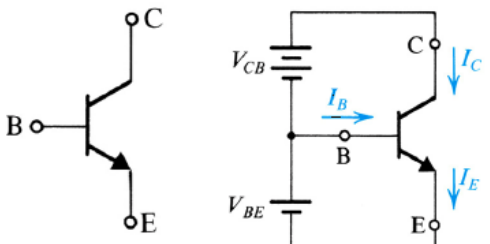
NB:

i. The arrow indicates the direction of flow of the conventional current
ii. n-p-n means **n**ot **p**oint **in**

Operation/Mechanism Of N-P-N Transistor

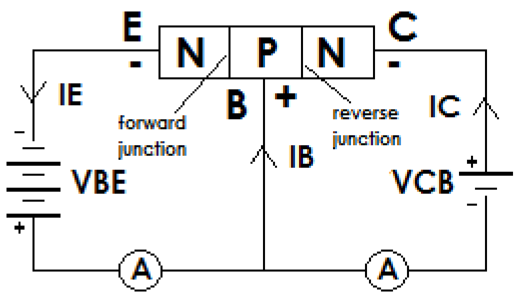
Consider the diagram below

Symbol Diagram:



npn

Block Diagram:



1. In the basic connection of NPN transistor, the emitter is forward biased since electrons are repelled from the negative emitter battery bias because electrons are flowing away from the

collector towards the positive collector battery terminal (**VCB**)

2. Elections are repelled from the negative terminal of **VBE** and injected into the emitter junction as emitter current (**I_E**), overcoming the potential barrier
3. Since the P region (base) is only **lightly doped** and **very thin**, most of the electrons diffuse or recombines through the base and reach the collector junction
4. A few electrons (about 5%) combine with the holes present in the P region
5. each electron that recombines with holes in bas region, another electron moves out through the base as base current *(**I_B**)* and returns to the emitter battery (**V_{BE}**)
6. The remainder (majority) cross into the collector region
7. the electrons move easily through the n-type material and return to the positive terminal of the collector supply battery (**V_{CB}**) as collector current (**I_C**)
8. Electron conduction thus takes place continuously in the direction shown as diagram above

Nb:

i The majority carriers of electricity in the NPN are electrons and PNP are holes

ii The collector current in any transistor is less than the emitter current because of the recombination of holes and electrons occurring in the base area

iii Since the electrons are more speedy carriers than holes, thus, NPN transistors are used in high frequency circuits where the carriers are required to respond very quickly to signals

iv transistor used in dc and ac signal

v emitter is always biased in forward direction

vi Collector is always biased in the reverse direction

vii The main difference between the PNP and NPN transistor is that, the current conduction NPN carried by electrons while the charge in PNP carriers by holes

Nb:

The base is thin and lightly doped, some electron recombine with holes to form neutral charge and fraction of electron cross to the collector. In order to compensate holes recombined with electrons at the base current IB is allowed to enter in it from power supply

From the diagram

IE = IB + Ic

But: IC = ∝ IE

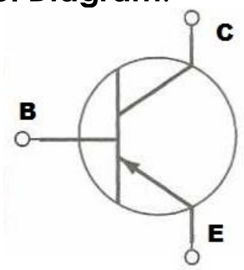
Where:

∝ = electrons fraction reaching the collector from emitter

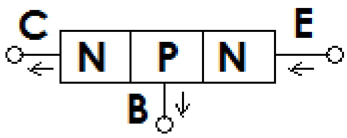
P-N-P Transistor

Defn: n-p-n transistor is the kind of transistor in which current emitter (I_e) point in.

Symbol Diagram:



Block Diagram:



NB:

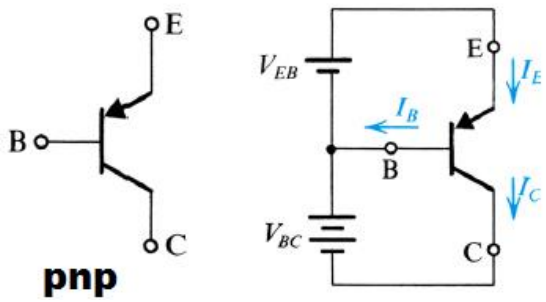
i. The arrow indicates the direction of flow of the conventional current

ii. p-n-p means **p**oint **in**

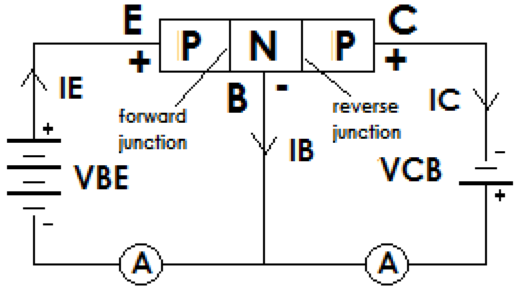
Operation/Mechanism of P-N-P Transistor

Consider the diagram below

Symbol Diagram:



Block Diagram:



i In the basic connection of PNP transistor, the emitter is forward biased since holes are repelled from the positive emitter battery bias because holes are flowing away from the collector towards the negative collector battery terminal (**VCB**)

ii holes are repelled from the positive terminal of **VBE** and injected into the emitter junction as emitter current (**I_E**), overcoming the potential barrier

iii Since the N region (base) is only **lightly doped** and **very thin**, most of the holes diffuse or recombines through the base and reach the collector junction

iv A few holes (about 5%) combine with the electrons present in the N region

v each holes that recombines with electrons in bas region, another holes moves out through the base as base current *(**I_B**)* and returns to the emitter battery (**V_{BE}**)

vi The remainder (majority) cross into the collector region

vii the holes move easily through the p-type material and return to the negative terminal of the collector supply battery (**V_{CB}**) as collector current (**I_C**)

viii holes conduction thus takes place continuously in the direction shown as diagram above

Nb:
The base is thin and lightly doped, in order to recombine with few holes from the emitter forming neutral charge and some holes cross to the collector. To compasate electrons at the base recombine with the holes from the emitter low current called base current IB is allowed to leave from the base so as to inlet electrons

From the diagram

IE = IB + IC

But: IC = ∝ IE

Where:

∝ = holes fraction reaching the collector from emitter

Why always NPN most used lather than PNP?

Most transistors in use today are n-p-n because the majority charge carriers are electrons which move faster that holes in p-n-p transistors which cause thermal energy (destruction of transistor by excess heat)

Uses of Transistors

Transistors are said to be the base elements of modern electronics. They are used in virtually all electronic devices such as **calculators**, **televisions**, **radios**, **computers**, etc. Transistors

i. It used in switching circuits
ii. It used in amplifier circuits
iii. It used in oscillator circuits
iv. It used in current source circuits
v. It used in voltage regulator circuits
vi. It used in power supply circuits
vii. It used in digital logic integrated circuits
viii. It used in any circuit that uses small control signals to control larger currents

Application of Transistor

There are two common uses of transistor

i. As an amplifier (electronic amplifier)
ii. As a switch (electronic switch)

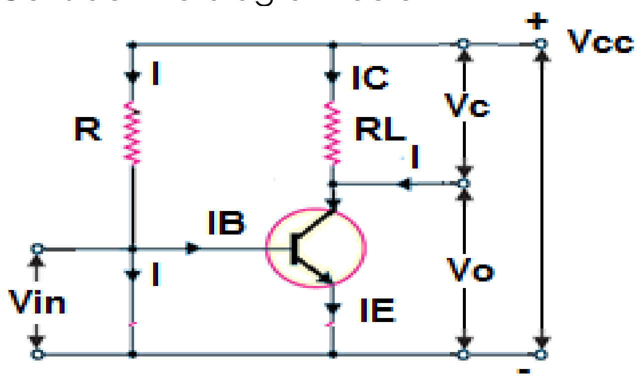
Transistor as Regulator/Amplifier/Active Mode

Defn: Electronic amplifier is the circuit that increases the amplitude of a given input

Or Electronic amplifier is the magnification of input signal

Simple Circuit Transistor as an Amplifier

Consider the diagram below



From the circuit diagram above

Vcc = IcRc + Vo

Vo = Vcc – IcRc

Where:
Vcc = power supply voltage
Vo = output voltage
Rc/RL = load resistance
Ic = collector current
IcRc = Vc = collector voltage

When input voltage Vin is low produce low a input current and output current as a result product IcRc become small and high output voltage Vo produced

Thus for the transistor to produce high output voltage the input voltage Vin should be very small approaching to zero i.e. Vin ≈ 0

From: 0 < Ic < Ic.max
Ib = (Vb - Vbe)/Rb
Ic = β x Ib
Vc = Ic x Rc
Vo = Vcc - Vc
0V < Vo < Vcc
Vo = Vcc – IcRc

When: Vin≈ 0, IB≈ 0 and Ic ≈ 0
Vo = Vcc – 0 x Rc = Vcc – 0 = Vcc
Vo = Vcc

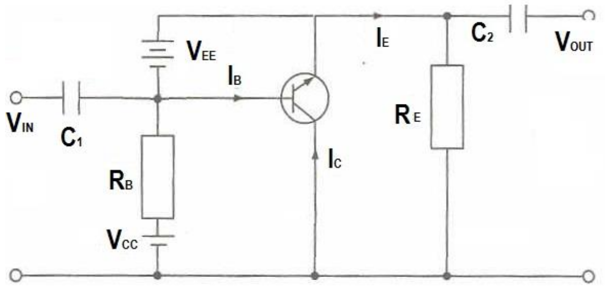
Types of Electronic Amplifiers
These are two types/classified according to the number of amplifying device includes
i. Single-stage amplifier
ii. Multi-stage amplifier

NB:
i. relationship between the input and output of an amplifier is called the **transfer function**
ii. The magnitude of the transfer function is referred to as the **gain**
iii. Amplifiers commonly used in **radio** and **television transmitters** and **receivers**, **stereo equipment**, **microcomputers** and **digital musical instruments**
iv. Transistors are commonly used as amplifying elements
v. In this section we will consider single-stage amplifiers only

Single-Stage Amplifiers
Defn: Single-stage amplifier is the type of amplifier in which consists only one amplifying device. It consists of transistor (amplification stage) which is connected to a load resistor through which a load current flows
.

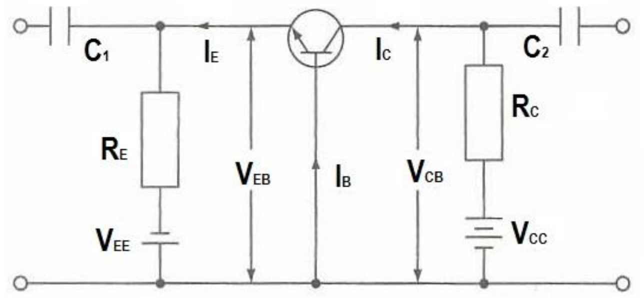
Types of Single-Stage Amplifiers
We have three types include
i. Common-collector (CC) amplifiers
ii. Common-base (CE) amplifiers
iii. Common- emitter (CE) amplifiers

Common-Collector Amplifier
The base terminal of the transistor serves as the input, the emitter the output, while the collector is common to both. The emitter-base junction is forward-biased by the power supply V_{EE} while the collector-base junction is reverse-biased by V_{CC}
Diagram:



Mechanism
i. The input signal is fed to the base-collector circuit while the output signal is tapped from the emitter terminal with respect to the ground
ii. C_1 and C_2 are coupling capacitors to provide Direct current isolation at the input and output of the amplifier

Common-Base Amplifier
The emitter terminal serves as the input, the collector as the output, and the base is common to both. The emitter-base junction is forward-biased by the power supply V_{EE} while the collector base junction is reverse-biased by V_{CC}
Diagram:



