PHYSICS - FORM 2 CLASSICAL NOTES

TABLE OF CONTENTS

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"Expand your knowledge through solving problems"

1st Edition

TOPIC: 01 STATIC ELECTRICITY

- ***Static electricity (*****Electrostatics)** *is the study of charges at rest*.

Origin of Charges

- When a body is rubbed, it causes the atoms to loose or gain electrons which are revolving around the atomic structure and causing the body to become charged.

Types of Electric Charges

- Positive charge (+)
- Negative charge (-)

Positive charge

- Positive charge is a charge acquired when an object loose electrons from its atomic structure

Negative charge

- Negative charge is a charge acquired when an object gain electrons from its atomic structure

Charge acquired after rubbing

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 (static charges)

- The law states that: "***Like charges repel, unlike charges attract each other***"

Charging

- Charging is the process whereby a material looses or gains electrons

Methods of charging a body

- ✓ By Rubbing or friction
- ✓ By Conduction or contact
- ✓ By induction

By Friction

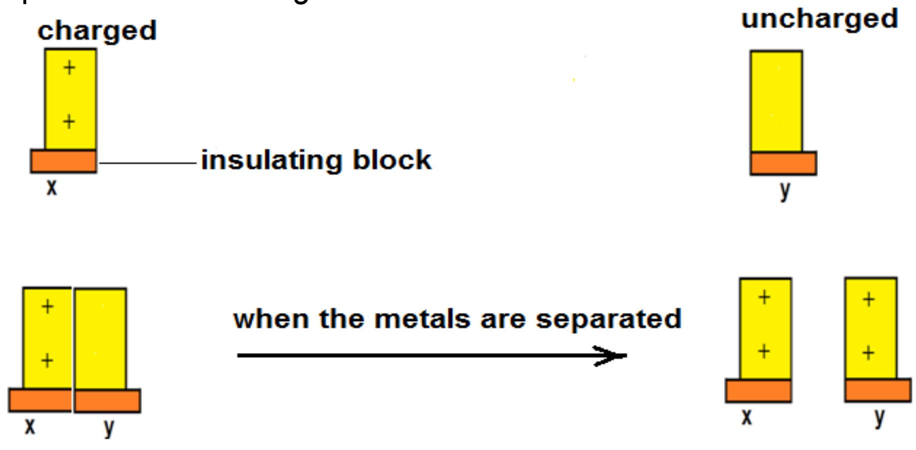
- Is the method of charging a body by rubbing

For example

- ✓ When an ebonite road is rubbed with fur some of electrons are transferred from the fur to the ebonite .Therefore the ebonite becomes **negatively charged** while fur becomes **positively charged**.
- ✓ When the glass rod is rubbed with silk electrons will be transferred from glass rod to silk, the glass rod will be **positively charged** while silk will be **negatively charged**.

By Contact

- This is the method of charging the body by touching each other.
- Let us say **x** is positively charged while **y** is neutral charged. Both plates are then placed on insulating blocks as shown below

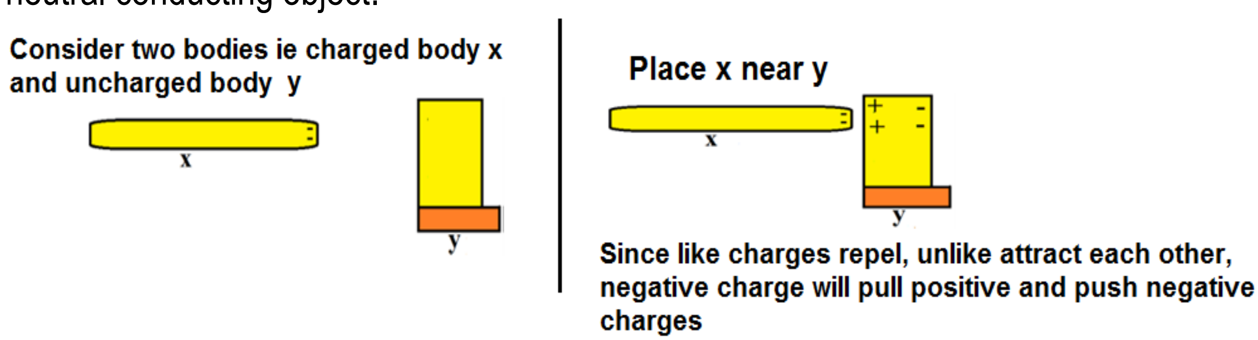


Charging by contact

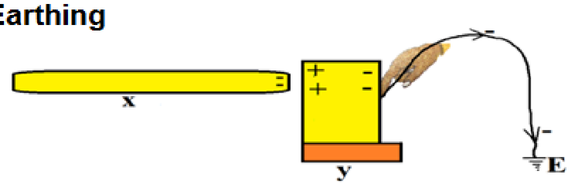
- If the two plates are brought together ,**Then plate x loses electrons while y gains electrons and become Positively charged**

By Induction

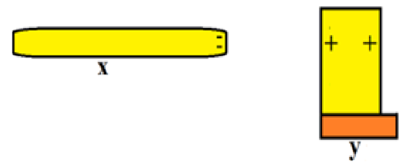
- Is the method where by a charged object is brought near but not touched to a neutral conducting object.



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

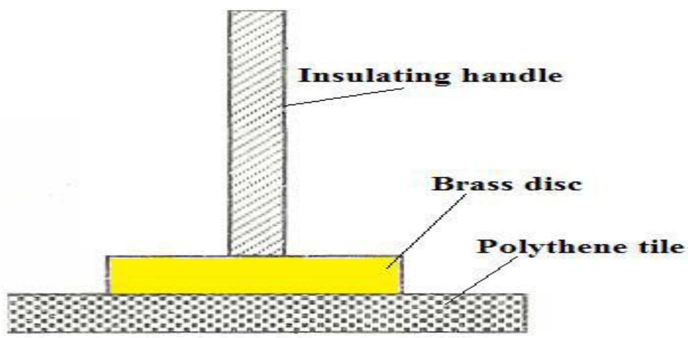


Now uncharged y became positively charged



Electrophorus

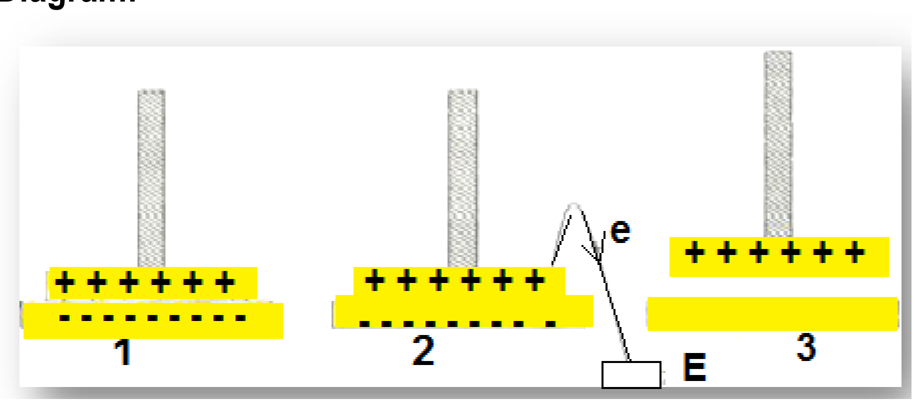
- Is a device used to produce electrostatic charges through the process of electrostatic induction.
- An electrophorus consists of a metal disc made of brass fitted with an insulating handle (usually an ebonite rod) resting on polythene base.
- It can produce numerous positive charges from a single negative charge.



Charging an Electrophorus

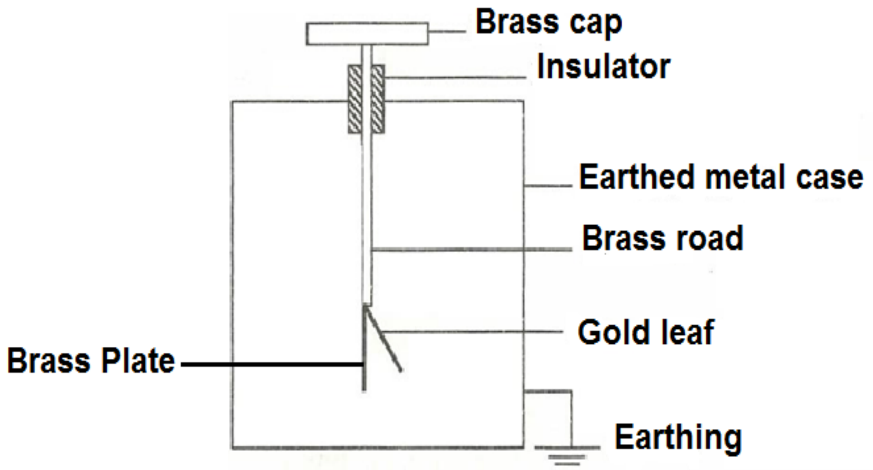
- The polythene is given a negative charge by rubbing it with fur causing positive charge to be induced on the upper part of the brass plate, and a negative charge on the lower part of the brass plate will leave the polythene plate charged negatively. The electrophorus is left with the excess positive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

Diagram:



Gold Leaf Electroscope

- *Gold leaf electroscope is an instrument used for detecting 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.



Gold leaf electroscope

Charging a gold leaf electroscope

- It is charged by **contact and Induction** by using a positively charged electrophorus

Discharging a gold – leaf electroscope

- It can be discharged effectively by induction.

Uses of Gold Leaf Electroscope

- To test the sign of charge on a charged body
- Identifying the insulating properties of materials
- Detecting the presence of charges on a body
- Estimating the amount of charge on a material

Conductor

- **C***onductor is a material which allows electricity to flow through it*.
- Examples of conductors are metals like iron, copper etc

Insulator

- **I***nsulator is a material that does not allow electricity to flow through it*.
- Examples of insulators are plastic, wood, rubber, mica, ebonite and glass.

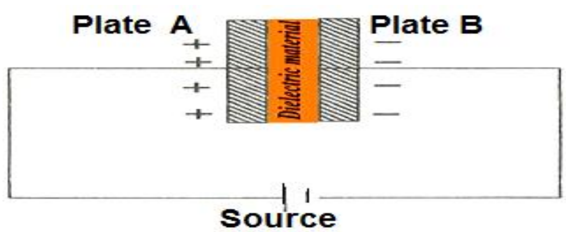
Capacitors

- **C**apacitor is a device used to store electric charges.
- The ability of a capacitor to store electric charges is known as **capacitance**.
- The SI unit of Capacitance is **Farad**
- **Farad** is the capacitance of a capacitor in which one coulomb of charge causes a potential difference of one volt
- Capacitors are found in all electronic circuits, e.g. in **radios**, **television**, **alarm systems**, etc.
- The potential difference, V across the two capacitor plates of the capacitor is directly proportional to the charge, Q accumulating on its plates that is $Q \propto V$
- Removing the proportionality constant. Q = kV **but**: k = C = capacitance

$$\boxed{\therefore Q = CV}$$

Charging a Capacitor

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



NB:

- **A dielectric material** is an electrical insulator that can be polarized by an applied electric field.
- **Polarization**: is the way of causing a separation of charges.
- **Potential difference (Pd):** Is the work done needed to move a charged particle from one point to another point.
- Its SI unit is voltage.
- **The earth is always at zero 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**.

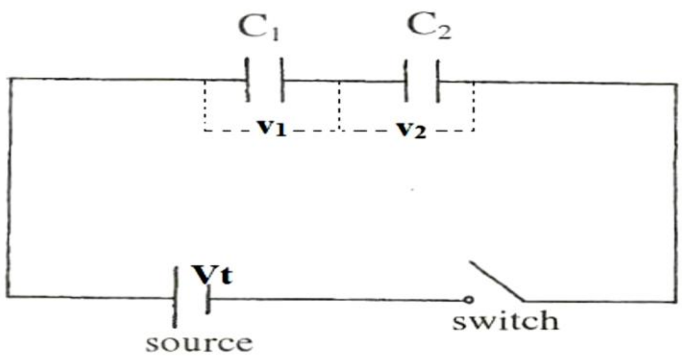
Types of Capacitors

There are different types of capacitors depending on the dielectric material used and the application.

- Paper (plastic filled) capacitor
- Oil filled capacitor
- Electrolytic capacitor
- Mica capacitor
- Variable (air filled) capacitor

Arrangement of Capacitors

(a) Capacitors in Series



From the figure above, $V_t = V_1 + V_2$

But: Q = CV ------------- make v the subject

Then, $\boldsymbol{V} = \frac{Q}{C} \rightarrow \boldsymbol{V_t} = \frac{Q_t}{C_t}$

But: Charge stored is the same, i.e **$Q_t = Q_1 = Q_2 = Q$**

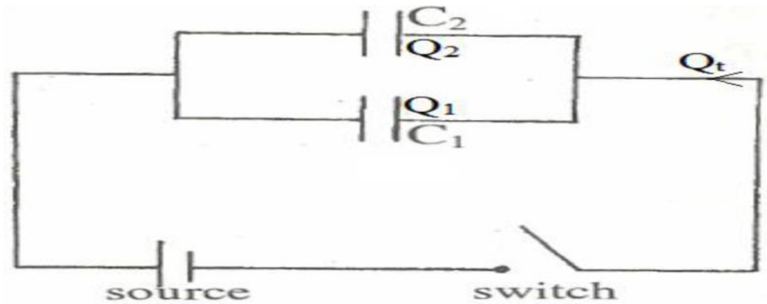
This gives: $\boldsymbol{V_t} = \frac{Q_t}{C_t} \longrightarrow \frac{Q}{C_t} = \frac{Q}{C_1} + \frac{Q}{C_2} \longrightarrow \frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2}$

If two capacitors are in series, then their total capacitance, C is given by:

$$\frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\boxed{\therefore\ C_t = \frac{C_1 C_2}{C_1 + C_2}}$$

(b) Capacitors in Parallel connection



From the diagram above
Q t = Q 1 + Q 2,   **but**: Q = CV

Then: $\mathbf{Q_t = C_tV_t}$ $\rightarrow \mathbf{C_tV_t = C_1V_1 + C_2V_2}$

Since: voltage across each capacitor is the same
Then: $C_tV = C_1V + C_2V \longrightarrow C_tV = V(C_1 + C_2) \longrightarrow C_t = C_1 + C_2$

If two capacitors are in series, then their total capacitance, C is given by:

$$\boxed{\therefore C_t = C_1 + C_2}$$

Individual work – 1

1. 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)? (**ANS: (i) 11.11 μF (ii) 45 μF)**
2. Determine the effective capacitance obtained when two capacitors each of 10 μF are connected first in parallel and then in series. **(ANS: (i) 5 μF (ii) 20 μF)**
3. 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.
   ANS: (i) It will be connected in series to the first, and its value will be 4 *μF*

Factors affecting Capacitance of a parallel plate capacitor

- The area of the plates
- The dielectric material
- The distance between the 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. **($C \propto \frac{1}{V}$ $\quad or \quad C \propto A$)**

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

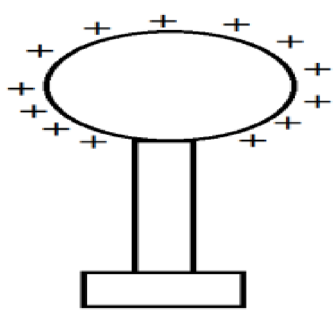
Distance between Plates

- A decrease in the distance between plates causes a decrease in potential difference between the plates, hence an increase in capacitance. ($C \propto \frac{1}{d}$)
- $\therefore C \propto \frac{A}{d} \rightarrow C = \frac{GA}{d}$ *, where by G is the permitivity of free space*

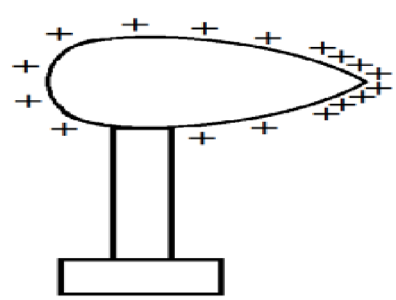
Charge distribution on a conductor

Conductors appear in many different shapes such as spherical, pear – shaped and cylindrical surfaces. It has been observed that:

- Hollow object only have charges on their outer surface
- Within the solid part of the conductor the net charge is zero
- Charges are normally concentrated on the sharp points of a conductor **(where the electric field is strongest)**



(i)



(ii)

Lightning

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

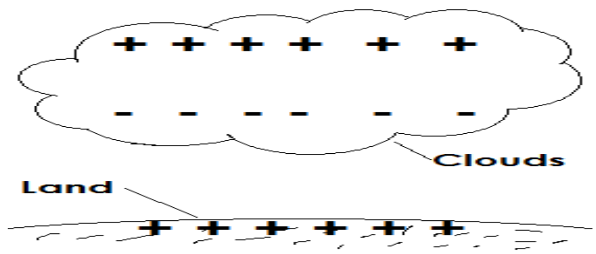
OR

Is a giant electric spark that arises due to discharge of atmospheric electricity.

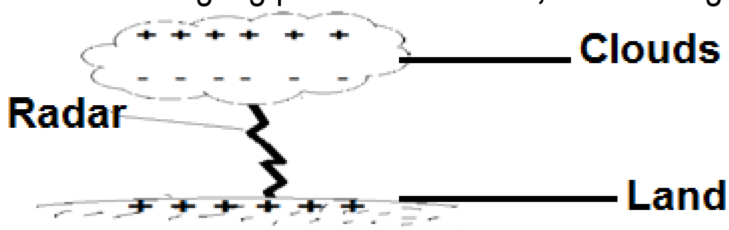
How Lightning Happens

- 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 the ground become positively after being induced by lower portion

See the fig. below



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



Question:

1. Why does lighting strike in zig – zag pattern?
   This is because: "The propagation of the lighting channel follows a path of the least resistance which is not a straight but a zig – zag line **because impurity (moisture) in the atmosphere causes the air to be ionized in different directions**.

Thunderstorm

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

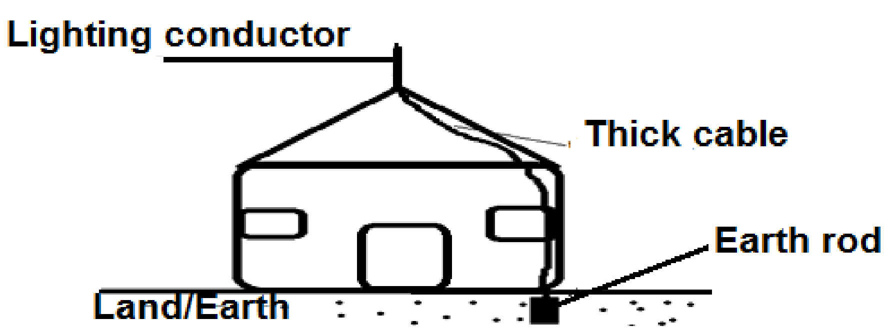
A lightning conductor

- Is a metal rod attached to a building and connected to a thick copper strip that leads into the ground.

OR

- Is a device that protects structure from strikes by providing an easier path for current to flow to earth than through the structure.

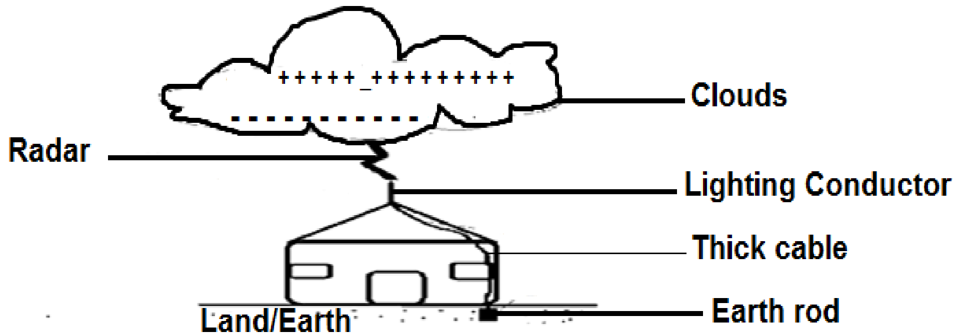
See the fig below



Mode of action

- The lightning conductor is placed above the highest point on the building because lightning tends to hit the highest object within its region or path.
- When lightning strikes the conductor, electric flow along the wire and dissipated to the ground there by protecting the building.

See the fig below



Ground (Earth)

- **Is** a large conductor which acts both as an infinite supplier of electrons or an infinite receiver for electrons

Earthing (Grounding)

- Is the process of connecting of a material with polarized charges to the ground

OR

- **Means** to neutralize a charged body

Point of action

- **Is** the behavior of charges to concentrate at the edges of sharp or pointed objects

Function of Lightning Conductor

- It helps to protect buildings and other structures from lightning strikes.

Application of Static Electricity

1. **Used in paint spraying** of car bodies by using an electrostatic spry gun
2. **Used in photocopying.** A photocopier uses electrostatic charge to produce a copy of any original document
3. **Used in printing**: A printer uses electrostatic charges to direct ink to the correct place on the page of paper
4. **Used in industrial chimneys**: **P**ollution in industries can be reduced using electrostatic charges

Dangers of Electrostatics

- When a liquid flows through a pipe its molecules become charged due to rubbing on the inner surface of the pipe .If the liquid is inflammable it can cause sparks and explode
- Similarly , explosive fuel carried in plastic cans can get charged due to rubbing which may result in sparks and even explosion
- It is therefore advisable to store fuels in metal cans so that any charges generated continually leak.

Class Activity

1. State what happen in the following conditions.
    a) An ebonite rod is rubbed with fur
    b) A negatively charged electroscope's cap is touched by a neutral glass rod
    c) A proof plane is inserted in a hollow and tested for charge
2. A glass rod rubbed with ---------------- becomes ---------------- charged
3. Draw the sketch of a large and well labeled gold – leaf electroscope.
4. Define capacitor and capacitance
5. A sharp needle was brought close to the cap of a charged gold – leaf electroscope .Explain why the leaf collapsed.
6. After walking across a carpeted floor you sometimes get a mild electric shock when you touch a metal door knob. Explain how this happens
7. List the three types of capacitors that you know and their uses
8. State the factors which affect the capacitance of a parallel plate capacitor
9. Explain how the factors affect the capacitance of the capacitor
10. State the appliances that use capacitors
11. Calculate the charge stored in a capacitor of 100 μF capacitance when connected to a **2 v** d.c supply. **(ANS: Q = 0.2 mc = 0.0002 C)**
12. **Two** capacitors of capacitance 10 μF and 15 μF are connected in:
    (a) series (b) parallel. Calculate the effective capacitance in each case
13. **T**he charge stored in a capacitor of capacitance 7 200 μF is 32.4 mC. Calculate the e.m.f of the battery charging the capacitor
14. A capacitor of two parallel plates separated by air has a capacitance of 15 **pF**. A potential difference of 18 volts is applied across the plate
    a) Determine the charge on the capacitor.
    b) If the space between is filled with mica, the capacitance now increases to 240 **pF** .How much more charge can be put on the capacitor using the 18 volts supply.
15. Two capacitors of capacitance 2 μF and 4 μF are connected in
    (a) series (b) parallel .Calculate the effective capacitance in each combination**. (ANS: (a) C_S = 1.33 μF , (b) C_P = 6 μF)**

16. When a capacitor is connected to a battery of e.m.f 12 v, the charge stored on each plate is 0.06 μF. Calculate the capacitance of the capacitor in μF

17. Mention at least five losses which are due to lightning strikes.

18. What is the difference between charging an object by induction and charging it by conduction?

19. A negatively charged object attracts a piece of paper because it ---------------- electrons away from the surface of the paper.

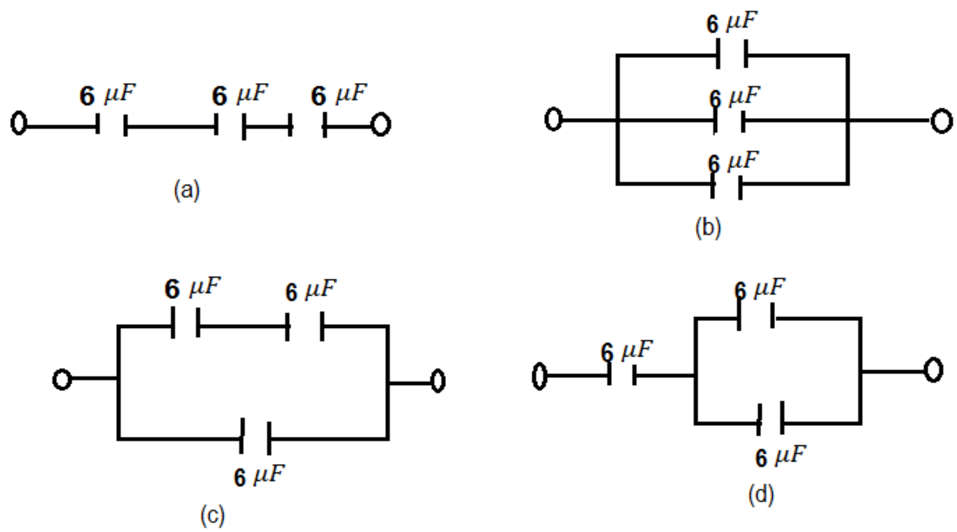
20. Explain why:

(a) Nylon cloth crackles as you undress.

(b) Are TV screens dusty after a while?

21. What is (a) Capacitor (b) Capacitance

22. Determine the effective capacitance in each of the following diagram



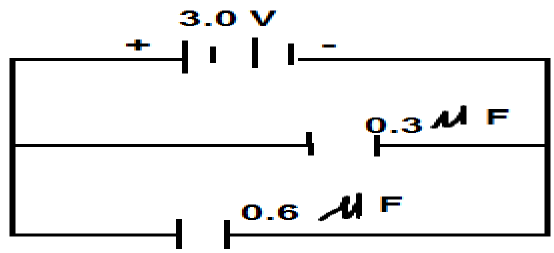
(ANS: (a) C = 2 μF (b) C = 18 μF (c) C = 9 μF (d) C = 4 μF)

23. Match the items in List A with those in List B

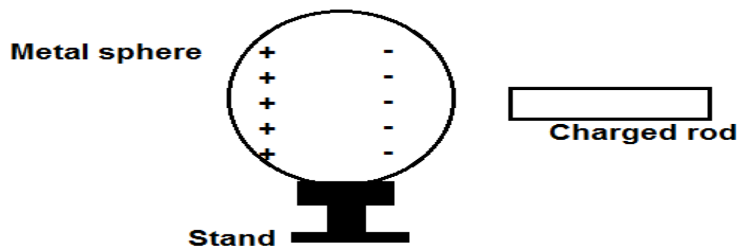
List A	List B
a) Stores charge	i) Repel
b) $C = C_1 + C_2$	ii) Capacitor
c) Glass	iii) Metal caps
d) Similar charges	iv) Positive charge
e) Detect charges	v) Gold – leaf
	vi) Insulator
	vii) Attracts
	viii) Capacitors in parallel
	ix) Capacitors in series
	x) Negative charge

24. (a) Determine the effective capacitance of the circuit below

(b) What is the value of the stored charge?



25. Explain why are metal chains attached to the trucks carrying petrol or other inflammable materials?
26. Are conductors and insulators? Give three examples of each
27. What does the study of electrostatics deal with?
28. State the law of charges. Explain the law with a suitable example
29. When a charged rod is held close to a metal sphere placed on an insulated stand ,the charge distribution on the sphere is also shown in the fig below



   a) What is the sign of charge on the rod?
   b) Describe a simple method to charge the rod
   c) Explain why the far side of the metal sphere has a positive charge.
   d) What happens to the charges on the metal sphere, if the charged rod is moved away from the sphere?
30. Explain any two day to day applications of static electricity
31. Define the terms below
   a) Ground (c) Farad (e) Dielectric material
   b) Induction (d) Conductor (g) Insulator
32. A lighting conductor protects building and other structures from damage in case of lighting attacks. Describe how it works
33. Describe the distribution of charges along:
   a) A negatively charged spherical conductor
   b) A negatively charged pointed metal rod
34. What is lighting conductor and what is its purpose?
35. Show that for capacitors arranged in a series configuration the effective capacitance is given by:

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

36. Four capacitors of capacitance 2.4 μF, 3.6 μF ,**4.0** μF **and 2.0** μF are connected in series to a potential difference of 15.0 V . Find:
   a) The effective capacitance **(ANS: C = 0.69 x 10^{-6} F)**
   b) The total charge (**ANS: Q = 10.35 x 10^{-6})**

c) The charge on each capacitor (**ANS: Q = 10.35 x 10^{-6})**

d) The voltage across each capacitor **(ANS: V_1 = 4.31 v, V_2 = 2.88 v, V_3 = 2.59 v and V_4 = 5.18 v)**

37. Two capacitors of capacitance 2.5 μF and 3.5 μF connected in series are connected to two other capacitors each of capacitance 4.0 μF which are connected in parallel to each other .If the circuit is supplied by a potential difference of 20.0 v, find:

a) The effective capacitance (**ANS: C = 1.23 μF**)

b) The voltage on each capacitor (**ANS: V_1 = 9.87 v, V_2 = 7.05 v)**

c) The total charge (**ANS: Q = 24.67 x 10^{-6})**

d) **The** charge on each capacitor. (ANS:**Q_1 = Q_2 = 24.67 x 10^{-6} C, Q_3 = Q_4 = 12.33 x 10^{-6}**)

TOPIC: 02 CURRENT ELECTRICITY

Current electricity: Is the study of electric charges in motion
OR Is a flow of electric charge

Electric current is a rate of flow of electric charges

- **Electric current (I) =** $\frac{\boldsymbol{Quantity\ of\ charge(Q)}}{\boldsymbol{Unit\ time\ (t)}} \rightarrow \boldsymbol{I = \frac{Q}{t}}$

- The common SI unit of current (I) is ***ampere (A)***
- **Ampere (A):** Is the current through a point in a conductor when a charge of one coulomb passes through the point after every one second.
- The device used to measure electric current is called **Ammeter.**
- The other units are Mill Ampere (mA),Kilo ampere (kA), and micro ampere (μA)
- Their equivalence to the ampere is as follows

1A =10 $^{-3}$ m A , 1A = 10 $^{-6}$ μ A and 1kA =1000A

Coulomb

- Is the charge transported by a constant current of one ampere in one second

OR

- Is the quantity of electricity passing at a given point in 1second when steady current of 1A is flowing in a circuit

Uses of Current Electricity

- Cooking
- Lighting
- Communication
- Heating

Source of Current Electricity

- Cells
- Batteries
- Generators

Batteries/Cell

- It converts chemical energy into electrical energy

Generators

- It converts mechanical energy into electrical energy.

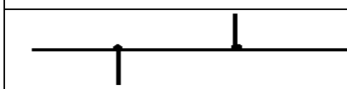
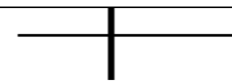
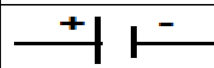
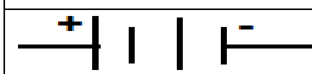
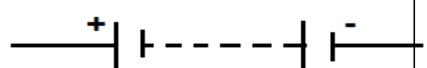
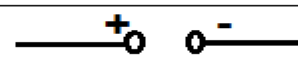
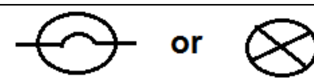
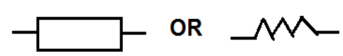
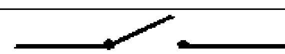
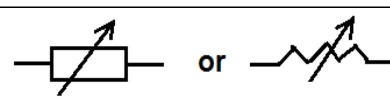
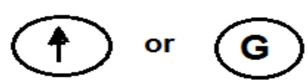
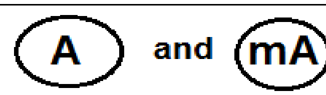
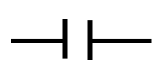
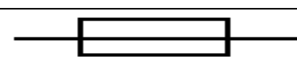
Simple Electric Circuit

It consists of

- ✓ Source of moving charge, it may be battery or generator
- ✓ Connecting wires made of a conducting material (usually copper metal)
- ✓ Electrical devices such as; Bulb, Switches, Resistors, Ammeter, Voltmeters etc

Consider the electric circuit components and their uses, in the table below,

Table Showing Electric circuit components

Circuit device	**Purpose**	**Symbol**
Connecting wire	**Ca**rrying current from one point to another	
Wire joined		
Wire crossing (not connected)		
Cell	**S**upplies electrical energy.	
Battery		
Battery (multiple cells)		
Alternate current (AC) supply		
Dc supply		
Lamp / Bulb	Convert electrical energy to heat and light energy	
Resistor	**Impedes** the flow of current	
Switch	**O**pens and closes a circuit	
Rheostat (variable)	**Controls a**mount of current	
Galvanometer	Detecting the presence of current	
Ammeter and milliammeter	**Measure current**	
Capacitor	**Stores electric charges**	
Fuse	**Breaks** the circuit if excessive current flows	

Example

1. An electric current of 0.12A passes a point B along a conducting wire. How much electric charge is flowing through this point in a minute?

   Solution:

   Charge = current x time

   Q = It = 0.12 x 60 = 7.2 C

Voltage

- Is an electromotive force or potential difference expressed in volts(v)
- Every cell has a voltage commonly referred to as **potential difference (P.d),** across its terminals.

Volt, V

- Is the potential difference between two locations when a charge of one coulomb will gain a potential energy of one joule when the charge is moved between the two locations

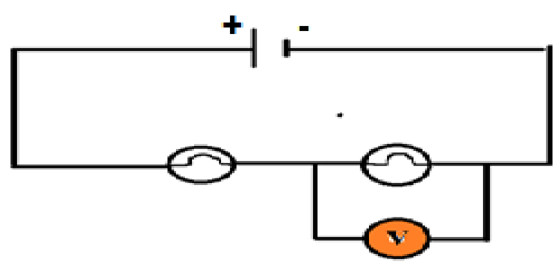
Potential difference:

- Is the difference of electrical potential between two points

  OR

  Is the work done in moving a unit charge from one point to another

- Voltage is measured by using a device known as **Voltmeter**
- **The SI unit** of voltage is **Volt (V)**
- It is always connected parallel to the device whereby you want to measure its voltage drop across it



- Wrong connection of an ammeter can damage it, so the red terminal of the ammeter should be connected to the positive terminal.
- Ammeter is always connected in series with a circuit

Resistance

- Resistance is a measure of the opposition to current flow in an electrical circuit
- Its SI unit is ***Ohm (Ω)***
- The device which measures the resistance is known as **Resistor**
- Resistor is an electrical component with two terminals that is used to limit or regulate the flow of electrical current in electronic circuits

Ohm (Ω) **Is** the resistance of a conductor such that, when a potential difference of 1volt is applied to its ends a current of 1 ampere flows through it.

Types of Resistor

- Fixed resistor
- Rheostat (variable resistor)

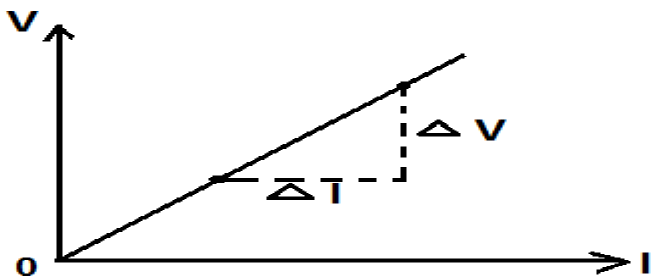
Ohm's Law

- It States that: ***"At constant temperature and other physical factors, a current in a conductor is directly proportional to the potential difference across its end"***
- That is: $V \propto I \longrightarrow$ **V=KI**
- **Where:** K= constant (R) = resistance

$$\therefore V = IR$$

Then: **R =** $\frac{V}{I}$

Graphically:



- From the graph above, Slope (m) = $\frac{\Delta V}{\Delta I}$
- **Whereby the physical meaning of the** Slope = Resistance

Factors affecting Resistance of a wire

1. Length of the conductor

- The longer the wire the higher the resistance and vice versa ($R \propto L$)

2. Temperature

- The higher the temperature the higher the resistance and vice versa ($T \propto R$)

3. Type of material (nature of material)

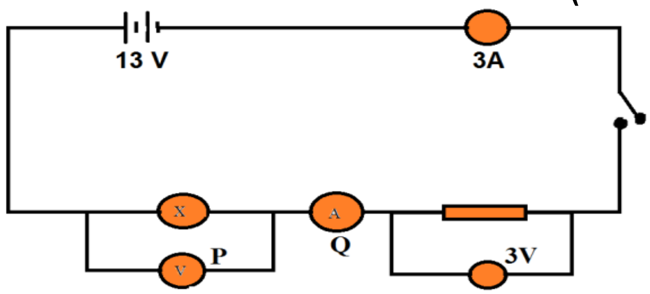
- Example nichrome wire has more resistance than a copper wire of the same dimension. ***That is why***
  a) *Nichrome wire is used in heating element of electric fires*
  b) *Copper wire is mostly used for connecting wires.*

4. Cross-section area

- A thin wire has more resistance than a thick conductor. ($\boldsymbol{R} \propto \frac{\mathbf{1}}{\boldsymbol{A}}$)

Individual Task – 1

1. A battery is 5V has a resistance wire of 20Ω connected across it. Calculate the current in the circuit. (**ANS: I = 0.25A)**
2. 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? (**ANS :** R = 3000 Ω = 3 kΩ)
3. Calculate the reading of the voltmeter, P and the ammeter, Q in the electric circuit battery. **(ANS: P =10V , Q = 3 A)**

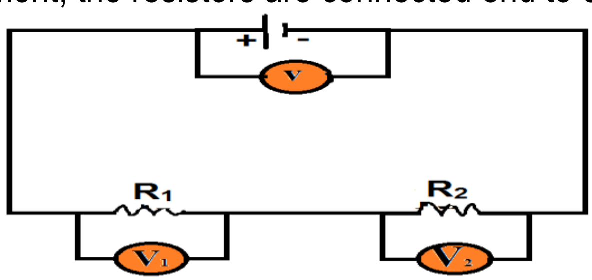


Combination of Resistors

- Resistors can be combined in series or in parallel arrangement

Series Connection

- In this arrangement, the resistors are connected end to end.



- **From: P.d across the battery = sum of p.d around a conducting path**

That is: $V_T = V_1 + V_2$ **but V = IR**

Then: $IR_T = IR_1 + IR_2 = I(R_1 + R_2)$, $(I \text{ is the same at all points})$

$$IR_T = I(R_1 + R_2)$$

∴ The sum of two resistors in series arrangement is given by

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

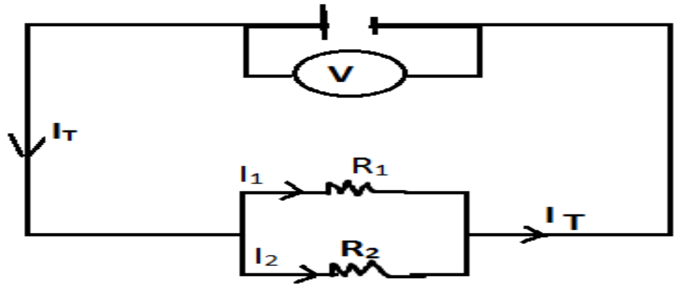
∴Total resistance (R_T) for n resistors in series connection is given by

$$\boxed{R_T = R_1 + R_2 + \ldots\ldots + R_n}$$

Where: R_n = the last resistor

Parallel Connection

- Resistors are connected across two common points in a parallel arrangement.



- In parallel connection, the current passing outside the branches is equal to the sum of the current in the individual branches ie $\boldsymbol{I_T = I_1 + I_2}$
- But voltage on in each branch is the same and is constant ($\boldsymbol{V_T = V_1 = V_2}$)

From Ohms' Law: **V = IR** $\rightarrow$ $\boldsymbol{I_T = \frac{V_T}{R_T}}$

ie $\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2}$ $\rightarrow$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

- **Therefore the sum of two resistors in parallel arrangement is given by**:

$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} \quad OR \quad R_T = \frac{R_1 R_2}{R_1 + R_2}$$

∴**Total resistance (R_T) in parallel connection for n resistors is given by**

$$\boxed{\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \cdots . + \frac{1}{Rn}}$$

Whereby: Rn = the last resistor

N.B

- **It** is advisable to connect bulbs in parallel during electrical installation so that when the bulb blows out or disconnected, the other bulbs will keep working
- **If** you connect in series when one bulb disconnected (blows out) will cause the other bulbs not working

Example

1. Two resistors of resistance 10 Ω and 50 Ω respectively are to be connected between two points A and B. What will be the resistance between A and B if the two resistors are to be connected in (a) series (b) parallel

   Solution:

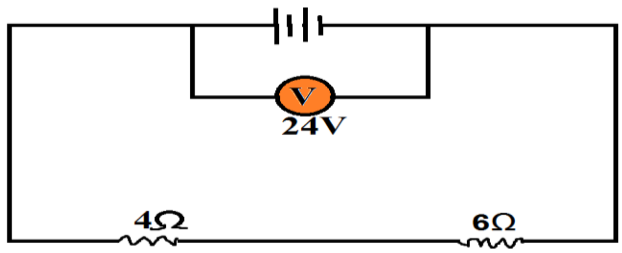
   Given: R_1 = 10 Ω, R_2 = 50 Ω

   (a) In series: $R_T = R_1 + R_2$ = 10 + 50 = 60 Ω

   (b) In parallel: $\boldsymbol{R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \ x \ 50}{10+50} = \frac{500}{60} = 8.3}$

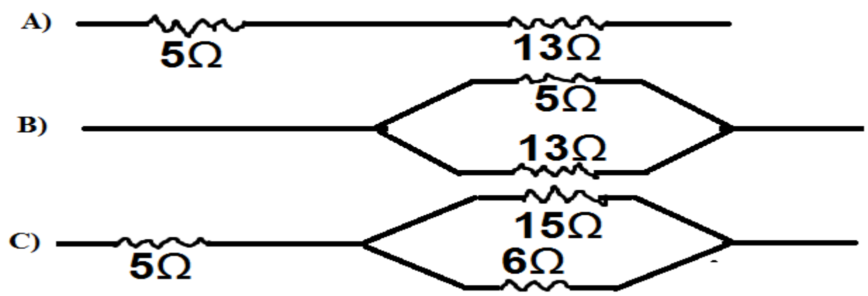
Individual Task – 2

1. Consider the figure below .Calculate P.d across: (a) 4 Ω (b) 6Ω



ANS: (a) **V1= 9.6 V** (b) **V2= 14.4 V**

2. Calculate the combination resistance in

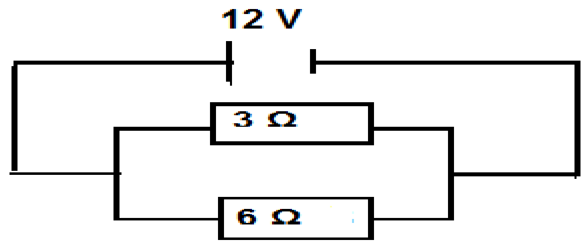


ANS: (a) **R = 18 Ω** (b) **R = 3.61 Ω** (c) **R = 9.2 Ω**

Class activity

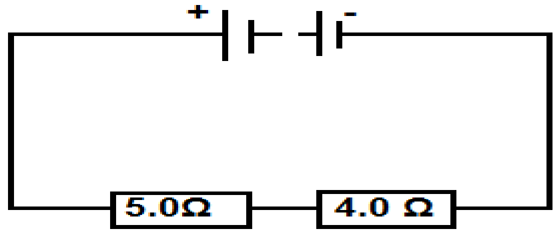
1. A p.d of 12 v is applied across two resistors of 10 **Ω and 20 Ω** connected in series .Find:
   a) The equivalent resistance for the circuit (**ANS: R = 30 Ω)**
   b) The total current in the circuit **(ANS: I = 0.4 A)**
   c) The current through each resistor (**ANS: I = 0.4A)**
   d) The voltage drop across each resistor (**ANS: V_1 = 4v, V_2 = 8 v)**
2. What do you understand by the following term?
   (a) electric current (b) electric circuit
3. **Calculate** the amount of charge that passes through a point in a circuit in 3 seconds, if the current in the circuit is 0.5 A (**ANS: Q = 1.5 C)**
4. A torch is switched on for 30 minutes .The current in the bulb of the torch is 0.45 A. Calculate the charge which flowed through the bulb. (**ANS: Q = 810 C)**
5. State the two conditions which are necessary for charge to flow in a circuit.
6. **A** charge of 4500 coulombs flows through a point in a conductor .It causes the ammeter to show a reading of 5.0 A .For how long does the charge flow through the point (in minutes) (**ANS: t = 15 minutes)**

7. A charge of 300 coulombs flows through a point in a conductor for two minutes. What is the ammeter reading for this flow? **(ANS: I = 2.5 A)**
8. Three resistors of resistances 5.**0 Ω, 7 Ω and** 12 **Ω were** arranged in series. Calculate the equivalent resistance in the circuit (**ANS: R_T = 24 Ω)**
9. A parallel circuit consists of two resistors. Calculate the effective resistance of the circuit **(ANS: R_T = 2.5 Ω)**
10. Three resistors of resistances 5 **Ω,7 Ω and 12 Ω** were placed in a parallel circuit. Calculate the equivalent resistance of the circuit (**ANS: R_T = 2.3 Ω)**
11. A 12 V battery is connected to two resistors as shown in the fig. below. Find



(a) Total current (b) the current through each resistor
(**ANS: (a) I = 6 A (b) I_1 = 4A , I_2 = 2 A)**
12. A current of 4.5 A flows through a point for 25 minutes. Calculate the charge through the point after 25 minutes.
13. During a flash of lightning, 600 C of charge is transferred in 0.15 s. Calculate the average current. (**ANS: I = 4000 A)**
14. Draw a series circuit containing a battery ,switch ,lamp, a variable resistor and an ammeter connected so that it can be used to measure the current in the lamp
15. Draw a circuit with a battery and switch in series, two lamps in parallel and a voltmeter connected so that it can be used to measure the voltage across one of the lamps
16. A student is carrying out an experiment with ten 10 **Ω** resistors. The student connects all of the resistors firstly in series, and then in parallel.
    (a) Calculate the total resistance of the ten resistors when they are connected in series. **(ANS: R_T = 100 Ω)**
    (b) calculate the total resistance of the ten resistors when they are connected in parallel (**ANS: R_T = 1.0 Ω)**
17. An electric torch contains two 1.5 V batteries .The current in the bulb of the torch is 0.45 A .Calculate the resistance of the torch bulb.**(ANS: R = 6.7 Ω)**
18. Define the terms below as used in Physics:
    a) Volt
    b) Current electricity
    c) Voltage
19. State two essential requirements of a circuit.
20. A current flows through a coil of wire of resistance 80 **Ω w** when it is connected to the terminals of a battery .If the potential difference is 60 V. Find **the** value of the current (**ANS: I = 0.75 A)**

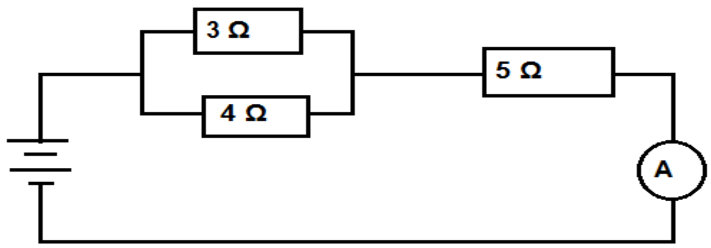
21. In the circuit below , the current in the 5.0 **Ω resistor** is 0.5 A



(i) State the current in the 4.0 **Ω resistor** **(ANS: I = 0.5 A)**

(ii) Calculate the battery voltage. (**ANS: V = 4.5 V)**

22. In a circuit below, a 12 volt power supply was used. Calculate.

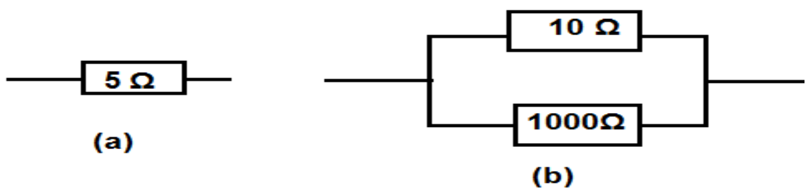


a) The equivalent resistance.