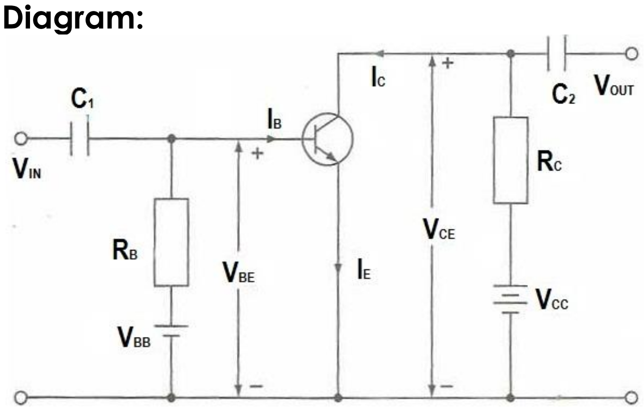
Mechanism

i. The input signal is fed to the emitter-base circuit while the output signal is tapped from the collector-base circuit
ii. C_1 and C_2 are coupling capacitors to provide Direct current isolation at the input and output of the amplifier

Common-Emitter Amplifier

The base terminal of the transistor serves as the input, the collector is the output, and the emitter is common to both. The emitter-base junction is forward-biased by power supply V_{BB} while the collector-base junction is reverse-biased by power supply V_{CC}

Diagram:



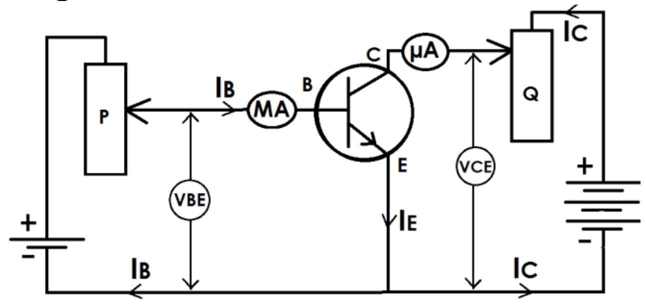
Mechanism

i. The input signal is fed to the base-emitter circuit and the amplified signal is tapped from the collector terminal with respect to the ground emitter circuit
ii. C_1 and C_2 are coupling capacitors to provide direct current isolation at the input and output of the amplifier

Nb: common emitter mode of arrangement are used

Common Emitter Characteristics Mode of Transistor

Common emitter is arrangement of transistor which the emitter is common to both collector and base. Consider the diagram below

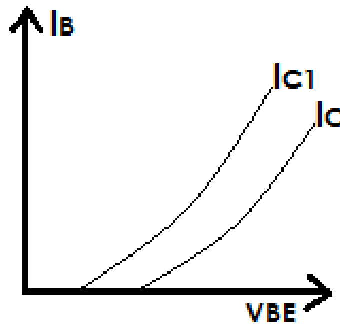


The transistor consists two circuit include input and output circuit in which the emitter is common to both base and collector of transistor

i. The input circuit made from input voltage VBE and base current IB
ii. Output consist output voltage VCE and collector current IC
iii. X and Y are power supply of voltage 1.5V and 4.5V respectively
iv. P and Q are rheostat which form potential divider
v. Base current IB and collector current are rewarded by using micro-ammeter and mill-ammeter respectively
vi. The voltmeter VBE is used to measure voltage between base and emitter (input voltage) and voltmeter VCE is used to measure voltage between collector and emitter (output voltage)

Input Characteristics Curve

It concerns the relation between base current IB and VBE at a constant collector current IC. Consider the diagram below



At very small value of VBE, base current IB is zero, further increase of VBE until overcomes barrier potential the base current IB flow

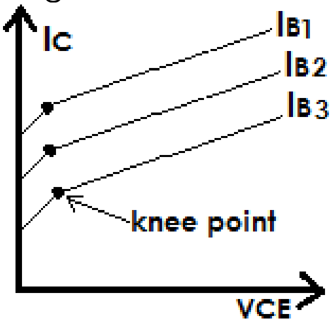
From the graph

Input resistance = $\frac{change\ in\ VBE}{change\ in\ IB}$

$$\textbf{Rin} = \frac{\Delta VBE}{\Delta IB}$$

Output Characteristics Curve

It concerns the relation between collector current IC and output voltage **VCE** at constant base current. Consider the diagram below



While base current IB is kept constant the potential divider Q is varies respect value of collector current IC and output voltage VBE are recorded

i. When current base is kept constant it produce collector current IC while output voltage VCE = 0
ii. Increase of VCE tends to increase IC up to knee point at which IC and VCE varies clearly. i.e. the output not distorted and the transistor act as amplifiers

From the graph above

Output resistance = $\frac{change\ in\ VCE}{change\ in\ IC}$

Ro = $\frac{\Delta VCE}{\Delta IC}$

Transfer Characteristics Ratio

It concerns relation between IB and IC. Experimentally shows that "IC = ∝ IB"

IC = ∝ IB

IC = KIB

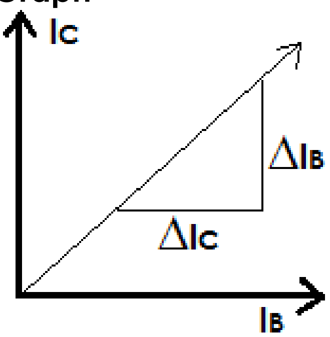
IC = KIB +0 - make comparison

| | |

Y = MX + C

Then: M = K, C = 0

Graph



From the graph

Slope M = $\frac{\Delta IC}{\Delta IB}$

M = $\frac{\Delta IC}{\Delta IB}$

But: M = K (proportionality constant called)

K = β = Current Gain

Then: $\beta = \frac{\Delta IC}{\Delta IB}$

$\boldsymbol{\beta = \frac{IC}{IB}}$

Current Gain

Defn: Current Gain is the ration of change in collector current to the change in base current **OR** is the a ratio of collector current to the base current

From: IC = ∝ IE – make IE subject

IE = $\frac{IC}{\propto}$ - - - - - - - - - - - - - - - - 1

Also: IE = IC + IB - - - - - - - - - - - - - - 2

Substitute equation 1 into 2

$\frac{IC}{\propto}$ = IC + IB

$\frac{IC}{\propto}$ - IC = IB

IC $(\frac{1}{\propto} - 1)$ = IB

IC $(\frac{1-\propto}{\propto})$ = IB

IB **=** IC $(\frac{1-\propto}{\propto})$

$\frac{IB}{IC}$ **=** $(\frac{1-\propto}{\propto})$ – inverse both sides

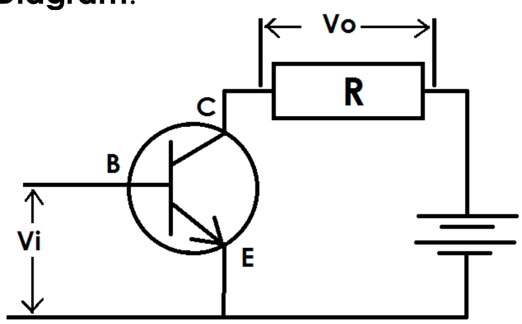
$\frac{IC}{IB}$ **=** $\frac{\propto}{1-\propto}$ **=** β

$\boldsymbol{\beta = \frac{\propto}{1-\propto}}$

Voltage Amplification

The transistor in the common emitter mode is an amplifier. To change the output (a.c) current to a voltage Vo (output voltage), a resistance load R can be used in the collector or output circuit

Diagram:



Voltage Gain

Defn: Voltage gain is the a ratio of output voltage to the input voltage

Mathematically

Voltage gain = $\frac{output\ Voltage}{input\ voltage}$

Vg = $\frac{Vo}{Vin}$ - - - - - - - - - - - - 1

But: Vo = IcRL - - - - - - - - - - - - - 2

Vin = IBRB - - - - - - - - - - - - - 3

Substitute equation 1 and 2 into 3

$$Vg = \frac{ICRL}{IBRB}$$

$$Vg = \left(\frac{IC}{IB}\right)\left(\frac{RL}{RB}\right)$$

But: $\beta = \frac{IC}{IB}$

$$\boldsymbol{Vg = \beta\left(\frac{RL}{RB}\right)}$$

Where: RL = load resistance (output)

Power Gain

Defn: power gain is the a ratio of output power to the input power

Mathematically

Power gain = $\frac{output\ power}{input\ power}$

$Pg = \frac{Po}{Pin}$ - - - - - - - - - - - - - 1

But: Po = ICVo - - - - - - - - - - - - - 2

Pin = IBVin - - - - - - - - - - - - - 3

Substitute equation 1 and 2 into 3

$$Pg = \frac{ICVo}{IBVin}$$

$$Pg = \left(\frac{IC}{IB}\right)\left(\frac{Vo}{Vin}\right)$$

$$Pg = \left(\frac{IC}{IB}\right)Vg$$

But: $\beta = \frac{IC}{IB}$ and $Vg = \beta\frac{RL}{RB}$

Then: $Pg = \beta.\beta\frac{RL}{RB}$

$$Pg = \beta^2\left(\frac{RL}{RB}\right)$$

$$\boldsymbol{Pg = \beta^2\left(\frac{RL}{RB}\right)}$$

Alternative:

$$Pg = \left(\frac{IC}{IB}\right)Vg$$

But: $\beta = \frac{IC}{IB}$

$$\boldsymbol{Pg = \beta\ Vg}$$

Example, : NECTA 2006 QN: 8

(a) (i) What is a diode? (ii) Make a sketch of the output voltage against time for half-wave rectification. Explain why the output flows in pulses

(b) Describe and explain how a full-wave rectification is achieved by using two diodes

Stabilization

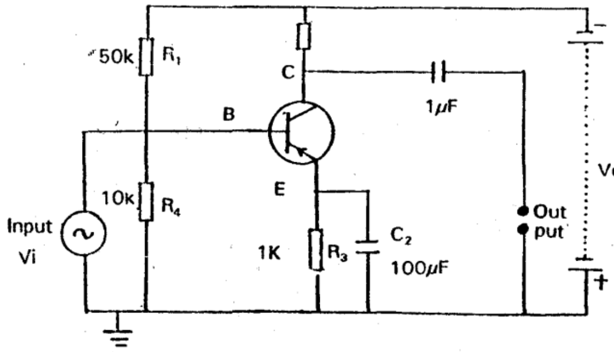
Defn: stabilization is the process of prevent a output from distort

How output distorted?

i. There is a leakage current which flows in the collector circuit due to minority carriers in the reverse bias
ii. At a temperature rise, say θ the leaked would increase the current by say I0μA. This would be amplified to β x IOμA
iii. This increase leads to a distorted output

How Stabilized?

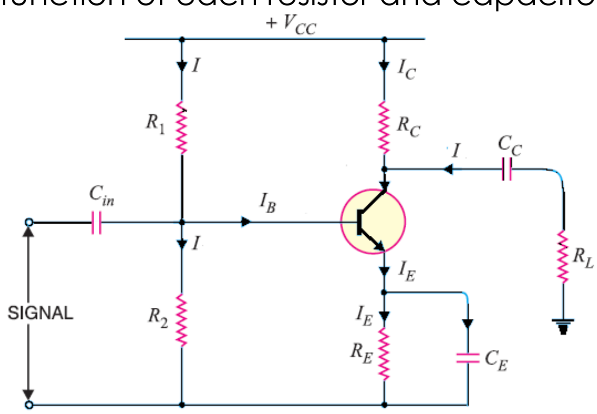
Consider the diagram below



i. For the common emitter arrangement there is a need to stabilize them for excessive temperature rise. Germanium and Silicon transistors are less sensitive thus preferred
ii. Resistors R1 and R4 are **potential dividers** which provide the base bias and R1 should be greater than R4
iii. Resistor R2 in the collector circuit produce the output voltage
iv. Resistor R3 is a **temperature stabilizer**: if the current in the collector increases, the current in R3 also increases where by decrease the voltage between the base and the emitter and hence the current in the collector is lowered automatically
v. The capacitor C1 isolates d.c. components in the circuit and it is of small value
vi. The large capacitor C2 prevents undesirable feedback of the amplified signal to the base-emitter circuit.