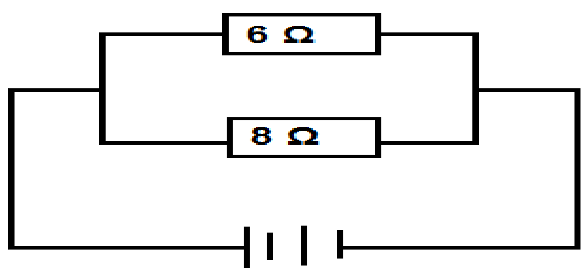
b) The total current through the circuit.

c) The voltage drop across each resistor.

23. Which figure below has a lower combined resistance?



24. The current through the 6 **Ω** resistor is 2.5 A. Calculate.



a) The voltage from the power supply

b) The current through the 8 **Ω** resistor.

c) The equivalent resistance.

d) The total current.

25. When resistors are connected are connected in series, which of the following is the same for all the resistors (a) current (b) potential difference?

26. If a pd of 6.0 V is measured across the ends of a wire of resistance 12 **Ω,**

(a) What current flows through it?

(b) What pd is required to make a current of 1.5 A flows through it?

27. How does ohm's law explain the fact that the resistance of a conductor depends on the area of cross – section of the conductor?

28. Why does a bird safely porch on a high potential electric wire? **(ANS: When a bird is perched on a single wire, its two feet are at the same electrical potential, so the electrons in the wires have no motivation to travel through the bird's body)**

29. Match the items in list A with those in List B.

Lit A	List B
(a) Ammeter	**(i)** Measures pd
(b) $V \propto I$	**(ii)** Measures current
(c) Rheostat	**(iii)** Ohm
(d) Series connection	**(iv)** Controls current
(e) Charge	**(v)** Ohm's law
	(vi) Controls pd
	(vii) Coulomb
	(viii) Constant current
	(ix) Galvanometer
	(x) Constant pd

30. State ohms' law

31. State the factors that affect the resistance of a conductor.

32. What do you understand by an ohmic conductor?

33. Which has a greater resistance between a long, thin, hot nichrome wire OR a short, thick, cool wire?

34. Distinguish between.

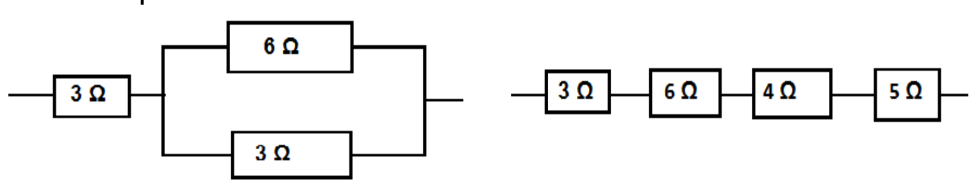
(a) Parallel circuit and series circuit.

(b) Ammeter and voltmeter

(c) Resistance and equivalent resistance

35. A current of 0.25 A flows through a circuit of voltage 10 V across a bulb .What is the resistance of the bulb?

36. Find the equivalent resistance for the resistors connected as shown below.



(a) **(b)**

37. In an experiment to determine the value of resistance, the following results were obtained.

Voltage (v)	2.0	3.0	4.0	6.0
Current (A)	1.0	1.5	2.0	3.0

(a) Plot a graph of V against the I

(b) Determine the resistance R of the conductor

38. Three resistors of resistance 8 **Ω, 10 Ω and** 12 **Ω** are connected in series. A voltmeter connected across the 10 **Ω resistor reads 6 V.** Calculate the.

(a) Current through the circuit

(b) Voltage across the circuit

(c) Total voltage in the circuit

TOPIC: 03 MAGNETISM

- **A magnet** is a substance which attracts metals or magnetic materials.
- **Magnetism** is the behavior shown by a magnet, the behavior of attracting metals (magnetic materials).
- **Magnetic dipoles:** Are the two poles on a magnet which are equal and opposite to each other
- **Magnetic poles:** Are ends of a magnet which show the strongest attraction or repulsion power compared to the other parts of the magnet.**ie**

N	***S***

- Whereby **N** is the north seeking pole while **S** is the south seeking pole
- **Magnetic domains** are minute regions in ferromagnetic materials with millions of atomic dipoles coupled together in a preferred direction.

NB: The strength of a magnet cannot be increased beyond a certain limit because when all magnetic domains have oriented in the same direction, no further magnetization is possible and material is said **to be saturated**

Magnetic and Non-Magnetic Materials

❖ ***Magnetic materials*** are all materials that can be magnetized or attracted by a magnet. E.g. **iron**, **steel**, **nickel** and **cobalt**

❖ ***Non-magnetic materials*** are all materials that cannot be magnetized or attracted by a magnet. E.g. **brass**, **copper**, **tin**, **zinc**, carbon, **aluminium**, **wood**, **plastic**, **clothes** etc

Properties of Magnets

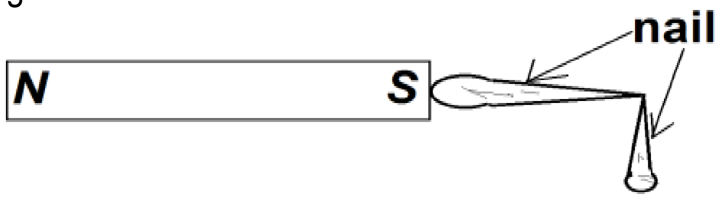
❖ Magnets attract magnetic materials
❖ Magnet possesses two poles northern pole (N) and southern pole(S).
❖ The magnetic force is strongest near the poles of a magnet
❖ Like magnetic poles repel but unlike magnetic poles attract
❖ The magnetic force is an action – at – a distance force
❖ If a magnet is suspended freely always points in the north– south direction.

Types of Magnets

❖ Temporary magnets
❖ Permanent magnets
❖ Electromagnets.

Temporary magnet

- Occur when magnetic material is magnetized in an external magnetic field but loses its magnetism when the field is removed



Permanent magnet

- Is a magnet that holds magnetic properties over a long period of time
- It is made from hard material such as steel.

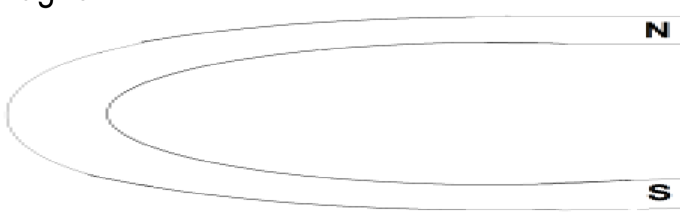
Electromagnetic

- Is a magnet formed when (dc) electric current is allowed to flow through a wire coil wrapped round a metal case

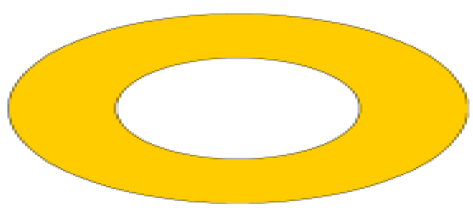
Magnets comes in different shapes include (shapes of magnet)

(a). A bar magnet

(b). A horse-shoe magnet



(c). Disc magnet



Magnet also varies in size include (size of magnet)

- ❖ Tiny discs used in speaker
- ❖ Giant magnets used in power generating plant
- ❖ Largest magnets is perhaps the earth itself

Application of Magnets

Magnets are used in:-

- ✓ **Magnetic recording media:** VHS tapes, audio cassettes, floppy and hard disc recording data on a thin magnetic coating
- ✓ **Common television and computer monitors**
- ✓ **Transformers :**Are used in power transmission and many electronic devices
- ✓ **Credit, Debit and ATM cards:** it uses magnetic ink to store information to contact and individual's financial institution and connect with their account
- ✓ **Speaker and microphones:** They use permanent magnets and current-carrying coils to convert electric energy into sound energy
- ✓ **Electric generator:** It uses permanent magnets convert mechanical energy to electrical energy
- ✓ **Electromagnets used in hospitals or steel works**

Magnetization

- Is the process of making a magnet

OR

- 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

NB:

- ❖ Magnetic dipoles arrange themselves in groups called **''Magnetic Domains''**
- ❖ Materials which are possible to cause this alignment or can be magnetized are either **ferromagnetic** or **paramagnetic**
- ❖ **Ferromagnetic material** is the material which can form permanent magnet. E.g. steel, nickel and cobalt
- ❖ **Paramagnetic material** is the material which can be temporarily magnetized. E.g. Aluminium and chromium

Methods used to magnetize materials

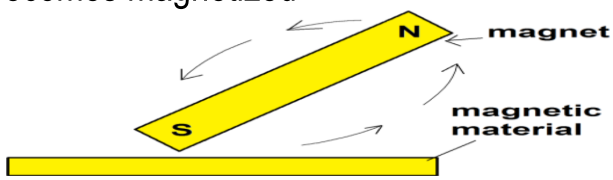
- ❖ By heating and Hammering method
- ❖ By stroking method
- ❖ By electric (solenoid) method
- ❖ By induction

Heating or Vibration Method

- When magnetic material is 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.

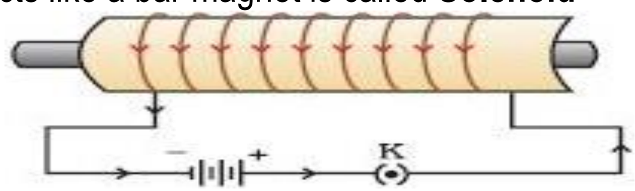
Stroking Method

- The pole of bar magnet is **dragged** along the bar from one end and the other then the material becomes magnetized



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 a bar magnet is called **Solenoid**



By Induction Method

- This is a method of magnetizing an object by placing it in an external magnetic field

NB:

- **Magnetic induction** is the process by which a piece of magnetic material becomes a magnet when it is near or touching a permanent magnet.

Demagnetization

- Is the process of removing magnetism from a given substance or material

  OR
- Is the process of disturbing the domains of an atom in a magnetized material

Methods Used to Demagnetize a Magnet

Heating Method

- If a magnet is placed in the East – West direction and heated to a temperature above its curie temperature, then the magnet loses it magnetism
- This is because, the increase in temperature results in greater atomic vibration which consequently prevent the domain from being aligned in the same direction

Hammering

- The magnet is placed in an East – West direction and then repeatedly hit or stroked with a hammer jarring the domains

Electrical Method

- A magnet is placed in an alternating magnetic field and then drawn slowly from the circuit and then the magnetic field is slowly decreased to zero. This principle is used in commercial demagnetizers to erase credit cards, hard disks etc. (The solenoid must be set in an East – West direction)

Storage of Magnets
In order to maintain the magnetism in magnets for a long period of time, the following practices have to be observed

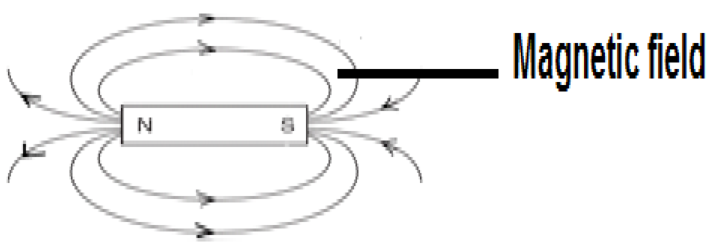
- Store away from ferrous materials
- Store magnets in pairs and using magnetic keeper to store them
- Store away from heat
- Store away from strong electric and magnetic field
- Store away from strong vibration or mechanical impacts which may brittle it

Magnetic field of a Magnet

- Is a space around a magnet where a magnetic force is experienced. (felt)

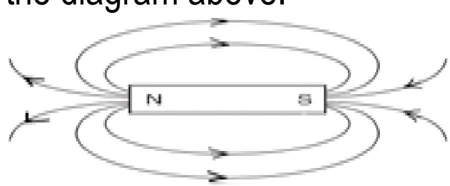
OR

- 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 magnetic force called "**field lines"**. Field lines show the direction of the magnetic force, hence are illustrated using the arrows



Magnetic Lines of force (Field Lines)

- **Are** the imaginary lines that cojoin the poles of a magnet indicating its magnetic field.
- The lines of force point away from the North Pole of a magnet and towards the South Pole, consider the diagram above.



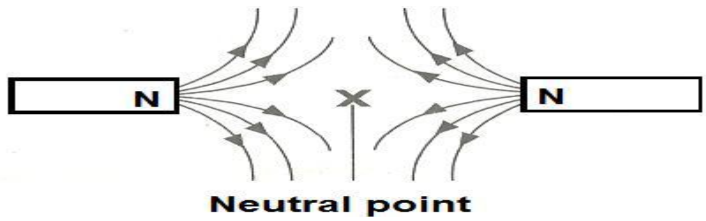
magnetic lines of force around a bar magnet

Properties of Magnetic Lines of force

- Lines of force are continuous and will always form closed loops start at North Pole and end at the South Pole
- Magnetic force is stronger where the lines are close together and weaker where they are far apart
- Lines of force will Never cross one another
- Magnetic lines of force pass through all materials (magnetic and non-magnetic)

- Parallel magnetic lines of force travelling in the same directions repel each other **while** lines of force travelling in opposite directions attract each other
- Magnetic lines of force always enter or leave a magnetic material at right angles (90^0) to the surface

NB: A point where the net magnetic field is zero is called **neutral point**

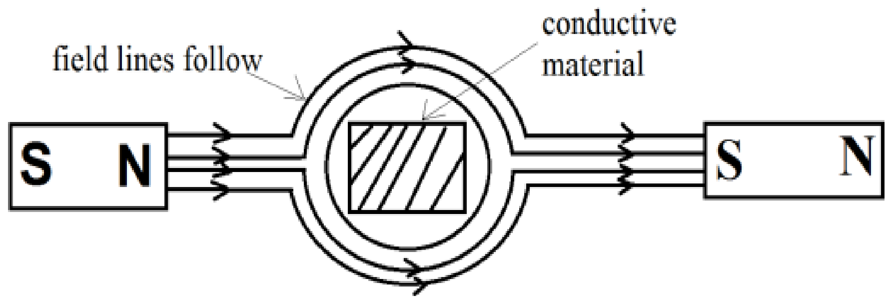


Magnetic Shielding

- Is the process of limiting the flow of magnetic fields between two locations by separating them with a barrier made of conductive material.

OR

- Is the process of limiting the penetration of magnetic fields into a region by redirecting the magnetic field lines through a material with a higher ability to be magnetized.



Earth's Magnetism

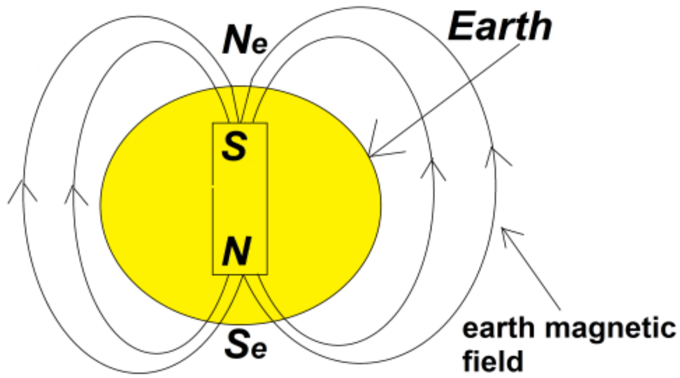
- Earth's Magnetism is the behavior of the earth to act as a magnet

Causes of Earth's Magnetism

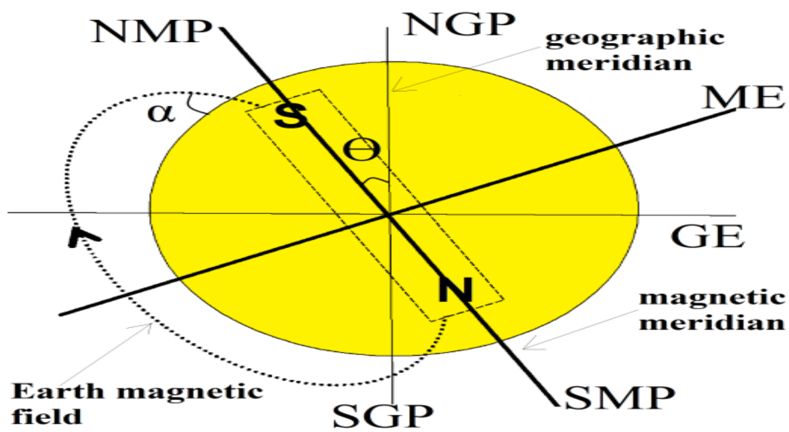
- The earth's magnetism is caused by the induced currents on it due to rotation on its own axis

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 points 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



Whereby:
GE = Geographic Equator
ME = Magnetic Equator
Ɵ = Angle of declination
SMP = south magnetic pole
NMP = north magnetic pole
NGP = north geographic pole
SGP = south geographic pole
α = Angle of dip or angle of inclination

Geographic Equator

- Is the imaginary line which divides the earth into Northern and southern hemisphere.

Magnetic Equator

- Is an imaginary line parallel to the equator where a magnetic needle has no dip

Magnetic Meridian

- Is the imaginary line joining the earth magnetic North Pole and South Pole

Geographic Meridian

- **I**s the imaginary line joining the earth North Pole and South Pole

South magnetic pole (SMP)

- **I**s the pole near the geographic south pole of magnet

North magnetic pole (NMP)

- **I**s the pole near the geographic north pole of magnet

Angle of declination (ϴ)

- **I**s the angle formed between the magnetic meridian and geographic meridian.

Angle of dip or angle of inclination

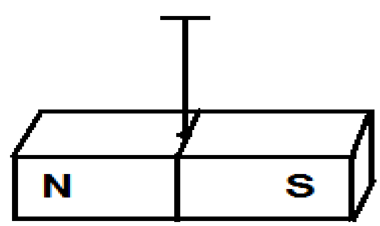
- **I**s the angle between the earth surface and the earth's magnetic field.

NB:

- The angle of dip and declination both vary from place to place
- The angle of inclination is measured by using **Dip needle**
- The angle of dip at the magnetic poles of the earth is **90^0** while at the equator is **0^0**

How to locate the position of the north pole of a bar magnet

- If a bar magnet is suspended so that it rotates freely, one pole of the magnet **will always turn toward the north**, with the opposite pole facing south



A free suspended bar magnet

- The pole of the magnet that orients northward is called the **north pole(N)** while the opposite pole is called **south pole(S)**

Application of the Earth's Magnetic Field

- Used by map – readers for finding locations of different places
- Gives useful information in the search for minerals
- Satellites transmit information through earth's magnetic field to the earth surface
- The earth's external magnetic field (magnetosphere) protects the earth from harmful emissions from the sun.
- The earth's magnetic field enables the compass needle to operate.

Class activity

1. Define the term magnet.
2. State three applications of a magnet
3. Differentiate forces due to magnetic force and the forces due to gravity on the earth
4. State the law of polarity and illustrate this law using large diagrams
5. What is:
   (a) A magnetic field (b) A magnetic line of force
6. Draw a magnetic field around a bar magnet using magnetic lines of force.
7. Why do some watches have a case of iron?
8. State the applications of the earth's magnetic field
9. Match the items in list A with the corresponding ones from list B

List A	List B
(a) Magnetic materials **(b)** Law of polarity **(c)** Magnetic shielding **(d)** Neutral point **(e)** Aluminium	(i) Like poles attract, unlike poles repel (ii) Magnetic field is zero (iii) Redirects magnetic lines of force (iv) Strong magnet (v) Iron nail (vi) Paramagnetic (vii) Direct neutral point

10. Draw the following diagrams:
    (a) Arrangement of domains of atoms
11. Mention any three features of magnetic field lines
12. What is magnetic shielding?
13. Explain how magnetic shielding is done.
14. Why is magnetic shielding necessary?
15. Explain how a ferromagnetic materials get magnetized
16. Briefly explain how a bar magnet can be demagnetized using the electrical method.
17. Explain with illustration how one can locate the position of a north pole of a bar magnet.