Example,

Study the diagram below and explain the function of each resistor and capacitors



Answer

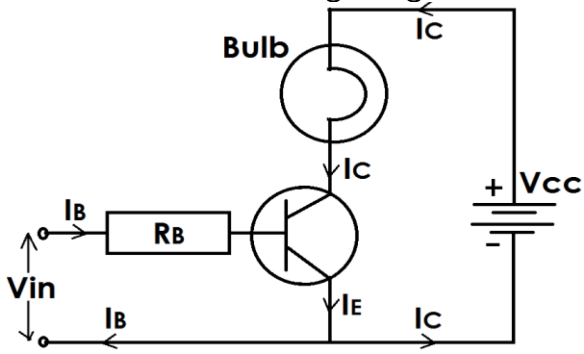
i. **Biasing circuit.** The resistances R_1, R_2 and R_E form the biasing and stabilization circuit. The biasing circuit must establish a proper operating point otherwise a part of the negative half-cycle of the signal may be cut off in the output
ii. **Potential divider.** The resistances R_1, R_2 are potential divider
iii. **Temperature stabilizes:** R_E is a temperature stabilizer. As collector current Ic increase the voltage between emitter and base decrease which is automatically lower the collector current
iv. **Load resistor.** Rc is used to control the output voltage
v. **The capacitor C_{in}:** it is used to couple the signal to the base of the transistor. If it is not used, the signal source resistance will come across R_2 and thus change the bias
vi. **The capacitor C_{in}** allows only a.c. signal to flow but isolates the d.c. signal source
vii. Emitters bypass capacitor C_E. ***An emitter bypass capacitor C_E is used in parallel with R_E to provide a low reactance path to the amplified a.c. signal. If it is not used, then amplified a.c. signal flowing through R_E will cause a voltage drop across it***, therefore prevent feedback of undesirable amplified voltage back to the transistor
viii. **Coupling capacitor C_C.** The coupling capacitor C_C couples one stage of amplification to the next stage. If it is not used, the bias conditions of the next stage will be drastically changed due to the shunting effect of R_C. This is because R_C will come in parallel with the upper resistance R_1 of the biasing network of the next stage, thereby altering the biasing conditions of the latter. ***In short, the coupling capacitor C_C isolates the d.c. of one stage to the next stage, but allows the passage of a.c. signal only***

Transistor as A Switching

Transistor can uses as an automatic switch as follows

Saturation and Cut Off

Consider the following diagram



Saturation (Switch - On)

Saturation means 0V and maximum collector current. The lamp light on when input voltage Vin is high producing high base and collector current

At saturation point Vo ≈ 0 since Vin is high producing high base current and results high collectors current and voltage of the power supply drops at the lamp/bulb

From: $Ic > Ic.max$

$Ic.max = Vcc/Rc$
$Ic = \beta\ Ib$
$Ic = Ic.max$
$Vc = Ic \times Rc = Vcc$
$Vo = Vcc - Vc = 0V$
$Vcc = IcRc + Vo$
$Ic = (Vcc - 0)/Rc$
$Ic = Vcc/Rc$

Cut Off (Switch - Off)

Cut off means zero collector current and collector voltage (V_C) equal to the supply voltage. When input is low produce low base and collector current and transistor to be at saturated point, the lamp will light off and transistor is said to be cut off.

At cut off Vo becomes maximum since Vin is low producing very small collector current and much voltage of power drops at the output voltage. Vo ≈ Vcc

From: $Vb < Vbe$

So: $Ib = 0A$
$Ic = 0A$
$Vc = Ic \times Rc = 0V$
$Vo = Vcc - Vc = Vcc$
$Vcc = IcRc + Vo$
$Ic = (Vcc - Vcc)/Rc$
$Ic = 0/Rc = 0$
$Ic = 0$

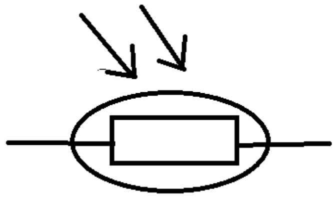
NB:

i. When a Transistor acts as a Switch is called a **Gate**
ii. Transistor in Active Mode it said to **Analog Electronics**
iii. Transistor in Cutoff/Saturation Mode it said to be **Digital Electronics**

Light Depent Resistor (LDR)

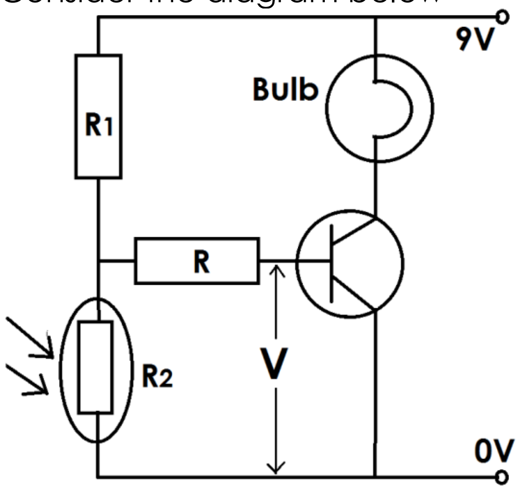
Defn: light depent resistor is a semiconductor device whose resistance depends on the light falling on it

Symbol



Mode of action of LDR circuit

Consider the diagram below



The resistance R_1 and R_2 form potential divider with Vcc

During a day

In day light of free holes and electrons capable to conduct electricity and thus the resistance of LDR become low

In the presence of light the resistance, R2 of LDR becomes low so produce low input voltage, V results small input current, IB which creates low output current, IC which is not sufficient to light lamp, L

During night

In darkness the LDR has high resistance since there is no thermal excitation of electrons to produce free holes. Thus in the LDR there is no free charge carrier to conduct electricity.

In the absence of light the resistance, R2 of LDR becomes high so produce high input voltage, V results large input current, IB which creates high output current, IC which is sufficient to light lamp, L

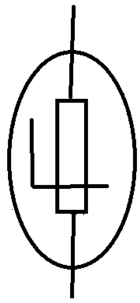
Used Of LDR

Used to switch on or switch off automatically street lamp

Thermistor

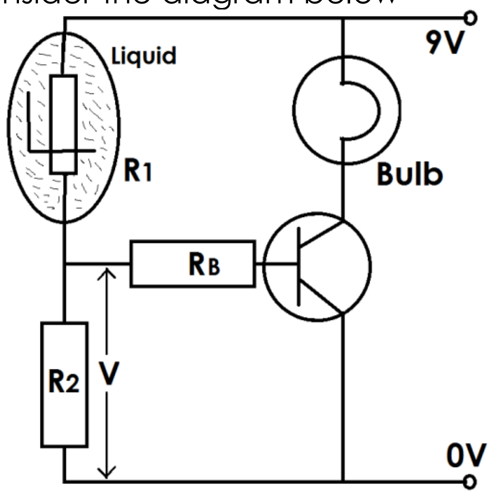
Defn: Thermistor is semiconductor device whose resistance depends on thermal energy

Symbol



Mode of Action of Thermistor

Consider the diagram below



At room temperature

The resistance of Thermistor becomes high and much voltage of power supply drops across it and result low input voltage, V across R2 producing low output current, Ic which is not sufficient to light the lamp

At maximum temperature

The resistance of Thermistor becomes low and much voltage of power supply drops across it and result high input voltage, V across R2 producing high output current, Ic which is sufficient to light the lamp

Used Of Thermistor

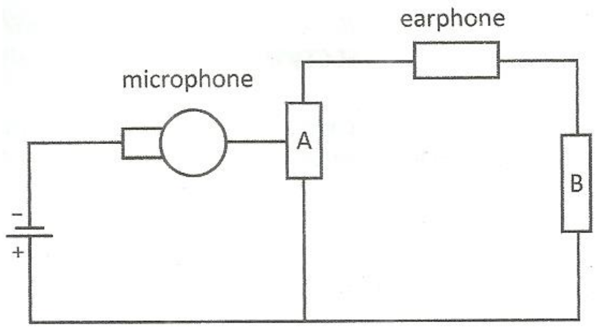
Used to control maximum temperature of hot liquid

Example, : Form IV NECTA 2002 QN: 10 SECT. C

(a) Explain how an extrinsic semiconductor is constructed

(b) Describe the model of action and application of PN junction diode

(c) The diagram below shows a circuit in which important components A and B are removed



Answer the following questions

i. What does A and B represents?
ii. Describe briefly the purpose of component A and B
iii. Draw a well labeled circuit diagram for the circuit above

Integrated Circuit (IC)

Defn: An integrated circuit (IC) is a combination of several resistors and transistors which are built out of the same crystal. Two or more transistors can be joined together to increase the amplification

Nb:

i. The resistors and transistors which make up the circuit of the IC are built out of the same crystal of silicon
ii. The ICs are very tiny components assembled by machines

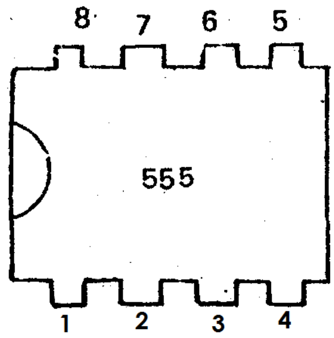
Type of Integrated Circuit

There various types of integrated circuit but will study One type of integrated circuit called **555 integrated circuit**

Integrated circuit of 555

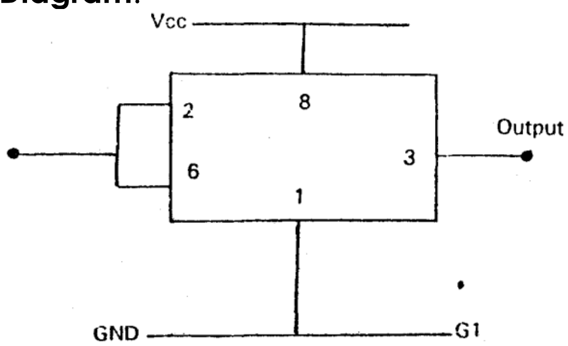
The 555 is a small black plastic package which has eight metal legs four on each side coming out of it. The legs allow electrical connections to be made to the circuit which is etched onto a slice of silicon at the centre of the plastic

Diagram:



Pins of 555 Integrated circuit

i. **Power supply Pins**
   Pins 1 and 8 are used for power supply where the ground and live connections are made respectively
ii. **input terminal Pins**
   Pin 2 and 6 are joined to the input terminal
iii. **output terminal Pins**
   Pin3 is the output terminal.
iv. Pins 4, 5 and 7 may not be connected to anything
   Diagram:



Transistor Operating Modes

The Transistor has 3 operating modes includes

1. Cut-off
2- Saturation (Switch - ON)
3- Active (Regulator)

1. **Cut-off Mode**

$V_b < V_{be}$ (Generally 0.7V)

So: $I_b = 0A$

$I_c = 0A$

$V_c = I_c \times R_c = 0V$

$V_o = V_{cc} - V_c = V_{cc}$

2. **Saturation Mode**

$I_c > I_{c.max}$

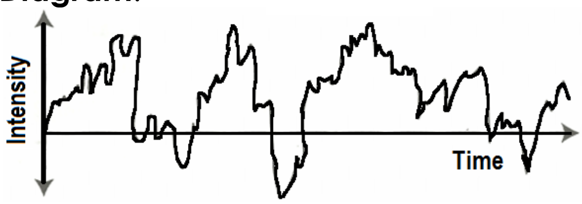
$I_{c.max} = V_{cc}/R_c$

$Ic = \beta\ Ib$
$Ic = Ic.max$
$Vc = Ic \times Rc = Vcc$
$Vo = Vcc - Vc = 0V$

3. **Active Mode**
$0 < Ic < Ic.max$
$Ib = (Vb - Vbe)/Rb$
$Ic = \beta \times Ib$
$Vc = Ic \times Rc$
$Vo = Vcc - Vc$
$0V < Vo < Vcc$

Information Signals
Information is usually transmitted in electronic devices in form of signals. Information signals are divided into two broad classes, namely
- i. Analogue signals
- ii. Digital signals

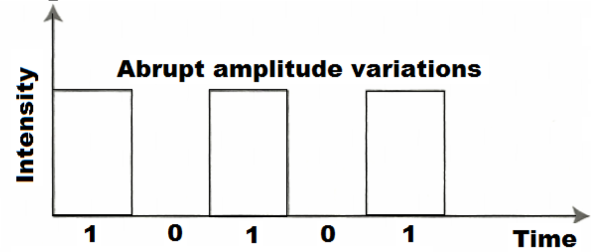
Analogue Signals
Analogue signals are electrical signals that convey or store information by means of variation in a *continuous* wave form
Diagram:



Electrical signals may represent information by changing factors such as their voltage, current, frequency or total charge. The information is converted from some physical form (such as sound, light, temperature, pressure) to an electrical signal by a device known as a **transducer**

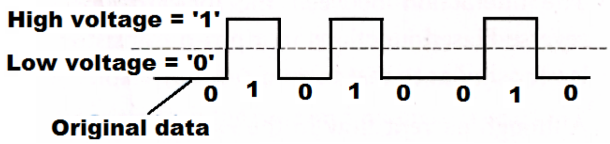
NB:
- i. **Defn:** transducer is a device that converts an input signal of one form into an output signal of another form
- ii. The signals take any value from a given range, and each unique signal value represents different information
- iii. Any change in the signal is meaningful, and each level of the signal represents a different level of the phenomenon that it represents
- iv. Example, s of analogue signals are **Mechanical**, **pneumatic**, **hydraulic** and other systems may also use

Digital Signals
Digital signals Analogue signals are electrical signals that convey or store information by means of variation in anon-continuous wave form
Diagram:



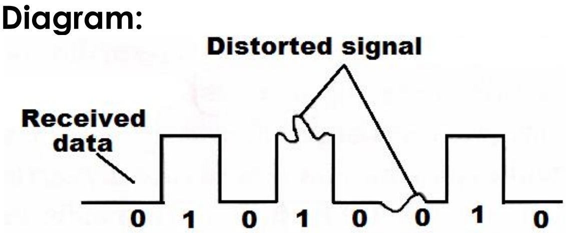
- i. It changes in steps. They convey information in pulses or digits of two discrete levels. This means that the value of each pulse is constant and moving from one digit to the next is an abrupt change
- ii. Digital signals have only two amplitude levels, usually called **nodes**. This means the values can only be given in one of two ways. The values may be specified, for Example, , as **1** or **0**,**TRUE** or **FALSE**, and **HIGH** or **LOW**
- iii. Digital signals are often derived from analogue signals
- iv. The main advantage of digital signals over analogue signals is that the signal level or value need not be precise
- v. It can be approximated within a fixed number of **digits** or **bits**
- vi. The process of approximating the precise value within a fixed number of digits is called **quantization**

  Diagram:



- vii. Signal can be distorted during transmission can still read correctly

  Diagram:



Elemental astronomy

The word astronomy is derived from two Greek words: **astron** for **"star"** and **Nomo's** for **"law"**. The people who study and specialized in astronomy are known as **astronomers**

Astronomy

Defn: Astronomy is the study of the universe and celestial bodies.

Or

Defn: Astronomy is the branch of science that deals with study of the origin, evolution, composition, distance and the motion of all bodies (objects) and scattered matters in the universe.

Universe

Defn: Universe is all of the space and everything in it

Or

Defn: Universe is the totality of space and time together with matter and energy.

Geocentric Theory

Geocentric theory was the theory based on religious beliefs, observations and common-sense. This theory state that

There was no direct evidence to suggest that the earth is in motion. The other bodies, like the sun, were observed to be in motion across the sky

Heliocentric Theory

Heliocentric theory was based on the position of the sun relative to the earth in which the sun and not the earth was stationary at the centre. This theory state that

i. ***All other heavenly bodies including the earth moved around the sun in circular orbits while rotating about their own axes.***
ii. ***The earth was just one of the six known planets that circled the sun.***
iii. ***The heliocentric theory could explain convincingly the occurrence of day and night***

Advantages of Learning Astronomy

The following are the ways in which astronomy is important

1. It was used to develop calendars that made it possible to predict the seasons. The seasons were very important in agriculture as they detected the planting time and the harvesting time
2. It was the earliest method of measuring time
3. Astronomy helps to present a new frontier for exploration.
4. Used in both land and sea navigation based on the knowledge of the position of the sun during the day and stars at night
5. Today, astronomy helps us to understand the position of the earth and the origin of the life it supports and how it is evolved.

Solar System

Defn: The solar system is the collection of heavenly bodies that revolve around the sun.

Composition of Solar System

This consists of **dwarf planets**, **eight planets** and their **moons**, as well as **asteroids**, **comets** and **meteors**.

NB:

i. Astronomers uses their unit called **astronomy unity** abbreviated as **AU**
ii. $1AU = 1.4960 \times 10^{11}m$
iii. Solar system objects such as planets, moons and comets are bright enough to be visible through binoculars and small telescopes

Stars

A star is a large celestial body made up of hot gases known as plasma.

Plasma refers to an ionized gas in which a certain proportion of electrons are free rather than bound to an atom or molecules. Stars radiate energy derived from the thermonuclear reactions in the interior region. The sun is the largest star.

Galaxy

Galaxy is a giant collection of stars, gas and dust. Most of stars in the universe are in the galaxies.

Milky Way

Milky Way is the group of galaxy in which the sun belongs to one of these galaxies. Nearly all of the stars visible in the night sky are within our galaxy, the **Milky Way**.

Planets

A planet is a major (large) object which is in its orbit around a star (sun). The planets revolve around the sun. They are held in orbit by the gravitational pull of the sun. Planets do not give their own light, but rather reflect the sun's light. These planets are

i. Mercury
ii. Venus
iii. Earth
iv. Mars
v. Jupiter
vi. Saturn
vii. Uranus
viii. Neptune

Characteristics of Planets

It have the follows characteristics includes

i. It must orbit the Sun.
ii. it must be big enough for gravity to compress it into spherical form
iii. It has a cleared the neighbourhood around its orbit. To clear an orbit, a planet must be big enough to have sufficient gravitational force that can pull all neighboring objects and material into the planet itself

Dwarf Planet

Defn: dwarf planet is a celestial body orbiting the Sun that is massive enough to be rounded by its own gravity but has not cleared its neighbouring region and hasn't satellite. We have about four dwarf planet include

i. Ceres
ii. Pluto
iii. Makemake
iv. Eris

Satellite

Satellite is the celestial body that revolves around the planets. Example, moon

Types of Satellite

There are two types includes

i. Natural satellite
ii. Artificial satellite

Natural Satellite

Natural satellite is the natural celestial in which revolves around the planet. Example, moon

Artificial Satellite

Artificial satellite is the natural man made satellite and spacecraft that orbit the planet. Example, **moon**

Difference between Stars and Planets

1. Stars emit their own light while planets do not emit their own light
2. Stars twinkle at night while planets do not twinkle at night
3. Stars appear to be moving from east to west while planets move around the sun from west to east
4. The temperatures of stars (eg sun) usually very high while that of planets depend on their distances from the sun
5. Stars are countless in number while the planets are eight in number in the solar system
6. Stars are very big in size but appear small because they are very far away while planets are very small in size as compared to star
7. Star is in gaseous form while planets is in solid form

Solar System Zones

The Solar system is sometimes divided into three separate zones, namely

i. Inner planets
ii. Asteroid belt
iii. Outer planets

Inner Planets

The inner planets consist of the four planets that orbit closest to the Sun. They are composed largely of minerals with high melting points, such as the silicates which form their crusts and mantles, and metals such as **iron** and **nickel**, which form their cores. Inner planets includes

i. Mercury
ii. Venus
iii. Earth
iv. Mars

Characteristics of Mercury

i. closest to the Sun (distance 0.4 AU))
ii. smallest planet
iii. rocky and dense
iv. no natural satellites

Characteristics of Venus

i. Close in size to the Earth (0.815 Earth masses)
ii. Superficially similar in composition to the Earth, but it is much drier than the Earth
iii. Hottest planet, with surface temperatures over 400 °C
iv. Rocky and dense
v. Volcanically active
vi. No natural satellites
vii. 0.7 AU distance from the sun

Characteristics of Earth

Largest and densest of the inner planets
The only known planet to have current geological activity
The only planet known to have life
Volcanically active
Moderate atmosphere
Has a large natural satellite
1.0 AU distance from the sun

Characteristics of Mars

i. Lowest density terrestrial world
ii. Thin atmosphere
iii. Seasonal weather/ice caps
iv. Extinct volcanoes
v. Have two tiny natural satellites
vi. 1.5 distance AU from the sun

Asteroid Belt

The main asteroid belt occupies the orbit between Mars and Jupiter, between 2.3 and 3.3 AU from the Sun. Hence, the main Asteroid belt is a wide and very thin belt 1 AU wide and 0.0002 AU thick. The asteroid belt contains tens of millions of objects over one kilometer in diameter.

Asteroids

Asteroids: are masses of stone of different sizes which are the resulting particles of a planet that used to lie between mars and Jupiter, but ultimately broke into pieces due to strong gravitational force between mars and Jupiter

Nb:

i. Asteroids are of different sizes and shapes
ii. Asteroids range in size from hundreds of kilometres across to microscopic
iii. Asteroids are mostly small Solar system bodies composed mainly of rocky and metallic non-volatile minerals

Meteors

Meteors or shooting stars are objects/asteroids from the asteroid belt pulled towards the Earth by the gravitational pull of the planets, which strike the Earth and burn in the atmosphere

Nb:

i. meteorites are asteroids which are not burnt up completely and manage to reach the earth
ii. meteorites consists **iron** and **nickel**
iii. incandescence due to friction with air from its rapid motion
iv. Asteroid that struck the Earth's atmosphere is called **meteoroid**
v. In Tanzania a 16 ton piece of meteorite found at Mbozi Mbeya called **Mbozi meteorite**

Outer Planets

These planets make up 99 percent of the mass known to orbit the Sun. Jupiter and Saturn consist largely of hydrogen and helium while the bulk of Uranus and Neptune consist of 'ices', such as water, ammonia and methane. Outer planets includes

i. Jupiter
ii. Saturn
iii. Uranus
iv. Neptune

Characteristics of Jupiter

i. Largest planet
ii. Low density
iii. Long term weather patterns
iv. Have sixty known satellites
v. 5.2 distance AU from the sun

Characteristics of Saturn

i. Second to Jupiter

ii. Spectacular ring system
iii. Have sixty known satellites
iv. 9.5 distance AU from the sun

Characteristics of Uranus

i. Tilted system
ii. Lightest of the outer planets
iii. Have twenty seven known satellites
iv. Much colder core than the other planets
v. 19.6 distance AU from the sun

Characteristics of Neptune

i. Slightly smaller than Uranus
ii. Radiates more internal heat, but not as much as Jupiter or Saturn
iii. Have thirteen known satellites
iv. 30.0 distance AU from the sun

Kuiper Belt

Kuiper belt is a wide region extends to 50 AU from the Sun which contains thousands of small bodies including hundreds of dwarf planets that are yet to be discovered

Nb:

i. Many more (hundreds to thousands) dwarf planets are thought to exist in the Kuiper Belt
ii. Kuiper belt objects consist of frozen gases such as methane, ammonia and ice. When they are attracted towards the Earth by gravitational pull of planets, they appear as **comets**
iii. When comets evaporate upon coming near the Sun, their dust forms long tail characteristics of comets
iv. Comets are also originate from even further out at the edges of the solar system about 100,000 AU from the Sun, where there is thought to be a spherical cloud called the **Oort cloud** which contains icy dust objects
v. Comets have extremely eccentric (elliptical egg shaped) orbits and reappear sometimes after decades