TOPIC: 04 FORCES IN EQUILIBRIUM

Moment of a Force

- Is the product of the force applied and the perpendicular distance from a fixed point or pivot

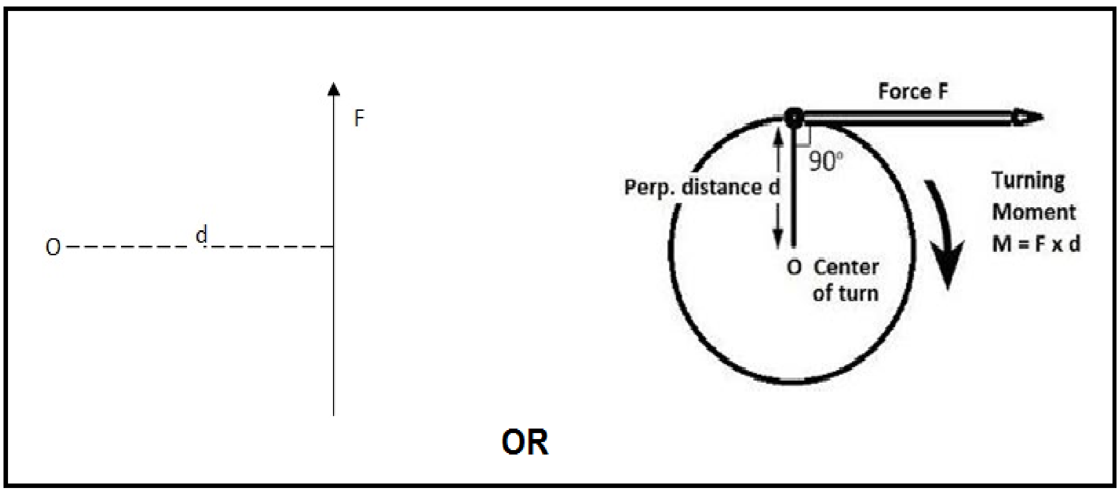
OR

M**oment of a force** is the turning effect of the force about a point

Moment of force = force x perpendicular distance from pivot
$\therefore\ \ \boldsymbol{M = F\,x\,d}$

- **The** SI unit of moment of force is Newton meter **(Nm)**

See the figure below



NB:

- The point where the object rotates after turning force is called **pivot** or **fulcrum**
- Moment of force is applied in different activities such as **opening bottle caps**, **door opening** and **tightening nuts** etc
- The moment of a force depends on the following
  - **a. Size of a force**
  - **b. Perpendicular distance**

Application of Turning Effect in daily life

- **It is app**lied by a hand to unscrew a stopper on the bottle
- **It** is applied by a spanner to unscrew a nut on a bottle
- **It** is applied when turning a steering wheel of a car.
- **A** force is a**pplied to** a door knob and the door swings open about its hinge
- **It is applied** when closing and opening the water tapes.

This gives some reasons as to why:-

- It is easier to open a nut with a long spanner opener than with short spanner fingers (This is **due to the high moment as a result of perpendicular distance arise from the long spanner)**
- It is easier to open the cap of the bottle with a bottle opener than with your fingers(This is due to the addition perpendicular distance arise from the opener)
- Knob on a door is placed as far as possible from the hinges (This is **due to the addition perpendicular distance arise from the hinges to the knob)**

Example,

1. 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

Solution

Data given

Force applied, F = 90 N

Perpendicular distance, d = 2.5 m

Moment, M =?

From

$M = f \times d$

$M = 90\ N \times 2.5\ m$

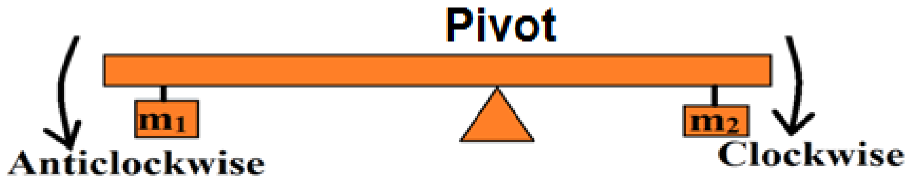
$\therefore$ **Moment of force = 225 Nm**

Individual Task – 1

1. The line of action of a force 48N is at perpendicular distance of 1.5m from the point. Find the moment of the force about the point.
   (**ANS: Moment of the force = 72Nm)**
2. The moment of a force about a point is 1120Nm. If the magnitude of a force is 5600N, find the perpendicular distance between the point and the line of action of the force**. (ANS: Perpendicular distance = 0.2m)**
3. The moment of a force is 1000 Nm. If the line of the force is at perpendicular distance of 100m, find the magnitude of a force.**(ANS: F = 10N.)**
4. **If** 150 N of force is applied on a spanner of 10 cm to open a nut. What is the length on a spanner when a force of 60 N is applied? (**ANS: L = 25 cm)**

Principle of Moments

Consider the ruler below



Now: The principle of moments states that

"When a body is in equilibrium, the sum of the anticlockwise moments about any point is equal to the sum of the clockwise moments"

OR

"***When a system is in equilibrium the sum of clockwise moments is equal to the sum of anti-clockwise moments***"

That is: $\boxed{CM = AM}$

Whereby:

M = F x d

CM = Clockwise moment (F_1d_1)

AM = Anticlockwise moment (F_2d_2)

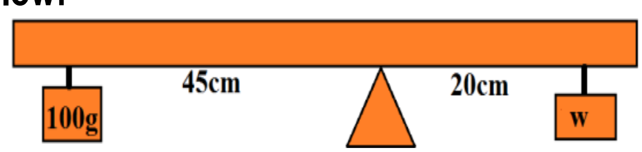
$$\boxed{\therefore F_1d_1 = F_2d_2}$$

Example,

1. A 100 g weight is suspended 45 cm from the pivot, of a light rod. If a weight w suspended 20 cm from the pivot balances the 100 g weight. Find weight w.

Solution

See the diagram below:



From: The principle of Moments, C.M = A.M ($M_1 = M_2$) , and $M = F \times d$

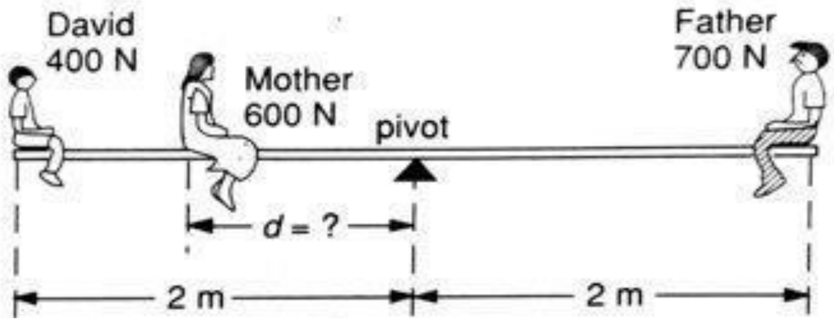
But: $F = m \times g$

Now: $m_1 \times g \times d_1 = m_2 \times g \times d_2 \rightarrow 100 \times 10 \times 45 = w \times 10 \times 20$

$100 \times 10 \times 45 = 200\,w \rightarrow \therefore w = 225$ N (**m = 22.5 g**)

Individual Task – 2

1. A uniform meter 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? (**ANS**: **d =26 cm)**
2. 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? (**T = 1.56 N)**
3. 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.



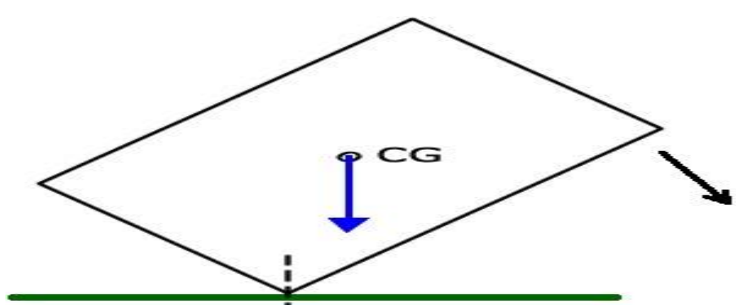
(ANS: Therefore, David's mother is sitting 1m from the pivot)

Application of Principle of Moments

- Used to unscrew a stopper on the bottle
- Used to unscrew a nut on a bolt
- Used to open a metal cap from a bottle of soda, etc
- Turning a steering wheel of a car
- When the door is opened, the force on the handle exerts a turning effect about the hinges

Center Of Gravity

- The weight of body is due to the attraction of the earth for its particles.
- This attracting force is the weight of each individual particle. Since the body consists of many particles then the weight is the resultant of all the parallel forces acting on the individual particles as shown below.



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

∴ **The center of gravity:** **Is the point through which the resultant of the weight of all the particles of the body acts**

OR **Is the point where the force of gravity can be considered to act**

OR **Is the point on a body along which all the weight of the body is likely to act**

Difference between centre of gravity and centre of mass

Centre of gravity	**Centre of mass**
Is the point at which the whole weight of the body is likely to act	Is the point at which the whole mass of the body is assumed to be concentrated
Weight distribution of the body around centre of gravity is uniform	**The** mass distribution around the centre of mass is uniform
It changes with the change in the force of gravity	**It** remains unchanged with the change in the gravitational field

Couple

A couple Is a pair of equal but opposite parallel forces applied to the same body but not acting in the same line

Characteristics of a couple

- Comprises a pair of forces
- The forces must be equal
- The forces must be parallel
- The forces must act in opposite directions

Moment (torque) of a couple

- Is the product of one of the anti – parallel forces, F by the perpendicular distance between them.

Equilibrium

- Is a state achieved by a body when all the forces which act upon it are balanced

OR Is the state of a body to balance

NB: The force which brings a body into mechanical equilibrium is called "Equilibrant"

Conditions for a body to be in equilibrium

- The net force on the object must be zero
- The system (body) must have an acceleration of 0 m/s^2

OR (also you can state in this way)

- The sum of the forces in one direction must be equal to the sum of the forces in the opposite direction
- The Sum of clockwise moment should be equal to the sum of anticlockwise moment

Conditions for equilibrium depends on three factors

- Magnitude
- Direction of forces
- Point of application

Factors which affecting the stability of a body

A stable body should have:-

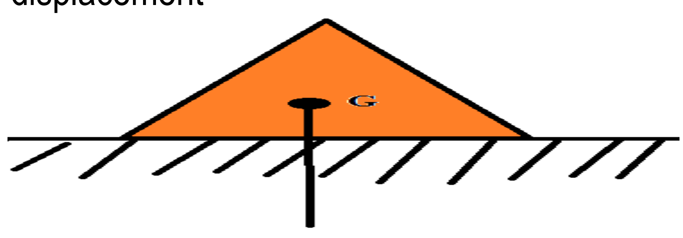
- Wide base
- Low centre of gravity

Types of Equilibrium

- Stable equilibrium
- Unstable equilibrium
- Neutral equilibrium

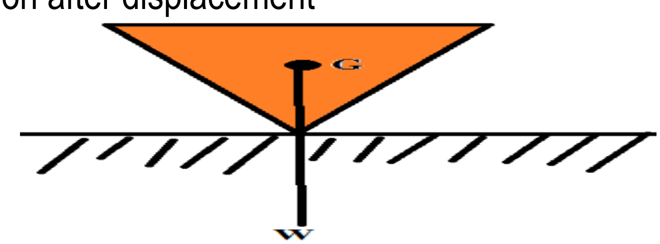
Stable Equilibrium

- This occurs when a body is slight displaced and then it returns to its original position after displacement



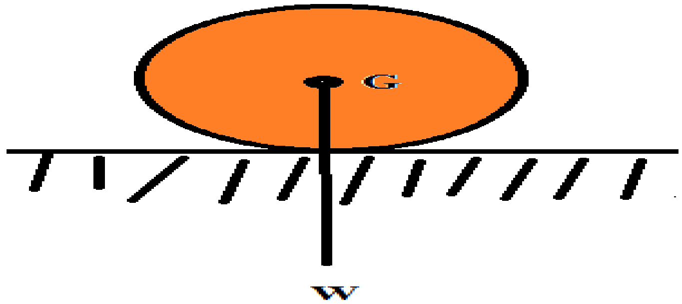
Unstable Equilibrium

- It occurs when a body is slight displaced and the body it does not returns to its original position after displacement



Neutral Equilibrium

- This occurs when a body is slight displaced and the body does not alter the position of the center of gravity

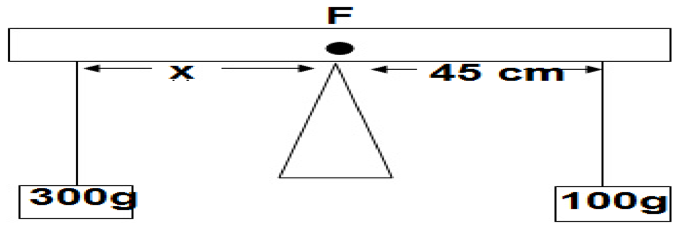


Application of Equilibrium

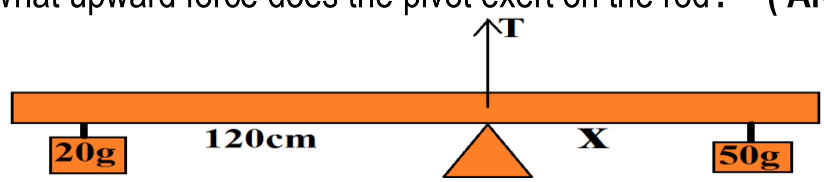
- Vehicles used in a car race have tyres wide apart to increase stability
- **Cambered wheels**: The wheels of a car are slightly tilted to increase stability. That is why when a car is tilted to the side, it only skids
- Used in designing of structures like bridges, Aeroplane, furniture, machines, car boats, ships etc
- Our bodies muscles are always kind of equilibrium that is why we can walk, seat, eat, run, squat, jump etc
- Tall structures such as buildings and pylon, they have wide base and low centre of gravity hence provide stability
- Bus (car) with seated passengers and loading the lower compartments is more stable than one with standing passengers and loaded at the top
- Ships have long and wide projecting plates extending from their bases into the water to increase stability
- **Beam balance -** used for measuring masses of different objects by comparison with known masses.
- **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.
- **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

Class Activity

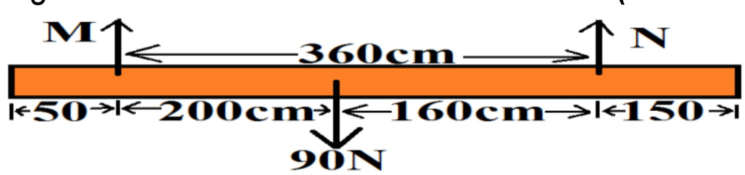
1. A spanner of length 40 cm is used to tighten a bolt. A force of 400 N is used. Calculate the moment of the force (**ANS: 160 NM**)
2. Abuu has a mass of 60 kg and he is sitting on a see – saw at a distance of 2.5 m from the pivot .Calculate the moment due to his weight
3. If a 100g weight is used to balance the weight determine the distance of the 300g weight from the point. (**ANS: x = 15 cm)**



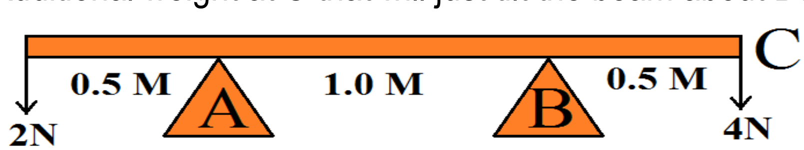
4. A heavy uniform beam AB of weight 500 N is supported at its ends. The beam carries a weight of 3000 N at a distance of 1.5m from the end A. if the beam is 4m long. Find the thrust (tension) / reaction at A and B **(ANS: 1375 N, 2125 N)**
5. Explain what is meant by stable, unstable and neutral equilibrium. Give one example of each
6. Explain what is meant by
   (i) Moment of a force about a point
   (ii) Centre of gravity of a body
   (iii) Equilibrium
   (iv) Equilibrant
7. A metallic rod of 2 m long has a mass of 500 g. The rod is balanced on a wedge when a 50 g solid is hung 40 cm from one of its ends. The wedge is 85 cm from the same end
   a) Sketch a diagram of the arrangement
   b) How far is the wedge from the centre of the metallic rod?
8. The diagram below shows a 150g rod balanced at its centre of gravity. A 20g mass is placed 120cm from the pivoted point
   a. Find the value of x **(ANS: 48 cm)**
   b. What upward force does the pivot exert on the rod**?** **(ANS: 0.7 N)**



9. From the diagram below calculate reaction M and N **(ANS: M = 40 N, N = 50 N)**



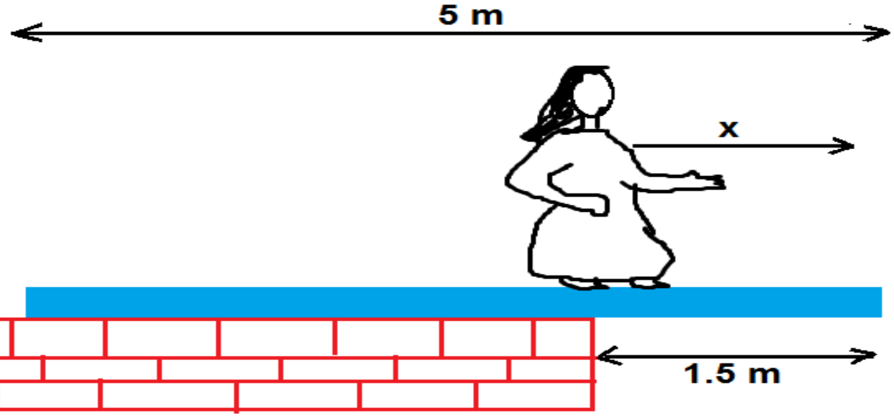
10. From the diagram below calculate
    i. Reaction A and B **(ANS: A = 1 N, B = 5 N)**
    ii. Additional weight at C that will just tilt the beam about B? **(C = 2 N)**



11. A metre rule is pivoted at its mid – point. If two objects of weight 1.0 N and 2.0N are suspended at 30 cm and 90 cm respectively from one end ,calculate

the position where an upward force of 3.0 N must be applied in order for the metre rule to balance horizontally (**ANS: 20 cm from pivot or 70 cm mark)**

12. A Uniform wooden plank with a mass of 75 kg and a length of 5 m is placed on top of a brick wall so that 1. 5 m of the plank extends beyond the wall's edge. How far beyond the edge of the wall can 100 kg woman walk before the plank began to rotate ?(Let the plank's axis of rotation be at the wall's edge)



13. A pole AB of length 10.0 m and weight 800 N has its centre of gravity 4.0 m from the end A and lies on a horizontal ground. The end B is to be lifted by a vertical force applied at B. Calculate the least force that is required to do this

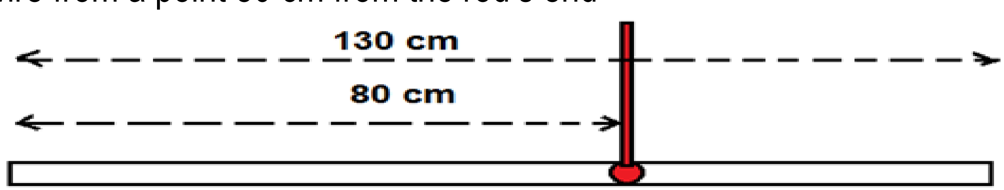
14. Does an object have to be at rest to be in a state of equilibrium? Explain your answer

15. A tree trunk of length 44 m is pivoted 12 m from one of its ends. It is balanced when a 1500 N solid is hung 8 m from the pivot. Calculate the weight of the tree trunk **(W = 1200 N)**

16. It is found that a uniform wooden lath 100 cm long and of mass 95 g can be balanced on a knife – edge when a 5 g mass is hung 10 cm from one end .How far is knife – edge from the centre of the lath? (**ANS: 2 cm)**

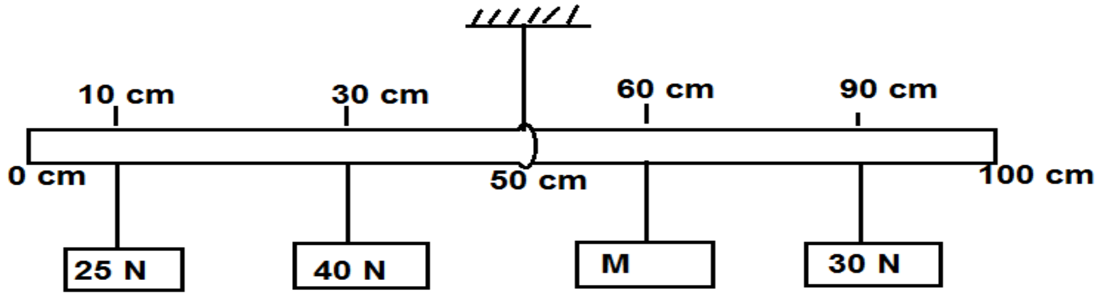
17. **State** the conditions of equilibrium when a body is acted upon by a number of parallel forces. A uniform metal tube of length 5 m and mass 9 kg is suspended horizontally by two vertical wires attached at 50 cm and 150 cm respectively from the ends of the tube. Find the tension in each wire **(ANS: 30 N, 60 N)**

18. A uniform rod with a mass of 120 g and a length of 130 cm is suspended by a wire from a point 80 cm from the rod's end



What mass must be hang from the right end of the rod for it to be in equilibrium? What will be the tension in the wire? **(m = 36g (w =0.36 N) ,T= 1.56 N)**

19. A uniform metre rule is pivoted at the centre is balanced by four suspended forces as shown in the figure below. Calculate the force exerted in the 60 cm mark (**ANS: 60 N)**



20. Mention the four properties (features) of a couple

21. Two parallel and opposite forces acted on the handle of a bicycle. Each of the forces had a magnitude of 45 N. The distance between them was 50 cm .What is the torque produced?

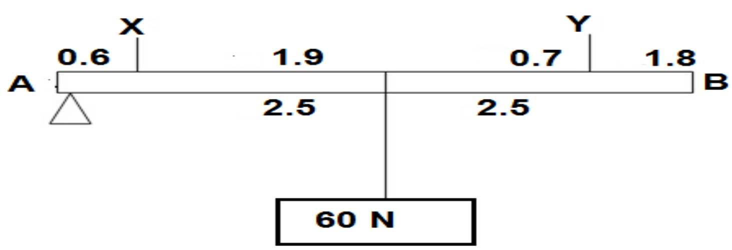
22. A uniform wooden bar AB of length 120 cm weighing 1.2 N rest on two sharp edged supports C and D placed 10 cm from its either ends .A 0.2 N load hangs from a loop of a string 30 cm from A and a 0.9 N load hangs at 40 cm from B. Find the: (i) Reaction at C **(ii)** Reaction at D

23. A uniform metre rule of weight 0.9 N is suspended horizontally by two vertical loops of thread A and B placed at 20 cm and 30 cm from its ends respectively. Find the distances from the centre of the rule at which a 2 N weight must be suspended

(a) To make loop A become slack **(ANS: 29 cm)**

(b) To make loop B slack (**ANS: 43.5 cm)**

24. A uniform bar AB of height 5m weights 60N. The bar is supported at a horizontal position by two vertical strings X and Y. If string X is 0.6m from A and string Y is 1.8m from B. Find the tension in the string**. (ANS: 16.5 N)**



25. A uniform half metre rule is freely pivoted at the 15 cm mark and it balances horizontally when a body of mass 40 g is hung from the 2 cm mark.

a) Draw a clear force – diagram of the arrangement

b) Calculate the mass of the rule

26. Explain the following:-

a) Why a loaded test tube floats upright?

b) It is more difficult to balance a nail on its tip than on its base

c) A bus carrying a very big load on its carrier can easily overturn

27. A metre rule of weight 1.0 N is supported horizontally on two knife edges each placed 10.0 cm from its ends. If the weight of 1.5 N is placed at its mid – point , calculate the reaction at the supports.

28. A simple weighing machine is made of a uniform bar 125 cm long and mass 5 kg and pivoted 2.5 cm from one end .Find the mass that must be suspended at the end of the short arm. (**ANS: m = 4.08 kg)**

29. A 2.0 N weight placed on a 10 cm mark of a meter rule just balances an object hanging from the 60 cm mark. Calculate the weight of the object. **(ANS: W =8N)**

30. **H**ow can a metre rule be balanced on a knife edge?

31. **B**riefly explain why the handle of a door is near its outside edge?

32. Two spheres of mass 3.0 kg and 2.0kg are joined by a light rod so that their centers are 0.45 m apart. Locate the center of gravity of the system.

33. **De**fine centre of gravity. Hence outline the main difference between the centre of gravity and centre of mass.

34. **List** the factors that affect the stability of a body

35. Explain why racing cars should have wide wheel tracks.

36. Define turning effect of force and give its SI unit

37. Why should a mechanic choose a long spanner to undo a tight nut?

38. A uniform half meter rule is pivoted at its 30 cm mark. A mass of 50 g hung at the 45 cm mark keeps the rule horizontal. Determine the mass of the half meter rule.

39. Force applied by a lady is 2 N and moment of force is 16 Nm, distance of pivot from effort would be --------------

40. **(a) W**hat is meant by balanced beam?

    (b) A uniform rod AB of mass 6.0 g is balanced horizontally about a knife edge at a distance of 3 cm from end A where a mass of 8.0g is hanging. Find the length of the rod (**ANS: L= 14 cm)**

41. Moment of force applied on a door is 15 Nm and force applied is 3.75 N, distance of the handle from the pivot is -------------

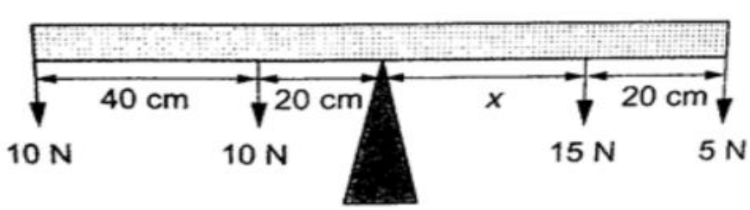
42. Door hinge is about 1.5 m away from handle, and a boy applies a force of 4 N. What will be the moment of force applied?

43. Bilqees has a weight of 300 N and sits 2.0 m from the pivot of see – saw. Asia has a weight of 450 N and sits 1.5 m from pivot. Who will move down

44. A uniform meter rule of weight 16 N is pivoted at the 60 cm mark. A 4.0 N weight is suspended from one end .At the instant when the rule is horizontal, what is the value of the resultant turning moment about the pivot.

45. A 2.0 N weight placed on the 10 cm mark of a meter rule just balances an object hanging from the 60 cm mark. Calculate the weight of the object. (**w= 8 N)**

46. Study the diagram below and determine the value of X and hence the length of the bar. **(ANS: L = 115 cm)**



TOPIC: 05 SIMPLE MACHINES

Machine Is any device by means of which a force applied at one point can be used to overcome a force at some other point

OR

Is any device which is used to simplify work.

OR

Is any device that uses energy to perform some activity (work) by making an applied force larger

Examples are screw driver, pulley, inclined plane, bicycle, typewrite, car. etc

Types of Machine

- Simple machine
- Complex machine

Simple Machine

- Is any device that requires the application of a single force to do work

  OR

  Is a mechanical device that helps to make work easier

- *Examples are* ***Screw driver, Crowbar, See-saw, Pulleys, Inclined plane, Hydraulic systems ,Levers ,wheel and axle*** **etc**

Complex Machine

- A Complex Machine is a combination of more than one simple machine.
- Examples are Bicycle*, Typewriter, Car, Sewing machine* etc

Terms Used

Effort (E)

- *Is a force which is applied to the machine so as to lift an object*.

OR is the force used to operate a machine

- Its SI unit is **Newton (N)**

Load (L)

- Is the resistance which a machine over comes

OR **Is the object to be moved from one place to another**

- Its SI is Newton

Mechanical Advantage (MA)

- *Mechanical advantage is the ratio of the load to the effort*.
- It has no SI unit

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

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

Example

1. 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?

Solution:

Given: Effort, E = 1000kg = 1000N

Load, L = 500kg = 5000N

Mechanical advantage, MA =?

From: MA = L/E

$\therefore \boldsymbol{MA = \frac{5000}{1000}}$ **= 5**

Velocity Ratio (VR)

- *Velocity ratio is the ratio of the distance moved by the effort to the distance moved by load*.

$$\textbf{Velocity Ratio} = \frac{\boldsymbol{Effort\ distance}}{\boldsymbol{Load\ distance}} \quad \rightarrow \quad \boldsymbol{V.R = \frac{Ed}{Ld}}$$

- Velocity Ratio has no SI unit.
- Velocity ratio does not affected by friction

Example

1. 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'

Solution:

Given: Distance moved by effort, Ed = 100 cm

Distance moved by load, Ld = 25 cm

Required: Velocity ratio, VR =?

From: **VR =** $\boldsymbol{\frac{Ed}{Ld} = \frac{100}{25} = 4}$

Work Output (WO)

- Work output is the product of load and distance moved by the load.

Work output = L × Ld

Work Input (WI)

- Is the product of effort and distance moved by the effort

Work Input = E x Ed

Efficiency of a machine

- Is the ratio of the useful work derived from a machine to the energy put into it

  OR

  Is the ratio of the work output to the work input

- **NB: This ratio is always expressed as a percentage.ie**

$$\text{Efficiency} = \frac{\boldsymbol{Work\ out\ put}}{\boldsymbol{Work\ input}}\ \boldsymbol{x}\ \mathbf{100\%}$$

Since: Work Out put = L × Ld
Work Input = E × Ed

Now, **Efficiency =** $\frac{\boldsymbol{L \times Ld}}{\boldsymbol{E \times Ed}} \times \mathbf{100\%} = \frac{\boldsymbol{L}}{\boldsymbol{E}}\ \boldsymbol{x} \frac{\boldsymbol{Ld}}{\boldsymbol{Ed}}\ \boldsymbol{x}\ \mathbf{100\%}$

But: $\frac{\boldsymbol{Ld}}{\boldsymbol{Ed}} = \frac{\mathbf{1}}{\boldsymbol{V.R}} \quad \boldsymbol{and}\ \frac{\boldsymbol{L}}{\boldsymbol{E}} = \boldsymbol{M.A}$

On Substituting:

$$\therefore\ \boldsymbol{Efficiency} = \frac{\boldsymbol{M.A}}{\boldsymbol{V.R}}\ \boldsymbol{x}\ \mathbf{100\ \%}$$

NB:

- **The mechanical efficiency of a machine is always less than 100% .This is because some energy is lost as heat due to friction**
- **A frictionless (ideal/perfect) machine would have an efficiency of 100%**

Example

1. 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

Solution:

Given: Velocity ratio, VR = 5
Work input, WI = 600 J
Load, L = 400 N
Load distance, Ld = 0.5 m

Mechanical advantage, MA =?
Efficiency, Eff =?

From: Eff = $\frac{WO}{WI}\ x\ 100\%$

Since: WO = L × Ld = 400 × 0.5 = 200

∴ Efficiency = $\frac{200}{600}\ x\ 100\% = 33.33\%$

But: Efficiency = $\frac{MA}{VR}$ × 100% ⟶ 33.33% = (MA/5) × 100%

∴ MA = (33.33% × 5) /100% = 1.67

Individual Task – 1

2. In a certain machine a force of 10N moves down a distance of 3cm in order to raise a load of 10N through a height of 0.5cm. Calculate the velocity ratio of the machine. (**ANS: 6)**
3. A certain machine is designed in such a way that a force of 150N is used to lift load of 600N. What is the mechanical advantage **(ANS: 4)**
4. 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 (**ANS: 20%)**
5. A simple machine was used to raise a load of weight 3920N through a height of 3.5m by applying an effort of 980N, if the distance moved by the effort was found to be 20m, find.

   (i) The mechanical advantages **(ANS: 4)**
   (ii) The velocity ratio (**ANS: 5.71**)
   (iii) The efficiency of the machine **(ANS: 70)**

Types of Simple Machine

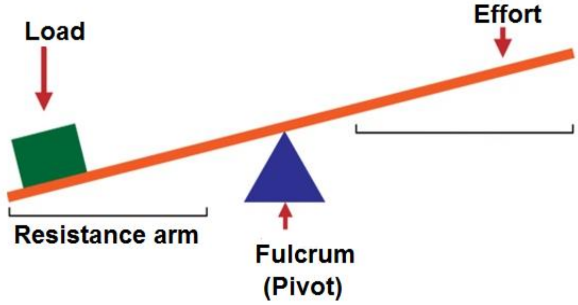
There are different types of simple machines but here we shall discuss the common forms of machines. This include

- **Levers**
- **Pulley**
- **Inclined planes**
- **Screw jack**
- **Wheel and axle**
- **Hydraulic press**

Levers

- A lever is a rigid bar (board or rod) that is supported on a single point around which it rotates
  OR
  A Lever is a rigid body which when in use turns about a fixed point

- A lever has three main parts, these are **Fulcrum, Load arm and Effort arm**



NB:

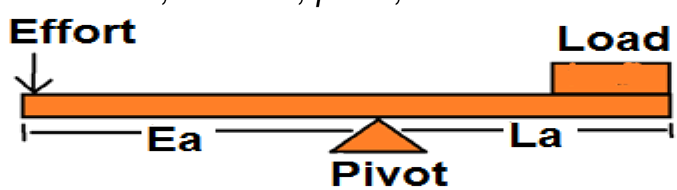
- **The** lever is used to lift heavy weights with the least effort (**the longer the bar the easier it is to lift the load)**
- The fixed point is called **Pivot (Fulcrum)**
- **Fulcrum** is the fixed point about which the bar moves
- Examples of levers are *wheel barrow, a pair of scissors, a shovel* etc**.**

Classes of Levers

- First class levers
- Second class levers
- Third class levers

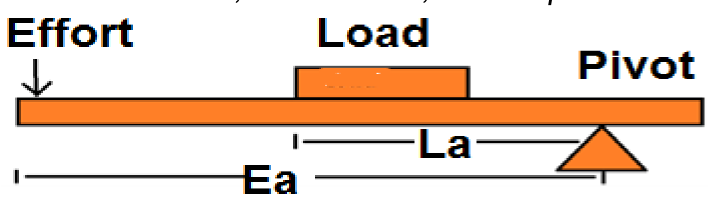
First Class Levers

- In a first class lever ,the pivot is located between the effort and the load
- Examples are *crowbars, scissors, pliers, see-saws* etc. See the fig below



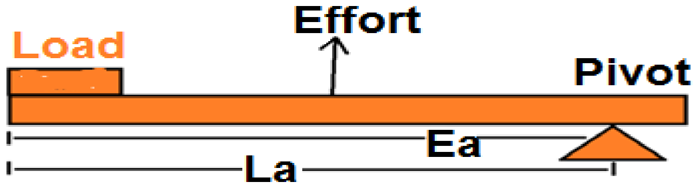
Second Class Levers

- In a second class lever ,the load is located between the pivot and the effort
- Examples are *wheelbarrows, nutcrackers, bottle openers* etc



Third Class Levers

- ✓ In a third class lever ,the effort is applied between the pivot and the load
- ✓ Examples are *shovel (spade), tweezers, fishing rod, tongs,* etc



Mechanical Advantage of Levers

- ✓ Is the ratio of effort arm (E_A) to the load arm, (L_A)

$$\boxed{M.A = \frac{E_A}{L_A}}$$

NB:

- Effort arm (Ea) is a distance between fulcrum and effort
- Load arm (La) is a distance between fulcrum and load
- MA of second class is greater than fist class lever
- MA of third class is less than fist class lever

Example,

1. 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

Solution:

Given: Load, E = 30 N
Effort, E = 150 N
Required: Mechanical advantage, MA =?
From: MA = L/E = 150/30 **= 5**

Velocity Ratio of Lever

$$\boxed{V.R = \frac{Ed}{Ld}}$$

Where: Ed = distance moved by effort, Ld = distance moved by load

Efficiency of Lever

$$Efficiency = \frac{work\ output}{work\ input}\ x\ 100\%$$

Individual Task – 2

1. 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 **(ANS: V.R = 10)**
2. 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 **(ANS: Eff = 75%, M.A = 4.5)**
3. 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 (**ANS: 30 m**)
   b) Force/effort required lifting a load weighing 75N **(ANS: 7.4 N)**

Uses of Lever in Daily Life

- Used in pair of scissors and tong
- Used in wheelbarrow to carry sand
- Spanner types like (wrenches) used by plumbers, electrician etc
- Crowbar to remove nails from piece of wood
- Fishing rod

Pulley

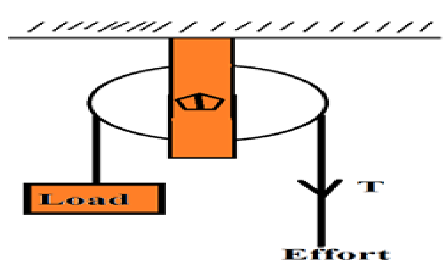
- Is a simple machine that consists of a **wheel** that rotates around a point called **axle**
- **T**he tension in the rope is the same at all points in an ideal pulley

Types of Pulley

- Single fixed pulley
- Single movable pulley
- Combination pulley
- The block and tackle pulley system

Single Fixed Pulley

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



A single fixed pulley

For single fixed pulley

- Neglecting the weight of the rope and friction of the pulley, the tension in the rope is equal to the effort and the load is equal to the effort applied on it.
- **Effort (E) = tension (T) = load (L), that is E = L**

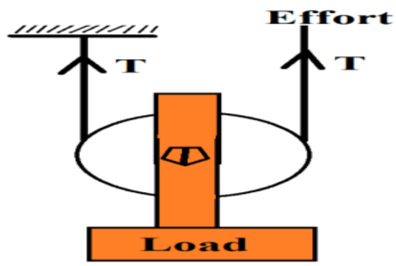
  $$\therefore M.A = \frac{L}{E} = \frac{L}{L} = 1$$

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

  $That\ is\ Ed = Ld$ $\therefore V.R = \frac{Ed}{Ld} = \frac{Ed}{Ed} = 1$

Single movable Pulley

It consists of one pulley which is free to move.



For single movable pulley

$MA = \frac{L}{E}$

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

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

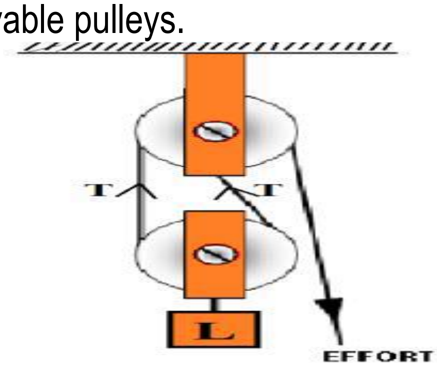
- When the effort moves a distance x, the two sections of the string each are shortened a length half x, Therefore the load moves upwards through a distance half x.

  $$V.R = \frac{Distance\ moved\ by\ the\ effort}{Distance\ moved\ by\ the\ load} = \frac{x}{\frac{1}{2}x} = 2$$

- Therefore: Velocity ratio = 2

Combined Pulley

It consists of fixed and movable pulleys.



For combined pulleys

- $MA = \frac{L}{E}$
- From the diagram above, the effort, E, moves a distance equal to **nx** while the Load, L moves a distance equal to **x** (This is because each of the two ropes bearing the Load ,L moves a distance equal to $\frac{x}{2}$ **.Then the distance moved by the effort is 2x , ie for n =2)**
- **Whereby:**

  x = distance moved by load and effort

  n = number of pulley (number of rope pull the road)
- Now, **Ed = nx and Ld = x Thus:** $VR = \frac{Ed}{Ld} = \frac{nx}{x} = n$

Therefore: VR = n (number of pulleys/ number of ropes pull the load)
From the diagram above: n = 2, therefore its **VR = 2**

The Block and Tackle Pulley

- Is a combination pulley that consists of several fixed and movable pulleys
- It is used in sailing ships to lift heavy sails

Individual Task – 3

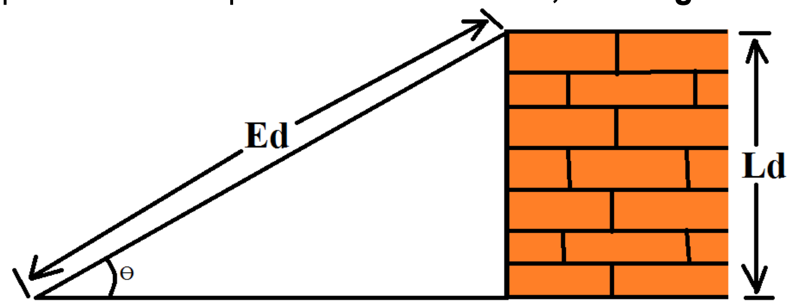
1. A pulley system is made up of 8 pulleys. An effort of 200 N is applied on the pulley system, if the pulley system has an efficiency of 80%. Find the maximum load (**ANS: L =1280 N)**
2. A block and tackle pulley system has a VR of 4, if a load of 100 N is raised by using a force of 50 N. find the mechanical advantage and Efficiency (**ANS: M.A = 2, Eff = 50%)**
3. A simple pulley system has velocity ratio of 3, if its efficiency is 90%. Find the load which can be raised by an effort of 100 N **(ANS: L= 270 N)**

Uses of Pulleys in Daily Life

- ❖ Applicable in winches for building works
- ❖ Uses as transport tourist up mountain slopes
- ❖ Used by fisher man to lift heavy clothes which used to move their boat as done at Mtwara coast
- ❖ Used in garage to lift car engine
- ❖ Used for fetching water in the well

Inclined Planes

- An inclined plane is a smooth flat rigid surface slanted at an angle to the horizontal.
- Examples of inclined planes are **staircases, winding roads** and **ramps**.



Whereby:
Vertical height = Load distance (Ld)
Slanted height = Effort distance (Ed)
Therefore:

- **M.A =** $\boldsymbol{\frac{L}{E}}$
- **V.R =** $\boldsymbol{\frac{Ed}{Ld}}$
- But $Sin\theta = \frac{(load\ distance)}{(Effort\ distance)} = \frac{h}{d}$
- **V.R =** $\boldsymbol{\frac{1}{\frac{h}{d}} = \frac{1}{Sin\theta}}$
- $\boldsymbol{Efficiency = \frac{M.A}{V.A} \times 100\%}$

N.B:
For smooth (frictionless) inclined plane

$$\boxed{\textbf{MA = VR =} \frac{Ed}{Ld} = \frac{1}{Sin\theta}}$$

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) **MA =**$\frac{L}{E} = \frac{3000}{600} = 5$

b) **VR =** $\frac{Ed}{Ld} = \frac{18}{3} = 6$

c) **Efficiency =** $\left(\frac{MA}{VR}\right) \times 100\% = \frac{5}{6}\ x\ 100\% = 83.3\%$

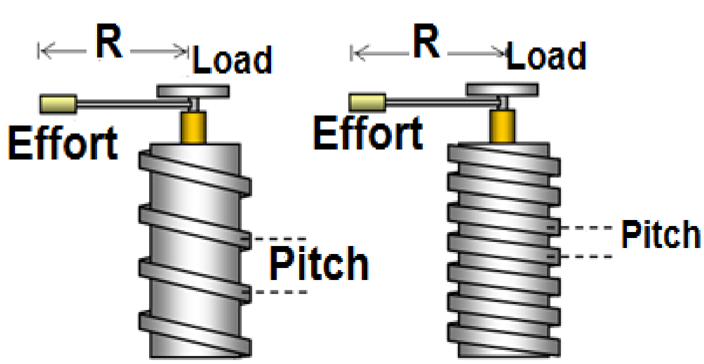
Individual task – 4

1. 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 **(ANS: V.R = 8, M.A = 5.3, Efficiency = 66.7%)**

Screw and Screw Jack

A screw is a form of an inclined plane in which the plane is wrapped around a rod

- Screw jack consists of a rod in which there is a thread
- The distance between two successive threads is referred to as **PITCH**
- **T**he M.A of a screw jack depends on its pitch
- **Pitch** = $\frac{length\ of\ the\ rod\ in\ cm}{number\ of\ threads}$



Mechanical advantage and Velocity ratio of a screw jack

- **MA =** $\frac{L}{E}$

- **VR =** $\frac{Ed}{Ld} = \frac{\textbf{circumference of a circle made by the turning arm}}{\textbf{Pitch of the screw}} = \frac{\mathbf{2\pi R}}{\mathbf{P}}$

$$\boxed{\therefore\ \boldsymbol{V.R} = \frac{\mathbf{2\pi R}}{\mathbf{P}}}$$

But:

a) **Efficiency =** $\frac{MA}{VR} \times \mathbf{100\%}$

NB:

- There is always much friction in a jack. In practice, more than half of the work done is wasted by friction. **A jack without friction is useless because the load or car would fall down as soon as the effort was removed**

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)

Solution:

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 =?

From: P = x/y

P = $\frac{l}{no.of\ threads} = \frac{1}{5} = \mathbf{0.2\ cm}$

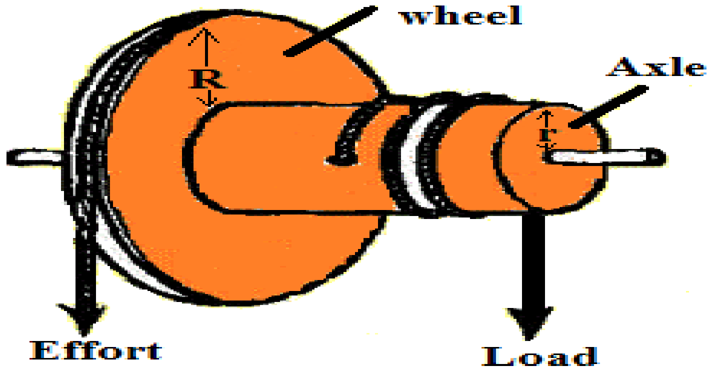
Also: VR = $\frac{2\pi R}{P} = \frac{2x3.14x20}{0.2} = \mathbf{628}$

Individual Task – 5

1. 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.
   (ANS: V.R = 1256 , M.A =1130.4 , E_{min} = 17.7 N E_{max} = 19.7 N)
2. 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% (**ANS: 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



Whereby:

Circumference of axle = Load distance (Ld)
Circumference of wheel = Effort distance (Ed)
Radius of wheel = R
Radius of axle = r

For wheel and axle

- $M.A = \frac{L}{E}$
- $V.R = \frac{Ed}{Ld} = \frac{2\pi R}{2\pi r} = \frac{R}{r}$
- $efficiency = \frac{M.A}{V.R}\ x\ 100\%$

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: $VR = \frac{R}{r} \rightarrow R = VR\ x\ r = 6x5 = 30\ cm$

(b) If radius of axle, r = 8 cm

But: $VR = \frac{R}{r} \rightarrow R = VR\ x\ r = 6x8 = 48\ cm$

(c) If radius of axle, r = 12 cm

But: $VR = \frac{R}{r} \rightarrow R = VR\ x\ r = 6x12 = 72cm$

Individual Task – 6

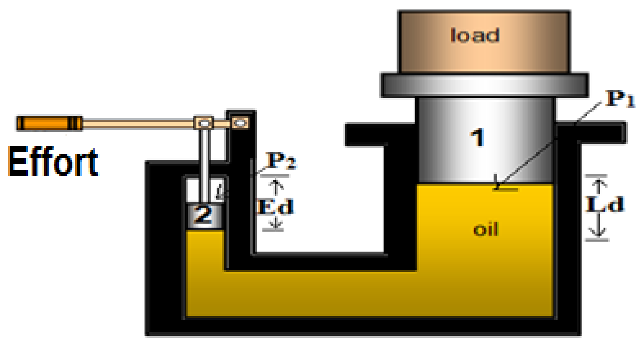
A wheel and axle with an efficiency of 90% is used to raise a load of 10000 N. the radius of the wheel is 40 cm while radius of the axle is 5 cm. find Velocity ratio, Mechanical advantage and Effort (**ANS: V.R = 8, M.A = 7.2, E = 1388.9 N**)

Uses of wheel and axle in daily Life

- Applied in riding a bicycle
- Used to fetch water in a 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



Assume there is no friction force (By principle of transmission of pressure in liquids, the pressure on effort piston equal to that on the load piston.)