Comets

Comets: is a small icy celestial body that revolves around the sun. It travelling masses visible as points of light that brighten suddenly (glowing asteroids) and they can often be seen by naked eyes. They stop glowing once the gaseous materials are all burnt off or when they are once again far away from the sun

Gravitational Force

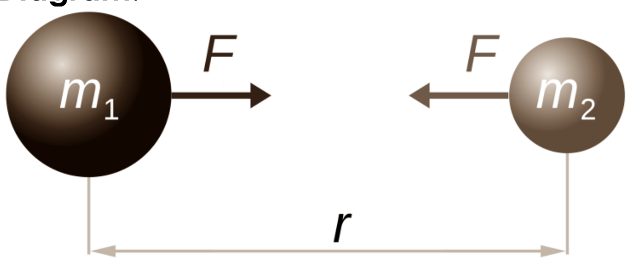
Defn: Gravitational force is the attractive force existing between any two objects that have mass

Newton's Law of Gravitation

Every single point mass attract every other point mass by a fore directed along the line joining the two masses. The law States that

"***Any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them***"

Diagram:



Mathematically:

F α $(M_1 \times M_2)/r^2$
F = $K(M_1 \times M_2)/r^2$

Where:

K= G = Universal gravitational constant
F = $G(M_1 \times M_2)/r^2$

$$F = G\frac{m_1 \times m_2}{r^2}$$

Where:

F = universal gravitation
M1 = is the mass of first point mass
M2 = is the mass of second point mass
r = distance between two point masses

NB:

i. Gravitational force actual very weak force due t too weak pull of felt between two point masses' between
ii. Hug gravitational force of nearest star, the sun, holds together the eight planets of the solar system
iii. Planet moves in the space at speed that just balance the sun's gravitational pull results moves in permanent orbit around the sun

iv. Satellite, and spacecraft orbit the earth due to speed that just balance the earth's gravitational pull results moves in permanent orbit around the earth

Gravity

Gravity is the gravitational force that occurs between objects toward the earth. This is the force that holds us on the ground and cause object to fall back to the ground after being thrown up in the air. Earth's gravitational force decrease as you move away from the earth's gravitational force.

NB:

i. Gravity on object is the weight of that object
ii. The weight change depending on the position as gravitation force

Constellations

Defn: constellation is a group of stars that form a definite shape or pattern when viewed from the earth

Or

Defn: constellation is small groups of bright stars that form patterns in the sky which resemble familiar animals and objects on the earth. Some of known constellations are:

LEO, **IRON**, **SCORPIO**, **URSA MAJOR**, **CORPUS**, **CANIS MAJOR**, **PISCES, GEMIN** and the **SOUTHER CROSS**

Note: There are about 88 known constellations.

Types of the Constellations

There are two types includes

i. Circumpolar constellations
ii. Seasonal constellations

Circumpolar Constellations

Circumpolar constellations are seen all year round in the night sky for observers in high northern or high southern latitudes because of the rotation of the Earth

Seasonal Constellations

Seasonal constellations are the constellations that appear at some time of the year and are not seen at other times of the year. in Tanzania and in central Africa are close to the equator so we do not see any circumpolar stars or circumpolar constellations. Hence all the constellations that we see in the Tanzanian night sky are seasonal constellations

Significant Of Constellation

The study of the constellation is important since they are used by the man from ancient times up to the present.

i. Constellations help to determine seasonal progress and therefore facilitate planning the course of activities according to the position of constellations in the sky
ii. Where proper calendar people where uses constellation to determine when sow or harvest by star
iii. Constellations also used in navigation.

The Earth

Defn: Earth is a third planet that moves in a circular orbit around the sun, held on orbit by gravitation force.

Properties of the Earth

i. largest and densest of the inner planets
ii. the only known planet to have current geological activity
iii. Has diameter of 6371 km
iv. the only planet known to have life
v. volcanically active
vi. moderate atmosphere
vii. has one large moon
viii. 1.0 AU distance from the sun

Earth's Moon

Defn: moon is a natural satellite that moves in a circular orbit around the earth, held on orbit by gravitation force.

Properties of Earth's Moon

i. The moon's gravitation field is one sixth of the earth's field (**g_{moon} = 1.6N/Kg**)
ii. It takes 27.3 days to revolve around the earth. This period called **sidereal month**
iii. It sixth largest in the solar system
iv. Has diameter of 3476 km
v. Has mass of 7.35×10^{22}kg
vi. Moon's orbit is titled at 5^0 relative to the earth orbit around the sun

vii. Moon Surface temperature are on the average of 107⁰C during the day and -53⁰C during night
viii. Has non molten iron core so its haven't magnetism
ix. Iron core is surrounded by a rocky mantle and crust
x. It revolves in an anticlockwise direction around the earth

Nb:
i. Moon has no atmosphere
ii. The side facing/near the earth is called **near side**
iii. The side far/faces away the earth is called **far side**

Earth's Moon Surface Features
There are two primary types of terrain on the moon, include the following
i. Lunar highlands
ii. Maria

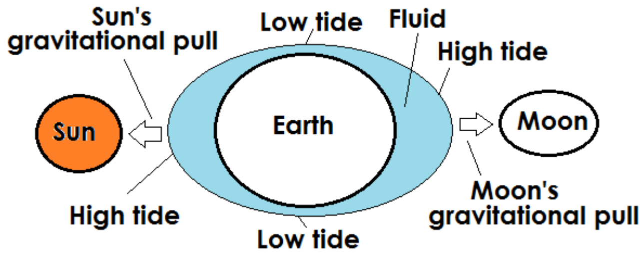
Lunar Highlands
Lunar highlands Is an oldest part of the moon's surface. A lunar highland is the bright area viewed with unaided eye. It consists;
i. **Craters** caused by impact of meteorites. The young craters are often surrounded by lines of splash material
ii. **Mountains** rise up to 5km high

Maria
Maria is Italian word Means Sea. Maria is the dark area viewed with unaided eye. It causes by hug impact craters that were later flooded with molten lava. Most of Maria is covered with regolith, a mixture of fine dust and rocky debris produced by meteor impact

Ocean Tides
Defn: Tides energy is the rising and falling of the ocean level

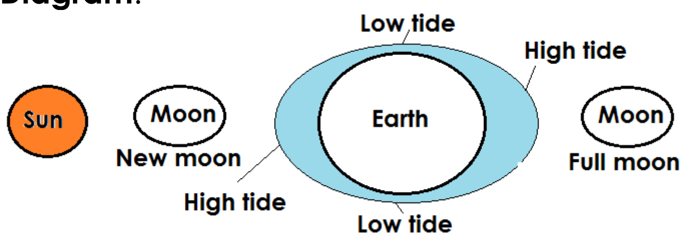
Causes of Ocean Tides
It causes by the gravitational pull of the moon and to some extent the sun

How Ocean Tides Occurs
Due to different in gravitation force the earth pull the moon to keep in orbit also the moon pull the earth and the sun pull the earth to keep in orbit also the earth pull the sun. This attraction tends to pull earth's fluid (gas and liquid especial in ocean) results rising and falling of the ocean level. As the earth rotates each of the earth gets two high tides and two low tides each day.
Diagram:



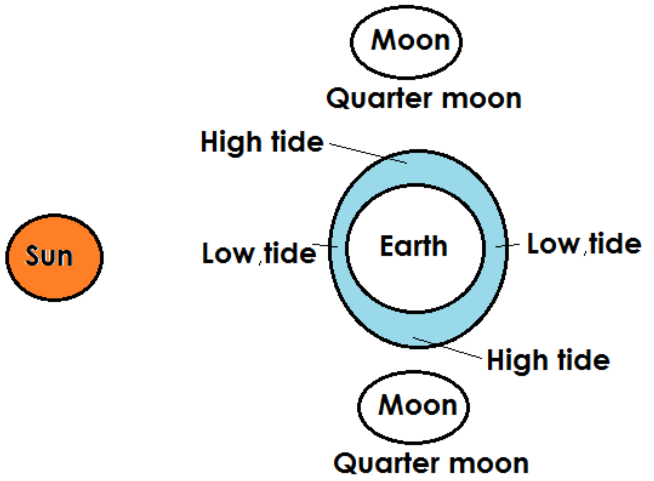
Types of Ocean Tides
i. Spring Ocean tides
ii. Neap Ocean tides

Spring Ocean Tides
Spring tides occur when there is a new moon or full moon. At that time the sun, moon and earth are in straight line. It is strong tides
Diagram:



Nb:
i. Rare unusually high tide may occur due to unusually close of moon to the earth
ii. This spring tide is called **Proxigean spring ocean tides**
iii. Proxigean spring ocean tides occurs at most once every 1.5 years

Neap Ocean Tides
Neap tides occur when there are a quarter moons. At this time, the sun and the moon are pulling at right angles to each other causes its gravitational forces to cancel each other. It weaker tides
Diagram:



Advantage of Tides

i. During high tides the water level in the harbour rises, with the result that bigger ships can be moved into harbour and unloaded
ii. The high tides clear the sea shore from garbage, etc
iii. High tides at suitable places are used for generating electricity

Example, : NECTA form IV 2010: QN 05

(a) (i) Define the term astronomy and asteroids
(ii) Is scorpion a galaxy or constellations? Give reason(s) for your answer

(b) Distinguish between
i. Planet and star
ii. Comet and meteor

(c) Which planet in the solar system is
i. Closest to the sun? (**mercury**)
ii. Furthest from the sun? (**pluto**)
iii. Closest to the earth? (**venus and mars**)
iv. Surrounded by ring? (**saturn**)
v. The second largest planet? (**saturn**)

Questions

1. What is solar system?
2. How many known planets are there in our solar system? Name them.
3. Why is Pluto not a planet as it used to be?
4. Which is the largest planet in our solar system?
5. Which planets in the solar system have satellites?

Geophysics

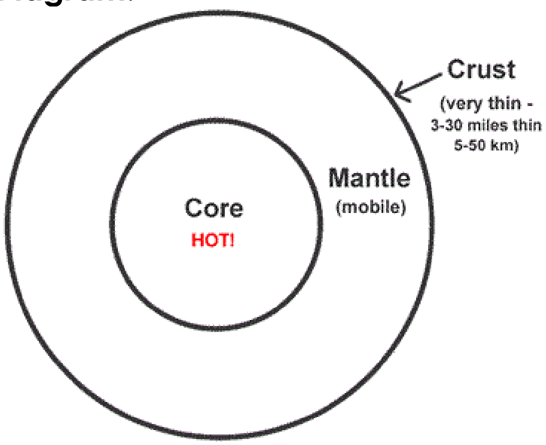
Defn: Geophysics is the scientific branch deals with physical, chemical, geological, astronomical and other characteristic properties of the earth

Interior Structure of the Earth

The Interior earth structure is divided into three zones namely

i. Earth's Core
ii. Earth's Mantle
iii. Earth's Crust

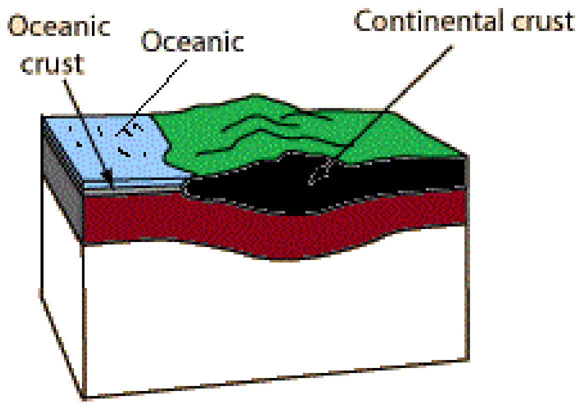
Diagram:



Earth's Crust

Earth's Crust is outer solid layer of the earth. It divided into two layers

Diagram:



Continental Crust

Continental crust is heterogeneous with low density about 2 – 2.8 tonnes per cubic metre. It mainly composed by granites and sedimentary rocks. Land mass and mountains located at continental crust. Continental crust that underlies the continent