That is **$P_1 = P_2$**

But: $P = \frac{F}{A}$

Whereby: $F_1 = E = P_1A_1$, $F_2 = L = P_2A_2$

Since M.A $= \frac{L}{E} = \frac{P_2A_2}{P_1A_1}$ $\boldsymbol{, but\ P_1 = P_2}$

$\boldsymbol{thus\quad M.A = \frac{A_2}{A_1}}$

Whereby: $A_2 = \pi R^2$ and $A_1 = \pi r^2$

$$\therefore M.A = \frac{\boldsymbol{R^2}}{\boldsymbol{r^2}}$$

- **Thus in practical cases, the mechanical advantage is less than $\frac{R^2}{r^2}$ due to frictional forces in the hydraulic press .Therefore the efficiency of a hydraulic press is less than 100%**

Velocity ratio of a hydraulic press

- Assuming that, the hydraulic press is frictionless then
  work output = work input
- That is L x Ld = E x Ed ------------------------ divide by E and Ed both sides

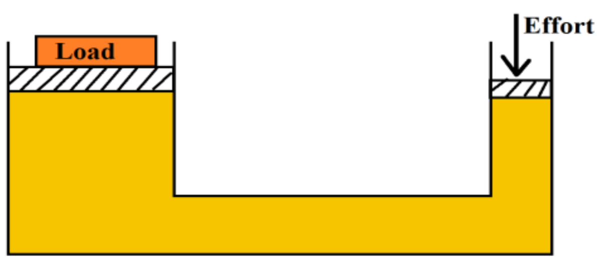
$$\frac{L}{E} = \frac{Ed}{Ld}$$

- But $M.A = \frac{L}{E} = \frac{R^2}{r^2}$
- $\therefore V.R = M.A = \frac{R^2}{r^2}$ **(if the hydraulic press is 100% efficient)**

Therefore for hydraulic press

- $MA = \frac{L}{E}$
- V.R = $\frac{R^2}{r^2}$
- $Efficiency = \frac{MA}{VR} \; x\ 100\%$

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) **V.R =** $\frac{\boldsymbol{R^2}}{\boldsymbol{r^2}} = \frac{\mathbf{5^2}}{\mathbf{0.2^2}} = \frac{\mathbf{25}}{\mathbf{0.04}} = \mathbf{625}$

b) From **Efficiency =** $\frac{\boldsymbol{M.A}}{\boldsymbol{V.R}} \times \mathbf{100\%}$ ……………….. make MA the subject

∴**MA =** $\frac{\boldsymbol{(eff\ x\ V.R)}}{\mathbf{100}} = \frac{\mathbf{90\ x\ 625}}{\mathbf{100}} = \mathbf{562.5}$

c) **From:** MA = $\frac{L}{E}$ ------------------- make E the subject

$$\therefore \boldsymbol{E} = \frac{\boldsymbol{L}}{\boldsymbol{MA}} = \frac{\mathbf{100000}}{\mathbf{562.5}} = \mathbf{177.78}\ \boldsymbol{N}$$

d) **From:** $VR = \frac{Ed}{Ld}$ ---------------- make Ld the subject

$$\therefore Load\ distance = \frac{Ed}{VR} = \frac{1}{625} = 0.0016\ m$$

Uses of Hydraulic Press in Daily Life

- It lifts heavy loads
- In ginneries to compress a lump of cotton into small bales
- In industries to form car bodies into the required shapes

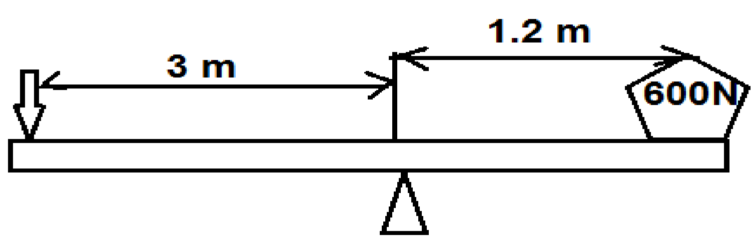
Class Assignment

1. **De**termine the effort required to lift a load of 100 N using:
   (a) Using a single fixed pulley
   (b) A single movable pulley
   (c) Combination pulley system made up of 5 pulleys
   (d) Compare your results, which is the best pulley to use in this case? Why is it the best?
2. **A m**achine has a velocity ratio of 5 and is 80% efficient .What effort would be needed to lift a load of 200 N with the aid of this machine?
3. While lifting a load of 200 N using a lever, an effort of 80 N moved through a distance of 20 cm to lift the load through a distance of 4 cm
   Calculate:

(a) The mechanical advantage
(b) The velocity ratio
(c) The efficiency of the machine

4. **A** block and tackle system consisting of a 5 pulleys is used to raise a load of 400 N through a height of 10 cm .If the work done against friction is 100 J , Calculate:
   (a) The work done by the effort
   (b) The efficiency of the machine
   (c) The effort applied
5. **If an** effort of 15 N is needed to lift a load of 150 N with a three pulley, what is the efficiency of this machine?
6. **(a) In a** pulley system , a load of 700 N requires an effort of 100 N to raise it .What is the mechanical advantage
   (b**) If** this effort moves through a distance of 10 m and the load is then moved up a distance of 2 m, calculate the velocity ratio and the efficiency of the machine
7. **A** machine requires 6000 J of energy to lift a mass of 55 kg through a vertical distance of 8 m. Calculate its efficiency
8. A pulley system has a velocity ratio of 3. Calculate the effort required to lift a load of 600 N, if the system is 75% efficient
9. **A machine** of efficiency 75% lift a mass of 90 kg through a vertical distance of 3 m. Find the work required to operate the machine.
10. A hydraulic machine has a piston P of cross – sectional area 5 cm^2 and Q of cross – sectional area of 50 cm^2 .Find the velocity ratio of the system
11. If the VR of a hydraulic machine is 441 and the effort distance moved by the effort piston is 7 m, Calculate the load distance
12. A load of 30 N is raised 2m when an effort of 10 N moves through 8 m. Calculate the mechanical advantage and velocity ratio of the machine
13. A 120 N load is pushed up a straight smooth inclined plane. The angle between the inclined plane and the horizontal is 30^0 .The load is moved a distance of 5 m along the inclined plane. Calculate:-
    a) The vertical height the load is moved
    b) The velocity ratio of the inclined plane
    c) If the machine has an efficiency of 75% ,calculate the effort force required
14. **The** frictional force in a car jack is great. Explain why this must be so?
15. What do you understand by the efficiency of a machine? A system of levers with a velocity ratio of 25 overcomes a resistance of 3300 N when an effort of 165 N is applied to it ,calculate:
    i. **Me**chanical advantage of the system (**ANS: 20)**
    ii. Its efficiency (**ANS: 80%)**

16. **Define** work and power .Name and define the SI unit of power .By using a block and tackle a man can raise a load of 720 N by an effort of 200N .Find:
   - **a)** The mechanical advantage of the method (**ANS: 3.6)**
   - **b)** The man's useful power output if he raises the load through 10 m in 90 s **(ANS: 80 w)**
17. **Draw** a diagram of a single – string pulley system with a velocity ratio of 4
18. **A** father exerting a force of 300 N was able to push a wheelbarrow with a load of mass 120 kg. Calculate the number of times the wheel barrow multiplied the father's force (g = 9.8 N/kg) (**ANS: M.A = 3.92)**
19. **A** machine, the load moves 2 m when the effort moves 8 m. If an effort of 20 N is used to raise a load of 60 N, what is the efficiency of the machine? **(ANS: Efficiency 75%)**
20. **A** block and tackle system has 3 pulleys in the upper fixed block and two in the lower movable block. What load can be lifted by an effort of 200 N if the efficiency of the machine is 60 %. (**ANS: L = 600 N)**
21. **A** wheel and axle is used to raise a load of 280 N by a force of 40 N applied to the rim of the wheel. If the radii of the wheel and axle are 70 cm and 5 cm respectively. Calculate the M.A, V.R and efficiency**.**
    (ANS: M.A = 7, V.R = 14, Efficiency = 50 %).
22. **A** man uses an inclined plane to lift a 50 kg load through a vertical height of 4.0 m. The inclined plane makes an angle of 30^0 with the horizontal. If the efficiency of the inclined plane is 72 % ,calculate:-
    - **(a) The** effort needed to move the load up the inclined plane at a constant velocity. **(ANS: Effort = 347.2 N)**
    - **(b) The** work done against friction in raising the load through the height of 4.0 m.(take g = 10 N/kg) (**ANS: Wd = 777.6 J)**
23. A car weighing 1 600 kg is lifted with a jack – screw of 11 mm pitch .If the handle is 28 cm from the screw , find the force applied. (**ANS: E = 10 N)**
24. In the figure below, a crowbar was used to lift a 600 N Load placed 1.2 m away from the turning point. An effort was exerted at a distance of 3m from the turning point



    - **(a)** Calculate the value of the velocity ratio (**ANS: V.R = 0.4)**
    - **(b)** Assume the machine was frictionless and weightless ,find the value of the load **(ANS: L= 240 N)**
25. A machine used to lift a load to the top of a building under construction has a velocity ratio of 6. Calculate its efficiency if an effort of 1 200 N is required to

raise a load of 6000 N .Find the energy wasted when a load of 700 N is lifted through a distance of 3 m.

26. **In o**rder to lift a car of weight 5000 N through a vertical height of 200 m, a 700 m long inclined plane is used. Calculate:

- **i.** **Vel**ocity ratio of the simple machine (**ANS: 3.5)**
- **ii.** The effort applied (**ANS: 1428.57 N)**
- **iii.** The mechanical advantage of the simple machine (**ANS: 3.5)**

27. **A** Crate of soda of mass15 kg was raised through a certain vertical height of a plane inclined at 30^0 with the horizontal .Assume that the plane is frictionless and g = 10 N/kg. Determine:

- a) **Vel**ocity ratio of the simple machine (**ANS: V.R = 2)**
- b) The effort applied (**ANS:E = 75 N)**
- c) The mechanical advantage of the simple machine (**ANS: M.A = 2)**

28. In a hydraulic press ,the small piston has an area of 0.2 m^2 while the large piston has an area of 1.5 m^2 .The effort applied on the small piston is 250 N. Calculate:

- **(a)** The mechanical advantage of the machine **(ANS: 7.5)**
- **(b)** The maximum load that the machine can lift **(ANS:1875 N)**
- **(c)** If the small piston (effort piston) moves inwards by 3 m, calculate the distance by which the load is lifted (**ANS: 0.4 m)**
- **(d)** What is the velocity ratio of the machine (**ANS: 7.5)**
- **(e)** Calculate the efficiency of the hydraulic press (**ANS: 100%)**

29. **An** experiment was carried out to investigate the performance of a single – string pulley system with a velocity ratio of five. The following results were obtained:

Load(N)	**50**	**100**	**200**	**300**	**400**	**500**	**600**
Effort (N)	**30**	**45**	**65**	**85**	**105**	**125**	**145**

Plot a graph of effort against Load, Hence find:

- a) The effort (**ANS: 115 N)**
- **b)** The mechanical advantage and **(ANS: 3.9)**
- c) The efficiency corresponding to a load of 450 N (**ANS: 78%**)

30. **D**raw a diagram of a single – string pulley system with a velocity ratio of 5 .Draw also two other mechanical devices having the same velocity ratio .Explain in each of the examples ,why you assert that the velocity ratio is indeed 5.Give one reason common to them all, why the mechanical efficiency is less than 100% ,and one way of increasing the mechanical efficiency of any of the machines you have described

31. Describe how a hydraulic press works

32. An inclined plane is 7 m long and its height is 1 m. If the efficiency of the plane is 70%, find the load which can be moved up the plane by an effort of 150 N parallel to the plane. (**ANS: L = 73500 N)**

33. Define the following terms
(a)Pitch of a screw (b) Fulcrum (c) Axle (d) Efficiency of a machine

34. Suppose a screw of radius 0.7 cm has 12 threads per inch .Calculate the velocity ratio of the screw (**ANS: V.R = 20.95)**

35. Draw a diagram of a single – stringed block and tackle pulley with a velocity ratio of: (a) 4 (b) 5 (c) 6 (d) 2

36. A box of mass 12 kg is pulled up a straight smooth incline at 30 to the horizontal , for a distance of 5 m .Calculate the work done (**ANS: 300 J)**

37. A bicycle has wheels 66 cm in diameter .Its crank wheel has 44 teeth and the rear sprocket 16 teeth .If the crank radius is 16.5 cm, Calculate the velocity ratio .Find the efficiency of the bicycle if its mechanical advantage is 0.14 (**ANS: V.R = 0.18, Efficiency = 77%)**

38. A screw jack with a pitch of 0.2 cm and a handle of length 50 cm is used to lift a car of weight 1200 N. If the efficiency of the screw is 30% calculate.
(a) The velocity ratio (**ANS: p = 1570)**
(b) The mechanical advantage (**ANS: M.A = 471)**
(c) The effort used to raise the car(**ANS: E = 2.55)**

39. A driving gear wheel having 25 teeth engages with a second wheel with 100 teeth. A third wheel with 30 teeth on the same shaft as the second ,engages with a fourth having 60 teeth .Find:
- **(a)** The total velocity ratio (**ANS:8)**
- **(b)** The mechanical advantage of the gear system if its efficiency is 85% **(ANS: 6.8)**

40. Draw a diagram of a single – string pulley system with a velocity ratio of 6.Calculate the efficiency of it if an effort of 1000 N is required to raise a load of 4500 N .Find the energy wasted when a mass of 500 kg is lifted through 2 m **(ANS: Eff = 75%, E = 3333 J)**

41. A man uses a rope to haul a packing case of weight 750 N up an inclined wooden plank of effective length 4.50 m and on to platform 1.50 m high .The frictional force between case and plank is 200 N. Find:
- **(a)** The effort he must exert on the rope (**ANS: 450 N)**
- **(b)** The velocity ratio (**ANS: 3**)
- **(c)** The mechanical advantage **(ANS: 1.67)**
- **(d)** The useful work done on the packing case in joules **(ANS: 1125 J)**

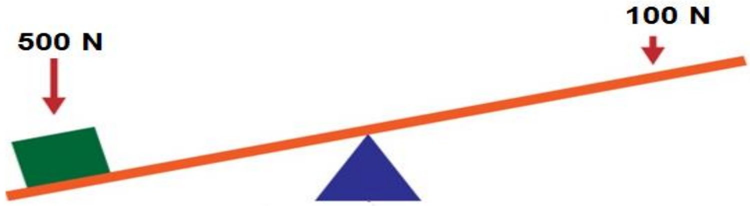
42. The machine is used to lift a container weighing 80,000 N. The radius of effort piston is 50 cm and the radius of a load piston is 5 m. If the efficiency of the machine is 90%, Calculate the velocity ratio and its mechanical advantage (M.A) **(ANS: V.R = 100, M.A = 90)**

43. Define velocity ratio and mechanical advantage .A common windlass is used to raise a 480 N load of earth from an excavation by the application of an effort of 200 N at right angles to the handle and crank .If the handle is 33 cm from the axis and the radius of the axle is 11 cm , find:

(a) The velocity ratio **(ANS: 3)**

(b) The mechanical advantage (ANS: 2.4)

44. A lever 2.4 m long is to be used to raise an object weighing 500 N by applying an effort of 100 N as shown below. How far from the object should the fulcrum be placed?



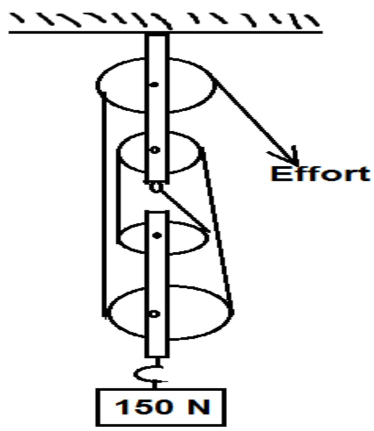
45. Identify the class to which each of the levers given below belongs
A hoe, pair scissors, wire cuter, bottle opener, *wheelbarrows*

46. The efficiency of a press is given as 75%.If the radius of the load piston is given as 3 m while the effort piston is 1.5 m, calculate:
(a) the VR (b) the MA of the press

47. Discuss the mode of action of a hydraulic press

48. Efficiency of a simple machine is never 100%. Why?

49. The pulley system shown below is to be used to raise a load of 150 N

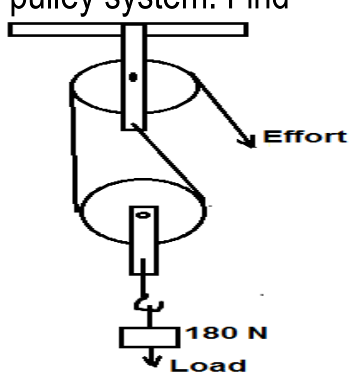


a) Ignoring friction and the weight of the pulleys, what force is required to raise the load at a constant speed?

b) If the cable (where the effort is applied) is pulled down 60 cm, how far will the object rise?

50. The effort distance moved by an effort force of 20 N to lift a bag is 10 cm. I f the M.A of the inclined system is 10, calculate the load distance

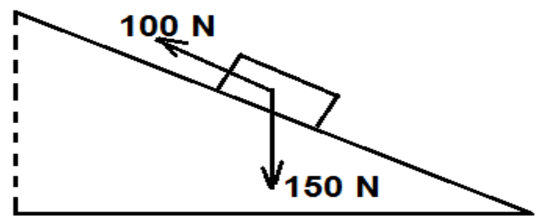
51. The figure below shows a pulley system. Find



(a) The velocity ratio of the pulley system
(b) The mechanical advantage, if the system is 80% efficient.
(c) The effort
(d) The work done by the effort in lifting the load through a distance of 0.7 m
(e) How much energy is wasted

52. A box weighing 560 N is pulled along an inclined plane of length 5 m onto a platform 2 m high with a force of 70 N. Calculate:
  a) The velocity ratio of the plane
  b) The mechanical advantage of the plane
  c) The efficiency of the plane

53. The diagram below shows a box of weight 150 N being pulled at a steady speed up a ramp by a force of 100 N

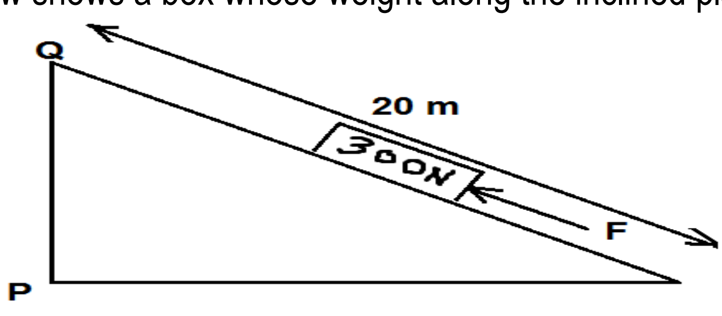


If the height of the plane is 2 m above the ground and the length of the plane is 4 m, Calculate:
  (a) The mechanical advantage
  (b) The velocity ratio
  (c) The work done by the effort
  (d) The work done on the load

54. A 200 kg crate is to be loaded onto the bed of a truck that is 1.4 m above the ground. A metal ramp 5 m long is leaned against the truck bed and the crate pushed along it. Neglecting the frictional force:
  (a) calculate the force required to push the crate up the incline at a constant velocity
  (b) calculate the ma of the incline
  (c) determine the efficiency of the machine

55. A trolley is pulled up an inclined plane 2 m high using a force of 4 N. If the mass of the trolley is 1 kg
  (a) What is MA of the plane   (c) Find its efficiency
  (b) Find the velocity ratio

56. The figure below shows a box whose weight along the inclined plane is 300 N



Calculate:

(i) **The work done** in sliding the box up the inclined from P to Q
(ii) **The** power used if it took 5 minutes to move the box from P to Q

57. A Pulley system has a velocity ratio of 5 and efficiency of 60%
   a) What effort force is required to lift a 750 N object using the pulley?
   b) How much work will be done in raising the object through a distance of 1.5 m

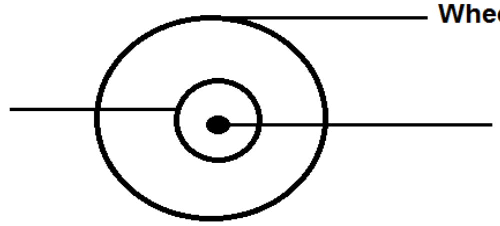
58. A hydraulic Press has effort and load pistons with areas 0.02 m^2 and 0.3 m^2 respectively. A force of 550 N is required to lift a car with a mass of 680 Kg using the press .What is the efficiency of the press?

59. Find the velocity ratio of a wheel and axle system if the load gear has 60 teeth and the driven gear wheel has 20 teeth

60. What is the significance of the gear wheel as a simple machine?

61. **(a)** why does a cyclist often zigzag when going up a hill?
   (b) Imagine that you are riding a bicycle, how many simple machines are in your possession?

62. The diagram below shows a cross section of a bicycle wheel .The wheel has a radius of 35 cm while the rear sprocket has a radius of 3.5 cm



   (a) If the axle has a radius of 1 cm ,determine
      i. The velocity ratio of the sprocket
      ii. The velocity ratio of the wheel
   (b) An effort of 200 N is applied at the sprocket .If the efficiency of the entire system is 80%, What is the maximum load that can be carried by the bicycle?