Oceanic Crust

Oceanic crust is basalts with high density about 3 – 3.1 tonnes per cubic metre. Oceanic crust that underlies the ocean basins

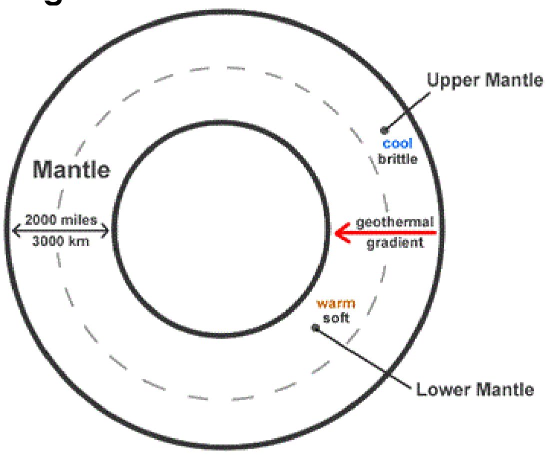
Nb:

i. The low density of the thick continental crust allows it to "float" in high relief on the much higher density mantle below
ii. The boundary which separate crust and mantle is called (**Moho**) **Mohorovicic discontinuity**

Earth's Mantle

Earth's Mantle is starting from Moho and extended to a depth of 2900km below the earth surface to boundary to core. It divided into two layers

Diagram:



Upper Mantle

Rocks in the upper mantle are cool and brittle,

Rocks in the lower mantle are hot and soft (but not molten). Rocks in the upper mantle are brittle enough to break under stress and produce **earthquakes**

Lower Mantle

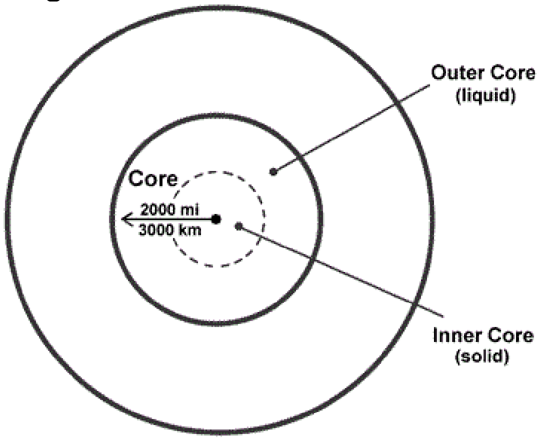
Rocks in the lower mantle are soft and flow when subjected to forces instead of breaking.

Nb:

i. The boundary separate core and mantle is called **Gutenberg discontinuity**
ii. Mantle contains about 70% of the earth's mass
iii. It made by plastic rocks (both in solid and molten state)
iv. Upper part of mantle has a temperature of about 870^{0}C

v. lower part of mantle has a temperature of about 2200^{0}C
vi. The lower limit of brittle behavior is the boundary between the upper and lower mantle
vii. This steady increase of temperature with depth is known as the **geothermal gradient**
viii. The heat energy is the source of force cause continental movement like volcanism and earthquakes

Earth's Core
Earth's Core is the innermost part of the earth. It extends from Gutenberg discontinuity to earth's geometric center. It composed mainly of an iron and nickel alloy. It divided into two layers
Diagram:



Outer Core
Outer core is a liquid (magma) because the temperatures there are adequate to melt the iron-nickel alloy.

Inner Core
Inner core is a solid even though its temperature is higher than the outer core. Here, tremendous pressure, produced by the weight of the overlying rocks is strong enough to crowd the atoms tightly together and prevents the liquid state

Nb:
i. The core is earth's source of internal heat because it contains radioactive materials which release heat as they break down into more stable substances
ii. It have high density

Atmosphere Structure
Defn: atmosphere is the gases layers contain numerous small suspended solid and liquid particles. The dense part of atmosphere lies within 30 km above the earth's surface.

Regions of Atmosphere
Atmosphere is divided into regions based on its **thermal characteristics** (temperature changes), **chemical composition**, **movement** and **density** .Therefore there are five regions includes
i. Troposphere region
ii. Stratosphere region
iii. Mesosphere region
iv. Thermosphere region
v. Exosphere region

Troposphere Region
Troposphere region is the region nearest to the earth. It extends to an altitude of up to 10 km above the poles and 20 km above the equator.

Nb:
i. This region is the densest part of the atmosphere. It contains 80% by mass of the atmosphere. It contains most of the atmosphere's water vapour
ii. The temperature in this region decreases with altitude at an average rate of 6°C/km
iii. Air molecules can travel to the top of the troposphere and back down again in just a few days. This mixing encourages changing weather
iv. Most weather phenomena occur in the troposphere. **Clouds** and **rain** are formed within this region
v. Boundary separates the troposphere and the stratosphere is called the **tropopause**
vi. Temperatures stop decreasing with height and become constant

Stratosphere Region
Stratosphere region starts from the tropopause and extends to 50 km high.

Nb:
i. This layer is more stable, drier and less dense compared to the troposphere.

The temperature in the stratosphere slowly increases with altitude

ii. Temperature increase due to the presence of the **ozone layer** which absorbs ultraviolet rays from the sun. The ozone layer lies in the middle of the stratosphere between 20 and 30 km. Ozone is a **triatomic** (three-molecule) form of oxygen
iii. This layer plays the important role of absorbing ultraviolet radiations which would otherwise reach the earth's surface
iv. Ultraviolet radiation is harmful to both animal and plant life on earth
v. The stable air of the stratosphere also prevents large storms from extending much beyond the tropopause
vi. Planes also fly in the stratosphere. This is because it has **strong steady horizontal winds** which are above the stormy weather of the troposphere
vii. Troposphere and stratosphere are collectively known as the **lower atmosphere**
viii. Boundary separates the stratosphere and the other layer is called **stratopause**

Mesosphere Region

Mesosphere region starts just above the stratosphere and extends to 85 km high

Nb:

i. Temperature at this layer decreases with altitude. The lowest temperature of the atmosphere (-90°C) occurs within this region
ii. mesosphere is the layer in which most meteors burn while entering the earth's atmosphere
iii. Boundary separates the mesosphere and the thermosphere is called **mesopause**

Thermosphere Region

Thermosphere region starts just above the mesosphere and extends up to 690 km high

Nb:

i. temperature increases with increasing altitude due to the sun's heat
ii. The temperature in this region can go as high as 1 727°C
iii. Chemical reactions occur much faster here than on the surface of the earth.
iv. This layer is also known as the **upper atmosphere**
v. The lower part of the thermosphere, from 80 to 550 km above the earth's surface, called **ionosphere**
vi. This region containing a high concentration of charged particles called **ions** and **free electrons**
vii. The large number of free electrons in the ionosphere allows the propagation of electromagnetic waves
viii. Ionosphere also absorbs dangerous radiation. The radiation absorbed in the ionosphere includes **hard and soft X-rays** and **extreme ultraviolet (EUV) radiation**.

Important Of Ionosphere

The ionosphere plays an important role in **communications**. Radio waves can be reflected off the ionosphere allowing radio communications over long distances

Exosphere Region

Exosphere region is the outermost region of the atmosphere

Nb:

i. Atmospheric gas pressure is very low. Light atoms such as hydrogen and helium may acquire sufficient energy to escape the earth's gravitational pull
ii. The upper part of the exosphere is called **magnetosphere**. The motion of ions in this region is strongly constrained by the presence of the earth's magnetic field
iii. This region satellites orbit the earth

Importance of the Atmosphere

The following are some ways in which the layers of the atmosphere are important:

i. The troposphere controls the climate and ultimately determines the quality of life on the earth
ii. The troposphere is important for life on the earth. The layer contains gases which include

a. **Oxygen** which is used for respiration by animals
b. **Carbon dioxide** which is used by plants in photosynthesis
c. **Nitrogen** found in this layer also provides an inactive environment for many chemical processes to take place
d. Gases also support many important chemical processes such as **combustion**, **weathering** and **oxidation**

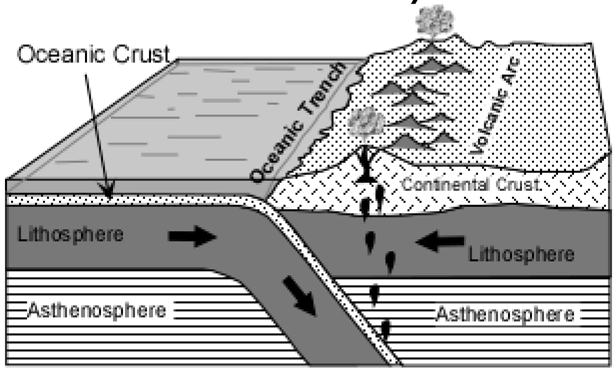
iii. The stratosphere prevents harmful ultraviolet radiation from reaching the earth
iv. The mesosphere, thermosphere and exosphere also prevent harmful radiation such as cosmic rays from reaching the earth's surface
v. Communication is also made possible by some layers of the atmosphere, specifically the ionosphere

Tectonic Plates
Defn: Tectonic plates are the huge pieces of cracked earth's crust and mantle part which floats over semi-molten rock. Also is called **lithospheric plate.** Tectonic plates are in slow motion/speed. This movement means continents are moving apart and toward each other. This process in which continents moving is called **continental drift**

Boundary
Defn: Boundary is the line where two tectonic plates meet

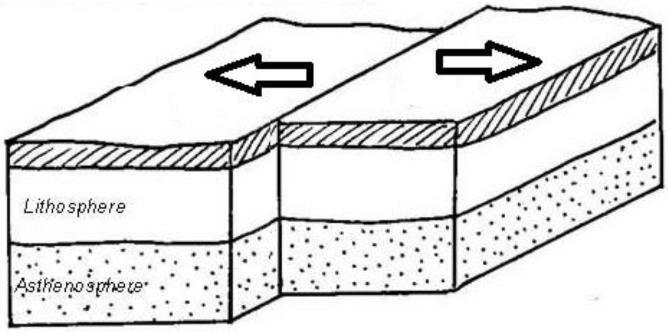
Types of Boundary
There are three types includes
i. Destructive/ converging boundary
ii. Constructive/diverging boundary
iii. Conservative boundary

Destructive Boundary
Defn: Destructive boundary is the kind of boundary in which edges of two plates moving toward each other
Diagram:

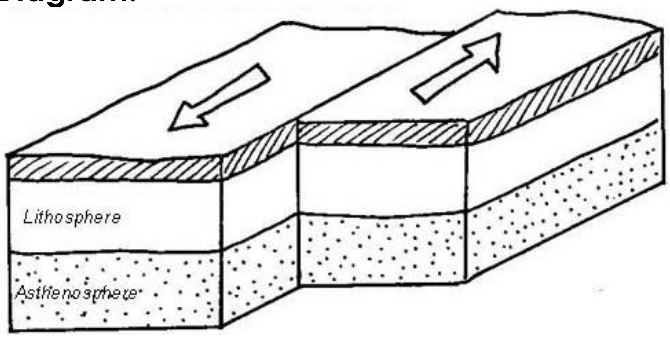


Ocean - Continent Convergence

Constructive Boundary
Defn: Constructive boundary is the kind of boundary in which edges of two plates moving away each other
Diagram:



Conservative Boundary
Defn: Conservative boundary is the kind of boundary in which two plates slide moving each other without apart or toward each other
Diagram:



Volcanoes
Defn: volcanoes are the process hot magma, volcanic ash and gases to escape from the magma chamber below the surface. Volcanoes found where tectonic plates are diverging or converging.

Causes of Volcanoes
Volcanoes are causes by movement of molten rock and heat energy inside the

earth. These movements is called **subterranean movements**

Nb:

i. Most volcanoes form along constructive and destructive boundaries
ii. Few form far from plate boundaries
iii. Magma that reached the earth's surface is called **lava**

Volcanoes at Destructive Boundaries

When ocean plate plunges under another plate, the ocean plate rubs against the plate above it and gets hot. Rock melts resulting magma under the upper plate. Magma forces away through weak points in the crust

Nb:

i. This magma tends to be very viscous due to its high silica content, so often does not reach the surface and cools at depth. When it does reach the surface, a volcano is formed
ii. Pacific Ocean is a line of destruction plate boundaries, it have circle of volcanoes around the pacific rim called **ring of fire**
iii. Typical Example, s for this kind of volcano are **Mount Etna** and the volcanoes in the Pacific Ring of Fire

Volcanoes at Constructive Boundaries

At the mid-oceanic ridges, two tectonic plates diverge from one another. For Example, the Mid-Atlantic Ridge, has Example, s of volcanoes caused by divergent tectonic plates pulling apart

Nb:

i. Most divergent plate boundaries are at the bottom of the oceans, therefore most volcanic activity is submarine, forming new seafloor
ii. **Black smokers** or **deep sea vents** are an Example, of this kind of volcanic activity
iii. Where the mid-oceanic ridge is above sea-level, volcanic **islands** are formed, for Example, , Iceland.

Volcanoes At Far From Plate Boundaries

This eruption occurs when mantle hotter than normal. The magma formed is forces toward earth's surface. For Example, Nyamalagira volcano located at Congo. This kind of volcanoes is called **Hot-sport volcanoes**

Types of Volcanoes

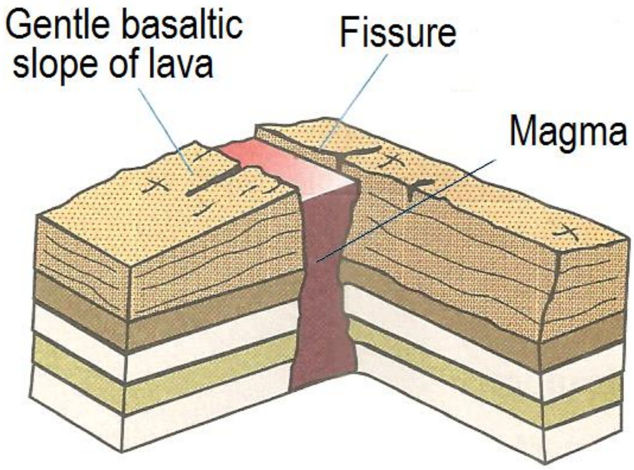
There are two types of volcanoes includes

i. Fissure volcanoes
ii. Central volcanoes

Fissure Volcanoes

Fissure volcanoes kind of volcanoes occurs along cracks in and between tectonic plates. It can be many kilometer long. Lava usually ejected quietly and continuously, forming enormous plains or plateaus of basaltic volcanic rock

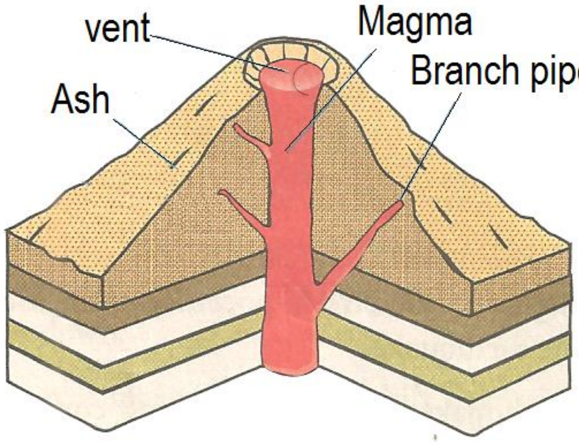
Diagram:



Central Volcanoes

Central volcanoes are a single vertical main vent through which magma reaches the earth's surface. It has cone shape builds up from successive layers of lava and ash

Diagram:



Classification of Volcanoes

It classified into three categories based by their frequency of eruption, include

i. Active volcanoes
ii. Dormant or inactive volcanoes
iii. Extinct volcanoes

Active Volcanoes

Active volcanoes are with those that erupt regularly in recent times. Example, **OL Donyo Lengai Volcano**

Dormant Volcanoes

Dormant volcanoes are those that have erupted in historical times but are now quiet but can erupt again. Example, **Mt. Kilimanjaro**

Extinct Volcanoes

Extinct volcanoes are those that have not erupted in historical times, probably never erupt again

Effect of Volcanoes

Volcanoes have positive effects and negative effects, as follows

Negative effects of volcanoes

i. **Human life and property**: Eruptions occurring close to human settlements may spill and destroy lives and property
ii. **Environment**: Ash discharged very high into the stratosphere can have negative consequences on the ozone layer
iii. **Landscapes**: Landscapes and natural sceneries can be destroyed
iv. **Lahars**: Ash and mud can mix with rain and melting snow, forming lahars. ***Lahars are mudflows flowing at very fast pace***
v. **acid rain**: Gas emissions from volcanoes are a natural contributor to acid rain

Positive effects of volcanoes

vi. **Tourism**: Provide extraordinary scenery, so beautiful and natural that they attract tourists to the area, bringing in some economic value.
vii. **geothermal energy**: Places close to volcanic activities tend to have higher potential for geothermal energy, which can be an advantage to the towns and cities
viii. **Soil**: Ash and lava breakdown become soils that are rich in nutrients, and become good areas for crop planting activities
ix. **Mineral**: it bring valuable mineral to the earth's surface
x. **Accident**: Ash thrown into the air by eruptions can present a hazard to aircraft, especially jet aircraft where the particles can be melted by the high operating temperature.

Earthquakes

Earthquakes are the rumblings, shaking or rolling of the earth's surface.

Causes of Earthquakes

There are two main causes of earthquakes, includes

i. Movements of Tectonic plates
ii. Volcanic eruptions

Movements of Tectonic Plates

Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break suddenly allowing sliding over the locked portion of the fault and releasing the stored energy. This energy is released as a combination of radiated elastic strain seismic waves, frictional heating of the fault surface, and cracking of the rock, thus causing an earthquake.

Volcanic Eruptions

Movement of magma in volcanoes, such earthquakes can serve as an early warning of volcanic eruptions. Earthquake swarms can serve as markers for the location of the flowing magma throughout the volcanoes. These swarms can be recorded by **seismometers** and **tilt meters** (a device that measures ground slope) and used as sensors to predict imminent or upcoming eruptions.

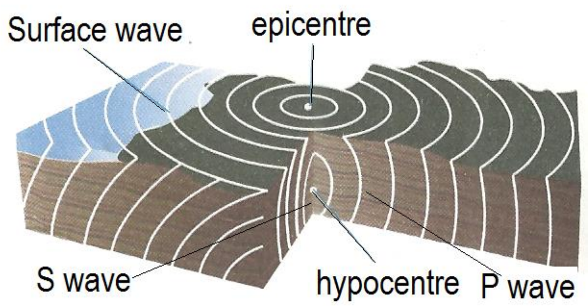
Nb:

i. Earthquakes rarely occur along constructive plates boundaries
ii. Earthquakes actual occur near constructive and destructive plates boundaries
iii. Beginning point of earthquakes is called **hypocenter** or **focus of the earthquake**
iv. Wave energy released by earthquakes is called **seismic waves**
v. **Epicenter** is the point on the ground immediately above the focus of the earthquake

Seismic Waves

Defn: is the energy released by earthquakes from hypocenter

Diagram:



Types of Seismic Waves

There are three seismic waves includes

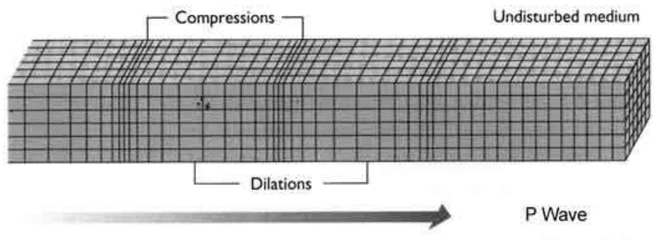
i. primary or P waves
ii. secondary or S waves
iii. Surface waves

Primary Waves

Primary or P waves

Its motion is the same as that of a sound wave in that, as it spreads out, it alternately pushes (compresses) and pulls (dilates) the rock. These P waves are able to

Diagram:



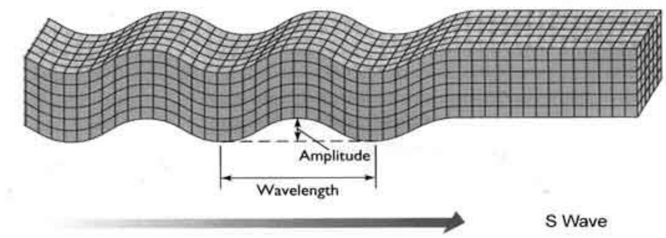
Properties of P Waves

i. It compresses waves
ii. It longitudinal waves
iii. It first detected/arrive seismic stations
iv. it travel at 1.5 - 8 km/sec in the Earth's crust
v. It shake the ground in the direction they are propagating
vi. It travel through the Earth's core
vii. It faster than S waves
viii. It travels through both solid rock, such as **Granite Mountains**, and **liquid material**, such as volcanic magma and the water of the oceans.

Secondary Waves

When S wave propagates, it shears the rock sideways at right angles to the direction of travel. If a liquid is sheared sideways or twisted, it will not spring back; hence S waves cannot propagate in the liquid parts of the earth, such as oceans and lakes.

Diagram:



Properties of S Waves

i. It shear waves
ii. It second to detected/arrive at seismic stations
iii. It 1.7 times slower than P waves
iv. It shake the ground perpendicular to the direction in which they are propagating
v. do not travel through liquid (i.e. water, molten rock, the Earth's outer core)

Surface Waves

Surface wave is the seismic waves in which propagates in earth's surface.

Types of Surface Waves

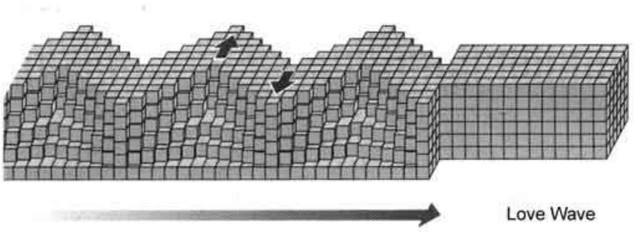
There are two seismic waves includes

i. Love waves
ii. Rayleigh waves

Love Waves

Love waves moves the ground from side to side in a horizontal plane but at right angles to the direction of propagation. The horizontal shaking of Love waves is particularly damaging to the foundations of structures.

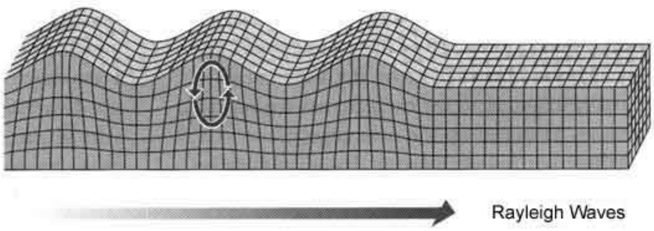
Diagram:



Rayleigh

Rayleigh is like rolling ocean waves, Rayleigh waves wave move both vertically and horizontally in a vertical plane pointed in the direction in which the waves are travelling.