63. A loaded wheel barrow weight 800N is pushed up an inclined plane by a force of 150N parallel to the plane. If the plane rises 50cm for every 400cm length of the plane, find the velocity ratio, mechanical advantage and efficiency of the plane. **(ANS: V.R = 8, M.A = 5.3 ,Eff = 66.25%)**

64. A block and tackle pulley system has a velocity ratio of 4. If a load of 100N is raised by using a force of 50 N. Calculate the mechanical advantage and efficiency of the system**.** **(ANS: M.A = 2, Eff = 50%)**

65. The handle of a screw jack is 35cm long and the pitch of the screw is 0.5cm. What force must be applied at the end of the handle when lifting a load of 2200N? If the efficiency of jack is 40% **(ANS: E = 12.5 N)**

66. **A** screw jack has an efficiency of 40% and it is used to lift a load of 400 kg. If its pitch is 0.5 cm and the effort arm is 0.5 m long ,find the effort required

67. **The** pitch of a screw jack is 0.5 m. When used to raise a load, the handle turns through a circle of radius 40 cm .What is the mechanical advantage of the screw jack if its efficiency is 25%? (Take $\pi = 3.14$)

68. The velocity ratio of the screw jack is 420 .If it has 10 threads per centimeter ,Calculate the length of the turning lever

69. A screw jack has 8 threads per centimeter of length .If the length of the turning handle is 10 cm ,Calculate the velocity ratio of the screw Jack

70. **An** electric pump raises 9.1 m^3 of water from the reservoir whose water – level is 4 m below ground level to a storage tank above ground .If the discharge pipe outlet is 32 m above ground level and the operation takes 1 hr ,find the minimum power rating of the pump if its efficiency is 70 per cent .(1m^3 of water = 1000kg) **[ANS: 1.3 kW]**

71. A simple pulley system has velocity ratio of 3. Its efficiency is 90%, what load can it raise by an effort of 100N. (**ANS: Load = 270 N)**

72. A lift of mass 500 kg containing a load of mass 700 kg rises through 25 m in 20 s. In the absence of friction, calculate the average power output of the motor driving the lift .Explain why ,in practice ,the power output will not be constant during this time (**ANS: 15 KW)**

73. A see – saw is 10 m long and is balanced on a fulcrum in the middle. A girl weighing 300 N is at one end. Where should a boy weighing 400 N sit if the see – saw is to balance?

74. A ladder 16 m long weighs 420 N and its centre of gravity is 7 m from one end. It is carried horizontally by two boys, each holding it 1 m from the ends. Calculate the forces exerted by them

75. A block and tackle pulley system has a velocity ratio of 4. If its efficiency is 75%. Find the
    (a) Mechanical advantage (**ANS: M.A = 3)**
    (b) Load that can be lifted with an effort of 500 N (**ANS: L = 1500 N)**
    (c) **Work done** if the load is lifted through a vertical distance of 4.0 m **(W.D = 6000 J)**
    (d) **A**verage rate of working if the work is done in 2 minutes. (**ANS: P = 50 W)**

76. Using a certain machine, a force of 250 N must move through a 5 meters in order to lift 100kg 1 meter off the ground. What is the efficiency of the machine?

77. The arm of a screw jack is R cm long and there are 4 threads to the centimeter. Calculate its velocity ratio.

78. A uniform meter rule is balanced horizontally on a wedged placed under the 40 cm mark by a weight of 0.5 N hanging from the 20 cm mark. What is the weight the rule.

79. A wheel and axle of efficiency of 80% is used to raise a load of 2000N. If the radius of the wheel is 50cm and that of the axle is 20m. Calculate:-
    (b) The velocity ratio and mechanical advantage of the machine. (**ANS: 25**)
    (c) The effort required to overcome the load (**ANS: 100 N)**

80. A crank handle with a length of 30 cm is attached to an axle with a radius 5 cm and is used to lift a bucket of water from a deep well. If the bucket of water weighs 120 N,
   a) How much force is required to turn the crank?
   b) Find the number of turns of the crank required to raise the bucket to the surface if the well is 510 m deep

81. A gearwheel A has 20 teeth .It is used to drive a gearwheel B with 80 teeth.
   (a). Calculate the velocity ratio
   (b) If wheel A rotates three times every second, how many times does wheel B rotate in a second?

TOPIC: 06 MOTION IN A STRAIGHT LINE

Motion:

- Motion is the process of continuously changing in position of an object from one place to another.

Types of Motion

- Linear motion
- Circular motion

Linear Motion

- Is a motion of an object in a straight line.

Circular Motion

- Is a motion of an object around the circle.
- Example of circular motion: **Rotation of the earth and motion of electrons around the nucleus**

Terms used to describe Motion

- Distance and displacement
- Speed and velocity
- Acceleration and Retardation

Distance and displacement

Distance

- **I**s the length of path taken by an object in motion.
- Distance is represented by letter **s**
- The distance is a scalar quantity.
- The **SI unit** of distance is **Metre** (m). Other units are **Centimeter** (cm), and **Kilometer** (km)
- The figure below shows the distance between two points(AB)

Displacement

- I*s the distance moved by an object in a specific direction*.
- It is a vector quantity.
- The **SI unit** of displacement is **metre** (m). Other units are **Centimeter** (cm), and **Kilometer** (km)
- The diagram below shows the distance in a particular direction between the two pints.

Speed and Velocity

Speed

- *Is the distance moved per unit time.*
- **OR** ***Is the rate of change of distance.***
- The speed is represented by letter **v.**
- It is a scalar quantity.

Speed (v) = $\frac{distance}{Time\ taken} = \frac{s}{t}$

- The SI unit of speed is *Meter per Second* (m/s). Other unit used is *kilometer per hour* (km/h)

Velocity

- *Is the rate of change of displacement*
- It is a vector quantity.
- **Velocity (v)** = $\frac{displacement}{Time\ taken} = \frac{s}{t}$
- **The** SI unit of velocity is *Meter per Second* (m/s). Other units used is *kilometer per hour* (km/h)

NB: 10 m/s = 36 km/h

NB:

- **Initial velocity** is the velocity of the body at the starting point of observation.
- **Final velocity** is the velocity of the body at the ending point of observation.
- **Average velocity** is the mean of initial and final velocities. → $V_a = \frac{u+v}{2}$
- **OR** Average velocity is the ratio of the total displacement to the total time.

  Average velocity, $V_a = \frac{s}{t}$
- **Uniform velocity i**s *the type of velocity in which the rate of change of displacement with time is constant*.
- **Instantaneous velocity** ***is*** *the velocity of the body at any instant.*

Example

1. An object travelled 20 m to the right in 4 s and then 12 m to the left in 3s, for its total motion. What was its average speed & its average velocity.

Data given

- Total distance traveled, s = 20 m + 12 m = 32 m
  Total time, t = 4s + 3 s = 7 s

$$Ave.Speed = \frac{total\ distance}{total\ time} = \frac{32}{7} = 4.57\ m/s$$

- When the object is moving to right its displacement is positive and when to the left its displacement is negative
  Total displacement (s) = 20 + -12 m = 8 m

$$\boldsymbol{Ave. velocity} \ = \frac{\textbf{total displacement}}{\textbf{total time}} = \frac{8}{7} = \mathbf{1.14\ m/s}$$

Individual Task – 1

1. 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 (**ANS: 2.03 m/s)**
2. A 100m runner finishes the race in 10s. What is her average speed? **(ANS: 10 m/s)**
3. A body covers a distance of 480 m in 6sec. Calculate its speed**.(ANS: 80 m/s)**

Acceleration and Retardation

Acceleration

- *Is the rate of change of velocity*.
- *It is denoted by small letter* ***"a"***

$$\boldsymbol{acceleration} = \frac{\textbf{final velocity} - \textbf{initial velocity}}{\textbf{time}} = \frac{v-u}{t}$$

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

- **Its SI unit is metre per second square (m/s²)**
- **Uniform acceleration i**s the type of acceleration in which the rate of change of velocity is **CONSTANT**.

Retardation (Deceleration)

- *Is the rate of decreasing of velocity*.
- It is referred as negative acceleration.
- **Uniform retardation** i*s the one in which the rate of decreasing of velocity does not change*

NB:

- ✓ When a body starts moving from rest its initial velocity become zero, u = $0m/s^2$
- ✓ When a body is brought to rest by the application of brakes its final velocity, v = $0m/s^2$
- ✓ When a velocity of a moving object increases its acceleration become positive
- ✓ When the velocity of a moving object decreases its acceleration become negative
- ✓ When a body is moving with a uniform velocity its acceleration becomes zero, a = $0\ m/s^2$

Example

1. An object is moving at 15 m/s to the right after 8 sec later it is moving at 5 m/s to the left, what was the acceleration of the object?

Solution

Initial velocity, u = +15 m/s
Final velocity, v = -5 m/s
Time taken, t = 8s
Acceleration, a =?

$$\therefore\ a = \frac{v-u}{t} = \frac{-5-15}{8} = -\frac{20}{8} = -2.5\ m/s^2$$

Individual Task – 2

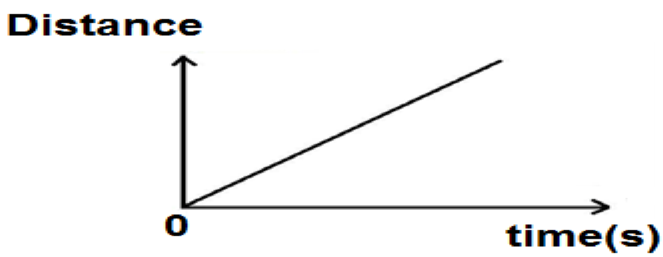
1. A car brakes and slows down from 20 m/s to 5 m/s in 3 sec. find its acceleration **(ANS: a = -5 m/s²)**
2. Starting from rest, a sports car accelerate to a velocity of 96 km/h in 16 sec. find its acceleration (**ANS: a = 1.67 m/s²)**
3. A car travels at 10 m/s and increase its velocity to 30 m/s in 10 sec. find acceleration of the car **(ANS: a = 2 m/s²)**
4. A car travels at 45 m/s and decreases its velocity uniformly to 20 m/s in 5 sec. find acceleration (**ANS: a = -5 m/s²)**
5. A car with a velocity of 90km/h under uniform retardation and brought to rest after 10s. Calculate its acceleration (ANS: **a = -2.5m/s²)**

Position – time graphs

Displacement, velocity and acceleration can be represented on a graph.

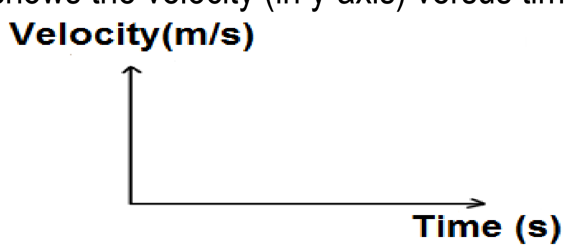
Distance (displacement) time graphs

- ✓ **Displacement time graph** is the graph which shows the displacement (y-axis) versus time (x-axis).

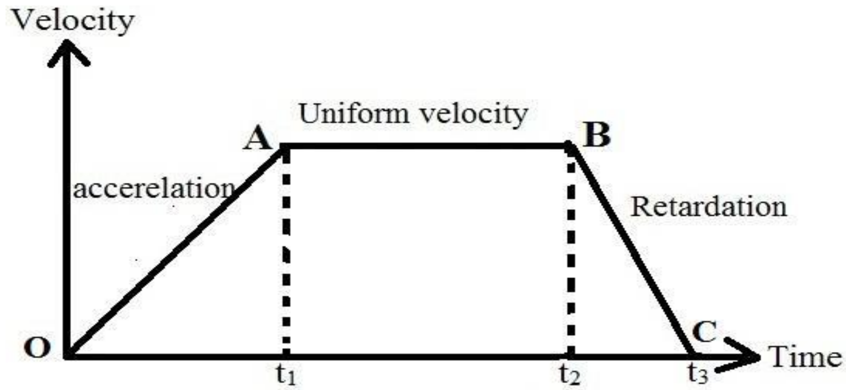


Velocity Time Graph

- Is the graph which shows the velocity (in y-axis) versus time (in x-axis).



- Consider a body starts moving from rest and accelerates uniformly to a velocity, v after time, t_1. It then moves with this velocity for time, t_2 and then comes to stop after another time, t_3.
- The above information can be represented on the velocity time graph as shown.



Deduction from velocity time graph

a) The Area under the velocity time graph = Total distance travelled by a body

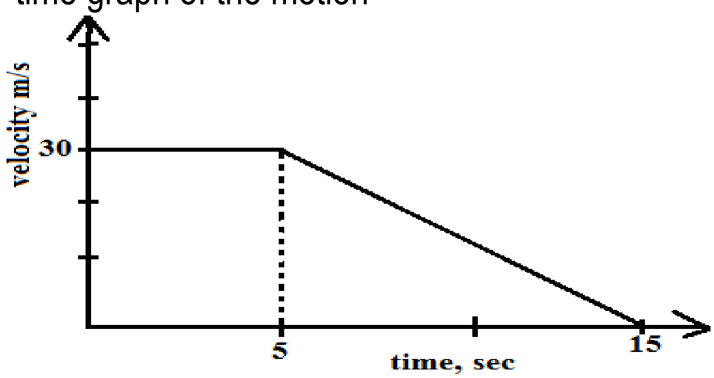
b) *The slope of the velocity time graph represents acceleration*

Example

1. 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 velocity.

Solution:

i) velocity-time graph of the motion



ii. Total distance travelled, s =?

S = (30 x 5) + (30 x 10)/2 = 150 + 300/2 = 150 + 150 = 300 m

iii. **From velocity time graph**

Total distance, s = 300 m

Total time taken, t = 15 s

$\therefore$ Average velocity **=** $\frac{s}{t} = \frac{300}{15} = 20\ m/s$

Individual Task – 3

1. A car starts from rest and is accelerated uniformly at a rate of 4 m/s2 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 (**ANS: v = 20 m/s)**
   (c) Find the total distance travelled. **(ANS: s = 480 m)**
2. A bike accelerates uniformly from rest to a speed of 7.10 m/s over a distance of 35.4 m. Determine the acceleration of the bike. (**ANS: a = 0.712 m/s^2)**
3. A body accelerates uniformly from velocity of 40 m/s to a velocity of 50 m/s in 4seconds

(a) Draw a velocity-time graph of the motion.
(b) Find acceleration of the body (**ANS: a = 2.5 m/s^2)**
(c) Calculate the total distance travelled by the body in meter **(ANS: s = 180 m)**

Equations of uniformly accelerated Motion (Equations of Linear Motion)

- First equation of motion
- Second equation of motion
- Third equation of motion

Consider a body moving with a constant acceleration $\boldsymbol{a}$ from an initial velocity $\boldsymbol{u}$, to a final velocity $\boldsymbol{v}$ .The body covers a displacement ,$\boldsymbol{s}$, after sometime $\boldsymbol{t}$.

❖ Derivation of first equation

Now, find the acceleration of the body

From: $a = \frac{\Delta v}{t} = \frac{v-u}{t}$, $\boldsymbol{make\ v}$ $the\ subject$

$at = v - u \ \rightarrow\ v = u + at$

$$\boxed{\therefore The\ 1^{st}\ equation\ is\ given\ by \qquad \boldsymbol{v = u + at}}$$

❖ Derivation of the second equation

Find the average velocity of the body

$$\boldsymbol{V_a = \frac{v+u}{2} = \frac{s}{t}\quad but\ \ v = u + at}$$

$$\boldsymbol{V_a = \frac{u+at+u}{t} = \frac{2u+at}{2} = \frac{s}{t}}$$

$\boldsymbol{\frac{2u+at}{2} = \frac{s}{t}}$ **---------------------** multiply by t each side

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

$$\boxed{\therefore\ the\ 2^{nd}\ equation\ is\ given\ by\quad s = ut + \frac{1}{2}at^2}$$

- **Derivation of third equation**

Consider the 1st equation: $v = u + at$

Then square the equation in each side: **$(v)^2 = (u+at)^2$**

This gives: **$v^2 = u^2 + 2uat + a^2t^2 = u^2 + 2a$**$(ut + \frac{1}{2}at^2)$

But: $s = ut + \frac{1}{2}at^2$

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

$$\boxed{\therefore\ the\ 3^{rd}\ is\ equation\ is\ given\ by\qquad v^2 = u^2 + 2as}$$

Example

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

   Initial velocity (u) = 30m/s, Final velocity (v) = 50m/s, Time (t) = 5s

Acceleration =?

- $a = \frac{v-u}{t} = \frac{50-30}{5} = 4\ ms^{-2}$

Distance traveled =?

- S = $ut + \frac{1}{2}at^2 = 30\ x\ 5 + \frac{1}{2}\ x\ 4\ x\ 5\ x\ 5 = \ 200\ m$

Individual Task – 4

1. A car initially at rest, attains a velocity of 20 m/s after 8 seconds. What is the acceleration of the car? (**ANS: a = 2.5 m/s^2)**
2. A rally car takes 5 minutes to cover a displacement of 20 km. If the initial velocity of the car is 40 m/s, Calculate the average acceleration of the car **(ANS: a = 0.178 m/s^2)**
3. A rocket initially moving at a velocity of 5m/s accelerates uniformly at 1.5 m/s^2 .What will be its velocity after covering 120 km? **(ANS: v= 600 m/s)**

4. Starting from rest, a car accelerates uniformly at $2.5 m/s^2$ 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 (**ANS: v = 54km/h)**
   (c) Displacement covered in km **(ANS: S = 0.375 km**)

5. A car accelerates uniformly from rest to a speed of 15km/h in 10s, Find:
   a) The acceleration in m/s^2 **(ANS: a = 0.42 m/s^2)**
   b) Distance covered in meters (**ANS: s = 21 m)**

6. A train with a velocity of 40m/s is uniformly retarded and brought to rest after 5 seconds. Determine its deceleration and draw the graph **(ANS: a = -8 m/s^2)**

Motion under Gravity

- All bodies on the earth will always fall down towards the earth's surface when released from a point. What makes these bodies falling downwards is the acceleration of free falling body called **acceleration due to gravity** which is **9.8 or 10 N/kg.**
- Acceleration of free falling body is denoted by **'g'**. Light bodies like feathers, paper etc are observed to fall down more slowly than iron balls. This is because light bodies are very much affected by air resistance.
- There are two important characteristics of free fall
  (a) **Free falling objects do not encounter air resistance**
  (b) **All free falling objects on earth accelerate downwards at a rate of 9.8 m/s^2 (often approximated as 10 m/s^2)**

- **For a body moving downwards the following formulae are applied**
  (Here $\boldsymbol{a = g \;\; and \;\; s = h}$)

1st equation is given by	$\boldsymbol{v = u + gt}$
2^{nd} *equation is given by*	$\boldsymbol{h = ut + \frac{1}{2}gt^2}$
3^{rd} *is equation is given by*	$\boldsymbol{v^2 = u^2 + 2gh}$

- **When the body moves upwards ,the formulae will change to:**
  (Here $\boldsymbol{a = -g \;\; and \; s = h}$)

1st equation is given by $\boldsymbol{v = u - gt}$
2^{nd} *equation is given by* $\boldsymbol{h = ut - \frac{1}{2}gt^2}$
3^{rd} *is equation is given by* $\boldsymbol{v^2 = u^2 - 2gh}$

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

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/s2

From: third equation of motion

$\boldsymbol{v^2 = u^2 - 2gh}$ **-------------------- make h the subject**

$$\boldsymbol{h = \frac{u^2 - v^2}{2g} = \frac{30^2 - 0^2}{2x10} = \frac{900}{20} = 45\ m}$$

b) Time taken for maximum height, t =?

From: first equation of motion

$\boldsymbol{v = u - gt}$ **-------------------- make t the subject**

$$\boldsymbol{t = \frac{u - v}{g} = \frac{30 - 0}{10} = \frac{30}{10} = 3\ s}$$

c) Time taken for reach ground again,(**T = 2t**) ?

T = 2t = 2 x 3 = 6 sec

d) Velocity reached half-way to the maximum height, v =?

When stone is halfway to maximum height, the height attained is

$$\boldsymbol{h = \frac{H}{2} = \frac{45}{2} = 22.5\ m}$$

Data given:

u = 30 m/s and a = -10 m/s^2

From: third equation of motion

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

$$v = \sqrt{u^2 - 2gh} = \sqrt{30^2 - 2x10x22.5} = \sqrt{900 - 450} = \sqrt{450}$$

$$\therefore v = 21.2\ m$$

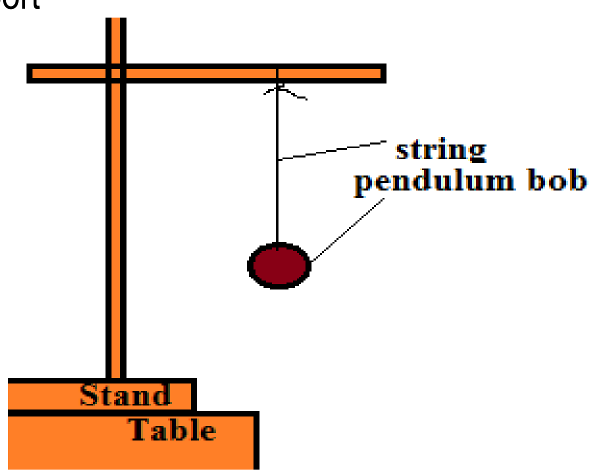
Individual Task – 5

1. Calculate the velocity of a paratrooper falling under gravity after 6 seconds **(ANS: v = 58.8 m/s)**
2. A ball is released from a cliff, 45 m high. Find the magnitude of the average velocity during its motion till it reaches the ground (g = 10 m/s^2) **(ANS: u=30 m/s)**
3. An object is thrown straight up with an initial velocity of 50 m/s
   (a) How long will take to reach its maximum **height** **(ANS: t = 5 sec)**

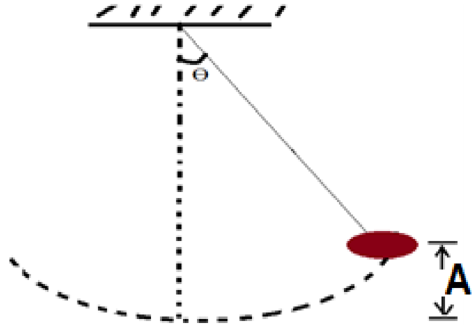
   (b) To what height will it rise? (**ANS: h =125)**
   (c) What will be its velocity when it returns to its starting point? (**AN: v = 50 m/s)**
   (d) How long will be in the air? **(ANS: t = 10 se)**
4. A ball initially at rest falls for 4 seconds at a constant acceleration. Calculate:
   (a) Its velocity after 4 seconds **(ANS: v = 39.2 m/s**)
   (b) Its distance from the rest position **(ANS: h = 156.8 m)**
5. A body moved upwards a distance of 20 m. Calculate
   (a) The initial velocity (**ANS: v = 20 m/s**)
   (b) The time taken to reach the maximum height (**ANS: t = 2 sec)**

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 is constant, the period is always constant and that constant time is given by

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

Where:
T = Period to complete oscillation
L = Length of string
g = Acceleration due to gravity

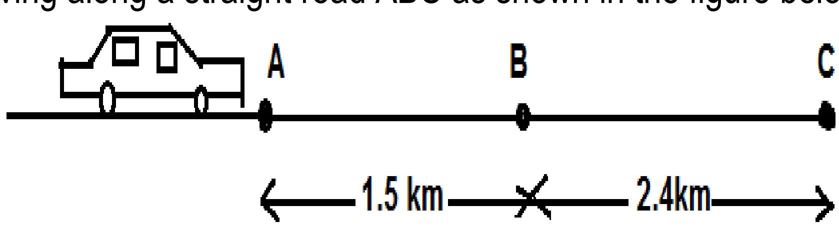
Application of gravitational force

- Used to launch satellites and space vehicle into space requires overcoming the gravitational attraction forces for take off
- Used to keep satellite rotating on the earth's orbit
- It causes everybody to be attracted towards the earth's surface
- It is used 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*

Class Activity

1. Calculate the distance in metres covered by a body moving with a uniform speed of 180 km/hr in 30 seconds. (**ANS: d = 1 500 m)**
2. **Calculate** the time in seconds taken by a body moving with uniform speed of 360 km/h to cover a distance of 3000 km. (**ANS: t = 30,000 s)**
3. What is the speed of a racing car in metres per second if the car covers 360 k/h in 2 hours? (**ANS: V = 50 m/s)**
4. **T**he average speed of a car is 25 m/s .Calculate the distance travelled by the car in 30 minutes.**(ANS: d = 45 000 m or 45 km)**
5. **W**hich of the following quantities are scalar?
   Displacement, speed, acceleration, velocity and distance.