Diagram:



Nb:

i. The actual speed of P and S seismic waves depends on the density and elastic properties of the rocks and soil through which they pass
ii. Surface waves travel more slowly than body waves (P and S)
iii. Love waves generally travel faster than Rayleigh waves
iv. Love waves (do not propagate through water) can effect surface water only insofar as the sides of lakes and ocean bays pushing water sideways like the sides of a vibrating tank
v. Rayleigh waves propagates through water due to vertical components of their motion

Earthquakes Scales

The nature of an Earthquakes described in term of their **magnitude** and **intensity**

Earthquakes Magnitude

The magnitude of an earthquake is a measure of the energy it releases. It is usually measured on the **Richter scale**. The Richter scale is based on the amplitude of the largest seismic wave recorded for an earthquake, no matter what type of wave was the strongest

NB:

i. The Richter scale magnitudes are based on a logarithmic scale (base 10)
ii. The scale has no upper limit
iii. Small magnitude expressed in negative numbers
iv. Large magnitude expressed in positive numbers

Earthquakes Intensity

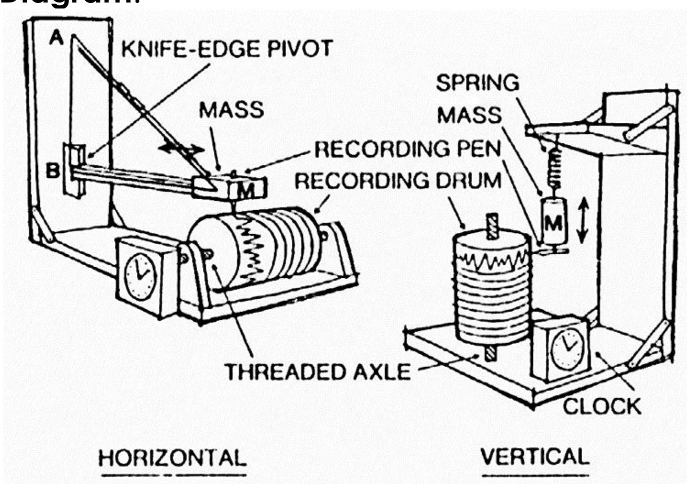
The intensity of an earthquake is a measure of its strength based on the changes it causes to the landscape. The intensity of an earthquake is usually measured on the Modified **Mercalli scale**. The scale is calibrated from 1 to 12. On this scale, level 1 is a minor tremor that causes no damage whereas level 12 causes total devastation. Consider the table below

Intensity Level	Effect
I	Not felt, except by very few people under especially favourable conditions.
II	Felt only by a few people at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings
IV	Felt indoors by many, outdoors by few during the day
V	Felt nearly by everyone. Many are awakened. Some dishes, windows broken. Unstable objects overturned
VI	Felt by everyone. Many are frightened. Some heavy furniture moved
VII	Damage negligible in buildings of good design and construction. Slight to moderate damage in well-built ordinary structures. Considerable damage in poorly built or badly designed structures. Some chimneys are broken

VIII	Damage slight in specially designed structures. Considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments and walls. Heavy furniture overturned
IX	Damage considerable in specially designed structures. Well-designed frame structures thrown out of plumb. Damage great substantial buildings with partial collapse. Buildings shifted off foundations
X	Some well-built wooden structures destroyed. Most masonry and frame structures destroyed with foundations. Rail bent
XI	Few, if any structures (masonry) remain standing. Bridges destroyed. Rails bent greatly
XII	Total damage Lines of sight and level are distorted. Objects thrown into the air

Nb:
Earthquake can only have one magnitude but, its intensity reduces as the seismic waves spread out from the hypocentre

Seismograph
The seismograph is an instrument used to record ground movements caused by earthquakes.
Diagram:



Mechanism
i. It consist heavy pendulum bob which can oscillates even in small earthquakes intensity and magnitude
ii. It measures ground oscillations by recording the relative motion between a pendulum and the ground.
iii. In order to measure ground motions, the seismograph must remain steady when the ground moves
iv. The time of initiation of ground oscillations is recorded and marked and are included on the graphs every minute and hour on the seismograph paper

Types of Pendulums
Various types of pendulums includes is a
i. **Simple pendulum**: Heavy mass suspended by a wire or rod from a fixed point
ii. **inverted pendulum:** has a heavy mass fixed to the upper end of a vertical rod pointed at its lower end
iii. **horizontal pendulum:** has a rod with a mass on its end which is suspended at two points so that it swings on a horizontal plane

Recording the Pendulum Motion
The recording of the motion of the pendulum can be done in various ways, includes
i. Mechanical method
ii. Optical method
iii. Electronic method

Mechanical Method
Sheet of smoked paper is wrapped around a rotating drum and mounted to move with the earth. A moving pen connected to the pendulum presses lightly on the paper. As time passes, the drum rotates so that the recorded lines are not superimposed on each other. Deflection of the pendulum is commonly magnified mechanically by single or double multiplying levers so that the graph is easier to see

Nb:
i. This method is simple and economical.

ii. Seismograph must have a heavy mass to overcome the friction between the pen and the paper
iii. Mechanical seismographs weigh one tonne or more

Optical Method

The optical method still uses a pendulum motion to record the ground movements. However, to overcome friction, mirrors are used to reflect the light onto photosensitive paper wrapped on a drum

Electronic Method

Coil is fixed to the mass of a pendulum and moves in a magnetic field. The voltages produced by motions of the pendulum are passed through electronic circuits to amplify the ground motion for more exact readings

Nb:

The seismograph records both the magnitude and the intensity of the earthquake.

Effect/ Hazards of Earthquakes

Earthquakes give rise to a number of hazards, includes

i. **Landslides**: earthquakes can cause unstable hillsides, mountain slopes and cliffs to move downwards, creating landslides
ii. **Snow slopes**: Earthquakes can also trigger avalanches on snow slopes which can collide with people, house etc
iii. **Tsunamis**: Tsunamis are the hug water waves cause water to rise or fall. When a tsunami reaches shallow water, it slows down, its wavelength reduces and its height grows.
iv. **Collapsing buildings:** A strong earthquake can flatten a whole city. An Example, is the Japanese city of Kobe which was completely flattened by an earthquake measuring 7.2 on the Richter scale
v. **Fire outbreak**: When gas or oil pipes break and collapse of electricity lines results trigger a fire
vi. **Backward rivers**: Tilting ground can also make rivers change their course. This can result in the creation of earthquake lakes that cover huge tracts of previously settled land

Earthquake Warning Signs

The following are important signs that are observed before an earthquake occurs:

i. **Thermal indicator**: few months before the earthquake, the average temperature of particular area increasing. On the day of the earthquake, the temperature of a place is about 5 to 9 degrees Celsius above the average normal temperature for that day.
ii. **Water indicator**: About one or three days before an earthquake, there is
    a. Sudden rise or fall in water levels in wells. The rise can be as high as one metre. The well water may turn muddy
    b. At times a fountain appears inside the well. Sometimes a fountain may appear in the ground. This normally happens a few hours before the quake
    c. There is also a sudden and rapid increase or decrease of water flow in the rivers. This happens about one to two days before the quake
iii. **Seismo electromagnetic indicator**: when Temperature raises results geomagnetic field to reduce which affects the propagation of electromagnetic waves (radio, television and telephone). This is a very reliable indicator. It is usually recorded about 10 to 20 hours before the quake.
iv. **Animal indicator**: Between 10 and 20 hours before the occurrence of an earthquake, the entire animal kingdom becomes highly disturbed and restless.
v. **Human indicator**: sensitive patients in hospitals become highly disturbed before an earthquake. They exhibit a sudden rise in blood pressure, heart trouble, headache, migraine and respiratory disorders. Indeed, the number of outpatients in hospitals increases by five to seven times, some 10 to 20 hours before the quake

Precaution Taken During an Earthquake

The following are some precautions that can be taken to minimize injuries to or death of human beings in the event of an earthquake:

i. If you are indoors during an earthquake, drop, cover and hold on. Get under a desk, table or bench. Hold on to one of the legs and cover your eyes. If there is no table or desk nearby, sit down against an interior wall. An interior wall is less likely to collapse than a wall on the outside shell of the building.
ii. Pick a safe place where things will not fall on you, be away from windows or tall, heavy furniture.
iii. Do not run outside when an earthquake happens because bricks, roofing and other materials may fall from buildings
iv. Wait in your safe place until the shaking stops, then check to see if you are hurt
v. Move carefully and watch out for things that have fallen or broken, creating hazards. Be ready for additional earthquakes called **aftershocks**
vi. Be on the lookout for fires. Fire is the most common earthquake-related hazard due to damaged gas and electrical lines.
vii. If you must leave a building after the shaking stops, use the stairs and not the elevator. Earthquakes can cause fire alarms and fire sprinklers to go off. You will not be certain whether there is a real threat of fire. As a precaution, use the stairs.

    If you are outside during an earthquake, stay outside. Move away from buildings, trees, streetlights and power lines. Crouch down and cover your head. Bricks, roofing and other materials can fall from buildings

Greenhouse Effect

Defn: *Greenhouse effect is the process whereby radiation reflected by the atmosphere to warms the earth's surface*

Or

Defn: *greenhouse effect is the trapping back of Sun's energy by a planet from atmospheres*

Or

Defn: *Greenhouse effect is the process whereby radiation reflected by the atmosphere to warms the planet's surface*

How Greenhouse Effect Occurs

When a planet's surface is heated by sunlight it emits thermal (heat) radiation which is absorbed by the greenhouse gases in the atmosphere. The atmosphere reflects (re-radiates) back thermal radiation in all directions to the earth's surface and lower atmosphere. Over time, this increases the planet's temperature due to presence of greenhouse gases

Sources of Greenhouse Effect

Greenhouse effect is caused by the greenhouse gases includes the follows

i. Water vapor
ii. Ozone layer
iii. Carbon dioxide
iv. Methane
v. Chlorofluorocarbons
vi. Dinitrogen oxide

Carbon Dioxide

Carbon dioxide is the main greenhouse gas. The gas contributes over 50% of the greenhouse effect. The following are some of the sources of carbon dioxide includes

i. Clearing and burning of vegetation (deforestation)
ii. Burning of fossil fuels (coal and petroleum)

Methane

The main source of methane is;

i. **Agricultural activities**. It is released from wetlands, such as rice fields and from animals, particularly cud-chewing animals like cows.
ii. mining of coal and oil
iii. When vegetation is burnt

Note: Methane molecules have a lifetime of 10 years in the atmosphere.

Dinitrogen Oxide

Dinitrogen oxide is produced from both natural and human-made processes. Human activities includes

i. combustion of fossil fuels in vehicles and power stations
ii. Use of nitrogenous fertilizers
iii. burning of vegetation
iv. Animal waste.

Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are organic compounds made up of chlorine, fluorine and carbon. The sources of CFCs in the atmosphere include **fridges**, **air conditioners**, **sprays** and **aerosols**

Note: CFCs are extremely effective greenhouse gases. A CFC molecule is 10 000 times more effective in trapping heat than a carbon dioxide molecule

Global Warming

Defn: *Global warming is the increase of the average temperatures near or on the earth's surface caused by greenhouse gases*

Or

Defn: *Global warming is the increase in temperature near or on the surface of the earth resulting into greenhouse effect*

Causes of global warming

Global warming is mainly caused by greenhouse gases

Effects of Global Warming

The effects of global warming include:

i. Increase the temperature of the oceans
ii. Rise in sea level due to melting land ice. This may lead to flooding of the coastal land
iii. Change in world's climate patterns
iv. Acidification of the oceans CO_2 dissolves in water and forms a weak carbonic acid and hence concept of PH of ocean
v. Extreme weather events which include floods, drought, heat waves, hurricanes and tornadoes
vi. higher or lower agricultural yields
vii. Melting of Arctic ice and snowcaps. This causes landslides, flash floods and glacial lake overflow
viii. extinction of some animal and plant species,
ix. increase in the range of disease vectors

Solutions to Minimize Global Warming

The major solution is to reduce the greenhouse gases emission into the atmosphere by:

i. Reduce the use of fossil fuels by use of public transport which will minimize the number of vehicles in the roads
ii. Use of fuel-efficient cars
iii. Use of clearer alternative sources of energy such as solar and wind.
iv. Afforestation
v. Countries to make a policy of minimizing the emission of greenhouse gases. Example, Kyoto protocol

Example, : NECTA form IV 2011: QN 09

(a) Define the term earthquake

(b) Briefly explain the meaning of the following terms as used on earthquake

i. Hypocenter
ii. Epicenter

(c) (i) What is global warming?

(ii) Name four gases that contribute to global warming and give one source of each