6. A race car accelerates uniformly from 18.5 m/s to 46.1 m/s in 2.47s. Determine the acceleration of the car and the distance traveled (**a = 11.2m/s^2 , d = 79.8 m)**
7. State the difference between distance and displacement
8. A man runs 800 m due North in 100 seconds , followed by 400 m South in 80 seconds .Calculate,
   a) His average speed (**ANS: V = 6.67 m/s)**
   b) His average velocity **(ANS:V = 2.22 m/s due North)**
   c) His change in velocity for the whole journey **(ANS:V = 3 m/s due North)**
9. Define speed and explain what is meant by average speed. A motorist travels from a town A to town B , 145 km distant in 3 h 45 minutes. Find his average speed:
   (a) In km/h (**ANS: V = 38.7 km/h)**
   (b) In m/s (**ANS: V = 10.7 m/s)**
10. A car initially moving at a velocity of 2 m/s takes 2 minutes to reach a velocity of 20 m/s. What is the average acceleration of the car? (**ANS: a = 0.15 m/s^2)**
11. How long does it take a truck initially at rest to accelerate to 20 m/s if the acceleration is 2 m/s. (**ANS: t = 10 s)**
12. **A** kangaroo is capable of jumping to a height of 2.62 m. Determine the takeoff speed of the kangaroo. (**ANS: v = 7.17 m/s)**
13. A car accelerates uniformly from rest to a speed of 15 km/hr in 10 seconds. Find
    (a) the acceleration in m/s^2 **(ANS: a = 0.42 m/s^2)**
    (b) distance covered during this period in meters . (**ANS: s = 21 m)**
14. A dragster accelerates to a speed of 112 m/s over a distance of 398 m. Determine the acceleration of the dragster. **(ANS: a = 15.8 m/s^2)**
15. The maximum retardation with which the breaks of a locomotive can reduce its speed is 1.8 m/s^2. Calculate the time in which the locomotive can be brought to rest . (ANS: t = u/1.8)
16. A bullet leaves a riffle with a muzzle velocity of 521 m/s. While accelerating through the barrel of the riffle, the bullet moves a distance of 0.840 m. Determine the acceleration of the bullet.(assume a uniform acceleration.) (**ANS: a = 1.62 x 10^5 m/s^2)**
17. A car moving along a straight road ABC as shown in the figure below.



It maintains an average speed of 90 km/h between point A and B and 36 km/h between point B and C. Calculate the:
   a) Time taken in seconds by the car between points A and C**.**
   (ANS: t = 300 s)
   b) The average speed in metres per second of the car between points A and C. (**ANS: V = 13 m/s)**

18. A tennis ball is thrown vertically upwards with a velocity of 20 m/s. Calculate the time taken for the ball to return to its starting point. **(ANS: t = 4 s)**
19. (a) Sketch a velocity – time graph for a car moving with uniform acceleration from 5 m/s to 25 m/s in 15 seconds.
    (b) Use the sketch graph to find the values for:-
    (i) The acceleration. **(ANS: a = 1.33 m/s^2)**
    (ii) The total distance travelled during acceleration. **(ANS: s = 225 m)**
20. A car with a velocity 50 m/s is uniformly retarded and brought to rest after 10 seconds. Calculate its acceleration. **(ANS: a = - 5 m/s)**
21. What is the mass of a body which when acted on by a force of 3 N accelerates at 7m/s^2 **(ANS: m = 0.428 kg)**
22. A car travelled from town A to town B 200 km east of A in 3 hours. The car changed direction and travelled a distance of 150 km due North from town B to town C in 2 hours. Calculate the average
    a) Speed for the whole journey (**ANS: V = 70 km/h)**
    b) Velocity for the whole journey (**ANS: V = 50 km/h)**
23. A tennis ball hits a vertical wall at a velocity of 10 m/s and bounces off at the same velocity. Determine the change in velocity. (**ANS:V = 20 m/s**)
24. A football kicked horizontally from a vertical cliff has a vertical velocity of 30 m/s when it reaches the sea below
    (a) Calculate the time the ball takes to reach the sea. (**ANS: t = 3 s)**
    (b) The initial horizontal velocity of the ball is 15 m/s. Calculate the horizontal distance travelled by the ball. (**ANS: s = 45 m)**
25. The velocity of a body increases from 72 km/h to 144 km/h in 10 seconds. Calculate its acceleration. (**ANS: a = 2 m/s^2)**
26. **A** car is brought to rest from 180 km/h in 20 seconds. What is its retardation? (**ANS: a = -2.5 m/s^2)**
27. **A** car starts from rest and accelerates uniformly at a rate of 2 m/s^2 for 20 s.It then maintains a constant velocity for 10 s. The brakes are then applied and the car is uniformly retarded and comes to rest in 5 s. Draw the velocity – time graph for the motion and find:
    (a) The maximum velocity. (ANS: v = 40 m/s)
    (b) The retardation in the last 5 seconds. (**ANS: a = -8 m/s^2)**
    (c) Total distance travelled. (**ANS: s = 900 m)**
    (d) Average velocity. **(ANS: V = 25.71 m/s)**
28. **A** car starts from rest and attains a velocity 20 m/s in 10 s. If it travels at this velocity for 5 s and then decelerates to stop after another 6 s. Draw the velocity time graph for this motion. From the graph:
    a) Calculate the total distance moved by the car (**ANS: s = 260 m)**
    b) Find the acceleration of the car at each stage
    (ANS: a_1 = 2 m/s^2, a_2 = 0 m/s^2 and a_3 = - 3.33 m/s^2)
29. Define the term acceleration due to gravity

30. A stone is let to fall vertically down from a window on the 10^{th} floor of a building 40 m above the ground. Find the time taken by the stone to reach the ground.

31. A ticker – tape is moved through a ticker – timer for 5.0 seconds. If the timer is operating at 25 Hz
    - **(c)** How many dots would have been printed on the tape? **(ANS: n=125 dots)**
    - **(d)** What kind of motion does the tape represents? (**ANS: Linear motion)**

32. A stone dropped down a well takes 3.0 s to reach the surface of the water .How far is the water surface below the top of the well? (**ANS: h = 45 m)**

33. A car on a straight road accelerates from rest to a speed of 30 m/s in 5 s. It then travels at the same speed for 5 minutes and then brakes for 10 s in order to stop. Calculate the:
    - **(a)** Acceleration of the car during the motion (**ANS: a = 6 m/s^2)**
    - **(b)** Deceleration of the car (**ANS: a = -3 m/s)**
    - **(c)** Total distance travelled (**ANS: d = 9 225 m)**

34. A car accelerates from rest to a velocity of 20 m/s in 5 s. Thereafter it decelerates to a rest in 8 s. Calculate the acceleration of the car
    - **(a) In** the first 5 s (**ANS: a = 4 m/s^2)**
    - **(b)** In the next 8 s **(ANS: a = -2.5 m/s^2)**

35. A rocket fired vertically upward with a velocity of 60 m/s falls back to earth .Ignoring the effects of air resistance ,Calculate the greatest height reached by the rocket (**ANS: h = 180 m)**

36. An electric train moving at 20 km/h accelerates to a speed of 30 km/h in 20 s. Find the average acceleration in m/s^2 and the distance travelled in metres during the period of the acceleration. (**ANS: a = 0.14 m/s^2 , s = 139 m)**

37. A tennis ball is dropped on to the floor from a height of 10 m. It rebounds to a height of 2.5 m. If the ball is in contact with the floor for 0.01 s. What is the average acceleration during the contact? Take g = 10 m/s^2 **(AN: a = 2121 m/s^2)**

38. The speed of goods truck which has been shunted on to a level siding falls from 10 km/h to 5 km/h in moving a distance of 30 m. If the retardation is constant, how much further will the truck travel before coming to rest? **(ANS: s = 10 m)**

39. A stone is dropped into a deep well and is heard to hit the water 3.41 s after being dropped. Determine the depth of the well. (**ANS: d = 57.0 m)**

40. A car travelling at 22.4 m/s skids to a stop in 2.55 s. Determine the skidding distance of the car. (**ANS: d = 28.6 m)**

41. A train, 90 m long, stops in a station with its front buffers in line with a lamp – post on the platform. Later it starts off with an average acceleration of 0.45 m/s^2. What will be its speed, in km/h, when the tail buffers pass the lamp – post? (**ANS: V = 32.4 km/h)**

42. A car runs at a constant speed of 15 m/s for 300 s and then accelerates uniformly to a speed of 25 m/s over a period of 20 s. This speed is maintained for 300 s before the car is brought to rest with uniform deceleration in 30 s.

Draw a velocity – time graph to represent the journey described above. From the graph find:

(i) The acceleration while the velocity changes from 15 m/s to 25 m/s. (**ANS: a = 0.5 m/s^2**)

(ii) The total distance travelled in the time described; (**ANS: s = 12 775 m**)

(iii) The average speed over the time described. (**ANS: V = 19.7 m/s)**

43. A bird flying horizontally at 4.8 m/s drops a stone from its beak. The stone hits the ground after it has travelled a horizontal distance of 12 m

(a) After the bird dropped it , how long did it take the stone to fall to the ground (**ANS: t = 2.5 s)**

(b) Calculate the vertical velocity of the stone when it hits the ground **(ANS: v = 25 m/s)**

44. A car initially at rest, attains a velocity of 20 m/s after 8 seconds. What is the acceleration of the car? (**ANS: a = 2.5 m/s)**

45. A body moves with a uniform acceleration of 10 m/s^2 covers a distance of 320 m. If its initial velocity was 60 m/s. Calculate its final velocity **(ANS: v = 100 m/s)**

46. A body whose initial velocity is 30 m/s moves with a constant retardation of 3 m/s^2. Calculate the time taken for the body to come to rest. (**ANS: t = 30 s**)

47. Two stones are thrown vertically upwards from the same point with the same velocity of 20 m/s but at an interval of 2 seconds. When they meet, the second stone rising at 10 m/s. Calculate:

a) **T**he time taken by the second stone in air before they meet. (**ANS: t = 1 s)**

b) The velocity of the first stone when they meet. (**ANS: V = 10 m/s, downward)**

48. Explain the difference between speed and velocity. Draw a graph of velocity against time for a body which starts with an initial velocity of 4 m/s and continues to move with an acceleration of 1.5 m/s^2 for 6 s. Show how you would find from the graph:

(a) The average velocity. **(ANS: V = 8.5 m/s)**

(b) The distance moved in the 6 s. (**ANS: s = 51 m)**

49. A body is uniformly accelerated from rest to a final velocity of 100 m/s **I** 10 seconds. Calculate the distance moved. (**ANS: s = 500 m)**

50. A stone is projected vertically upward with a velocity of 30 m/s from the ground. Calculate

a) The time it takes to attain maximum height (**ANS: t = 3 s)**

b) The time of flight **(ANS: T = 2t = 6 s)**

c) The maximum height reached (**ANS: h = 45 m)**

d) The velocity with which it lands on the ground (**ANS: V = 30 m/s)**

51. Two cars A and B start moving at the same time along a straight line with uniform acceleration of 5 m/s^2 and 3 m/s^2, respectively. If A is 60 km behind B, after how long will car overtake car B? (**ANS: t = 245 s)**

52. Define the term uniform acceleration of a body

53. A small solid sphere falls freely from rest, in air, with an acceleration of 10 m/s^2.How far does it fall in 5.0 s? (**ANS: h = 125 m)**

54. A motorcyclist accelerates from 10 m/s to 30 m/s in 20 s. Calculate:
  (a) The acceleration of the motorcyclist
  (b) The displacement of the motorcyclist

55. An object is thrown vertically upward from the ground at 30 ms^{-1}.
  (a) What is the displacement after 4 s? (**ANS: h = 42 m)**
  (b) What is the velocity after 4 s? (**ANS: v = - 9 m/s)**
  (c) What is the maximum height it attains? (**ANS: H = 46 m)**
  (d) What is the time of flight? **(ANS: T = 6.1 s)**

56. A small iron ball is dropped from the top of a vertical cliff and takes 2.5 s to reach the sandy beach below. Find:
  (a) The velocity with which it strikes the sand. (**ANS: v = 25 m/s)**
  (b) The height of the cliff .If the ball penetrates the sand to a depth of 12.5 cm, calculate its average retardation. (**ANS: h = 31.25 m ,a = 2500 m/s^2)**

57. A balloon is ascending at the rate of 12 m/s. When it is at a height of 65 m from the ground, a packet is dropped from it. After how much time and with what velocity does the packet reach the ground? Take g = 10 m/s^2 **(t = 5 s, v = 38 m/s)**

58. An object is seen to fall from an aeroplane and observed to take 15 seconds in reaching the ground . Assuming that air resistance is negligible, calculate
(a) the height of the plane. (**ANS: h = 1103 m)**
(b) the velocity with which the object strikes the ground (**ANS: v = 147 m/s)**

59. A stone is dropped from the top of a tower 400 m high and at the same time another stone is projected upward vertically from the ground with a velocity of 100 m/s. Find when and where the two will meet. (**ANS: t = 4 s, h = 78.4 m)**

60. A body is dropped from rest at a height of 150 m and simultaneously another body is dropped from rest from a point 100 m above the ground .What is the difference of their heights after they have fallen for 3 seconds? **.(AN: Δh = 50 m)**

61. A car travels at a uniform velocity of 20 m/s for 5 s. The brakes are then applied and the car comes to rest with uniform retardation in a further 8 s. Draw a sketch graph of velocity against time. How far does the car travel after the brakes are applied. **(ANS: s = 80 m)**

62. A trolley starts from rest on an inclined plane and moves down it with uniform acceleration. After having moved a distance of 40 cm its velocity is 20 cm/s. Find its acceleration: (a) in cm/s^2 (b) in m/s^2 **(AN: a = 5 cm/s^2 ,a = 0.05 m/s^2)**

63. A motorist, travelling at 90 km/h, applies his brakes and comes to rest with uniform retardation in 20 s**. Ca**lculate the retardation in m/s^2. (**ANS: a = 1.25 m/s^2)**

64. Define speed, velocity and acceleration.
  (a) A stone is released from rest at the top of a tall tower .Draw a distance – time graph of its free fall under gravity during the first 6 s. Show your table of values.
  (b) A bullet, fired vertically upwards from a gun held 2 m above the ground ,reaches its maximum height in 4 s. Calculate:
    (i) The initial velocity of the bullet. (**ANS: v = 40 m/s)**

(ii) The total distance the bullet travels by the time it hits the ground, given that g = 10 m/s^2. (**ANS: s = 162 m)**

65. A body starts from rest and accelerates at 3 m/s^2, for 4 s. Its velocity remains constant at the maximum value so reached for 7 s and it finally comes to rest with uniform retardation after another 5 s. Find by a graphical method:

(a) The distance moved during each stage of the motion.**(s =24 m, s= 30 m)**

(b) The average velocity over the whole period. **(ANS: V = 8.6 m/s)**

66. An object travelling at 10 m/s decelerates at 2.0 m/s^2 .How long does the object take before coming to rest? Calculate the distance travelled by the object before it comes to rest.

67. A car travelling at a speed of 72 km/hr is uniformly retarded by an application of brakes and comes to rest after 8 seconds. If the car with its occupants has a mass of 1,250 kg. Calculate

(a) The braking force (**ANS: F = 3,125 N)**

(b) The work done in bringing it to rest.(**ANS: Wd = -2.5 x 10^5 J)**

68. A bus starts to move with acceleration of 1 m/s^2 .A man who is 48 m behind the bus runs to catch it with a constant velocity of 10 m/s. In how much time he will catch the bus? **(ANS: t = 8 s or 12 s)**

69. A ball is thrown straight up. What is its velocity and acceleration at the top?
(ANS: V at top = 0 m/s, acceleration at top = 9.8 m/s^2)

70. A stone is thrown vertically upwards with an initial velocity of 30 m/s from the top of a tower 20 m high. Find:

(a) The time taken to reach the maximum height. (**ANS: t = 3 s)**

(b) The total time which elapses before it reaches the ground. (**A:t = 6.6 s)**

71. A projectile is fired vertically upwards and reaches a height of 125 m. Find the velocity of projection and the time it takes to reach its highest point.
(ANS: V = 50 m/s, t = 5 s)

72. A cyclist starts from rest and accelerates at 1.0 m/s^2 for 30 s. The cyclist then travels at a constant speed for 1 minute and then decelerates uniformly and comes to a stop in the next 30 s.

(a) Find the maximum speed attained in

i) Metres per second

ii) Kilometer per hour

(b) Calculate the total distance travelled

73. A racing car accelerates on a straight section of a road from rest to a velocity of 50 m/s in 10 s. Find:

(a) The acceleration of the car

(b) The distance travelled by the car in 10 s.

TOPIC: 07 NEWTON'S LAWS OF MOTION

There are three Newton's laws of motion. These include the following

- **Newton's first law of motion**
- **Newton's second law of motion**
- **Newton's third law of motion**

1. **Newton's First Law of Motion (the law of inertia or the seat belt – law)**
   This law is also referred to as **the law of inertia or the seat belt – law**

- **Inertia** is the tendency of an object to resist changes in its state of motion

OR

Inertia is the ability of a body to resist changes in motion

Types of Inertia

- Inertia of rest
- Inertia of motion
- Inertia of direction

Inertia of Rest

- Is the resistance of a body to change its state of rest

Inertia of Motion

- **I**s the resistance of a body to change its state of motion

Inertia of Direction

- **I**s 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 or uniform motion in a straight line unless external force act on it***"

OR

"An object will remain at rest or in uniform motion in a straight line unless acted upon by an external force"

Some examples of inertia in everyday life

- When you shake a branch the leaves get detached
- When you beat a carpet the dust particles come out
- When you quickly pull a book from the bottom of a file of books ,the other books remain arranged
- It is harder to stop a big vehicle like a bus than a smaller vehicle like a motorcycle .There is more inertia with the bigger object

- If a car is moving forward ,it will continue to move forward unless friction or the brakes interfere with its movement
- If you jump from a car or bus that is moving, your body is still moving in the direction of the vehicle. When your feet hit the ground ,the grounds act on your feet and they stop moving .You will fall because the upper part of your body didn't stop and you will fall in the direction you were moving
- When a bus suddenly starts moving, the passengers sitting or standing in the bus tend to fall backwards
- When a bus suddenly stops, the passengers sitting or standing in the bus are thrown forward

Momentum

- A body is said to be in motion if it changes its position with time and when it has velocity
- A body with zero velocity therefore it is not in motion and hence it is at rest
- The motion of a body can be measured by multiplying out its mass 'm' and its velocity 'v' the product M.V is known as the **linear momentum** of a body
- **Momentum is the product of the mass and velocity of an object**

Linear momentum = Mass x Velocity

$$\boxed{\therefore\ \mathbf{P = mv}}$$

- ∴ The S.I unit of momentum is **kg m/s**

Example A man of mass 1000 kg is moving with a velocity of 60 km/h. find its momentum

Solution:
Given: Mass of a car, m = 1000 kg , Velocity of a car, v = 60km/h = 16.7 m/s
Momentum of a car, p =?
From: Momentum (p) = mass x velocity = mv = 1000 x 16.7 = 16700 kgm/s

Newton's Second Law of Motion

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

- Suppose force F acts on a body of mass 'm' for time t. This force causes the velocity of the body to change from initial velocity 'u' to final velocity 'v' in that interval t
- The change in momentum will then be **mv – mu**

- The rate of change of momentum is $\frac{mv-mu}{t}$, by Newton's second law of motion

$$F \propto \frac{mv-mu}{t} \qquad \rightarrow F \propto m\frac{v-u}{t} .$$

But $\frac{v-u}{t}$ = a (acceleration of a body).

$\therefore$ **F $\propto$ ma**

- If a constant of proportionality **k** is introduced in the above relation, then **F = kma**. This equation can be used to define unit of force. If m = 1kg and a = 1m/s^2, then the unit of force is chosen in such a way that when F = 1 the constant k = 1, hence **F = ma**
- If a mass of 1kg is accelerating with 1m/s^2, then a force 1N is said to be acting on the body.

$\therefore$ A Force (F) of 1N is the force which when acting on the body of mass 1kg produces an acceleration of 1m/s^2.

$\therefore$ F = ma

Example

1. Suppose you exert an upward force of 10 N on a 3kg object. What will be the object acceleration?

   Solution:

Given: Force applied, f = 10 N, Mass of object, m = 3 kg = 30 N
Acceleration of an object, a =?

Net force (F) = 30 - 10 = 20 N

From: F = ma ------------------------- make **a** the subject

$$\therefore a = \frac{F}{m} = \frac{20}{3} = 6.67 \text{ m/s}^2$$

2. 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

Solution:

Mass of tennis ball, m = 150 g = 0.15 kg, Initial velocity, u = 20 m/s
Final velocity, v = 0 m/s Time taken, t = 0.05 s
Force applied/average, f =?

$$\therefore F = 0.15\ x\ \frac{0-20}{0.05} = -0.15\ x\ \frac{2000}{5} = -60\ N$$

NB:

- ❖ The product of force and unit time is called **impulse**

- **Impulse is the change in momentum → Impulse = change in momentum OR Impulse = Force x time**

  $\therefore$ I = Ft

- Its SI unit is **Newton second (Ns)**

Example

1. During a collision, a truck applies a force of 20000N on a 250 kg van for 0.5 seconds. Determine the impulse experienced by the van

   Solution

   Given: F = 20000 N, t = 0.5 s , m = 250 kg

   From**: Impulse (I) = Force x time = Ft = 20000 x 0.5 = 10000 Ns**

Application of Newton's second law (Momentum & Impulse) in our daily life

- The high jumpers usually bend their knees on landing. This increases the time of impact thus reducing the chance of injuries
- This reduces the possibility of them cracking on sudden stop or start
- While goalkeeper catching a ball, he extends his hands forward so that he has enough room to let his hands move backward after impact to prevent bounce of ball
- A person is better off falling on a wooden floor than a concrete floor. Because the wooden floor allows for a longer time of impact and, therefore a lesser force of impact than a concrete floor.
- Glass wares are wrapped in a paper before packing to avoid breakage. Because this increases the time of impact between various articles during jerks, thereby decreasing the force of impact on the articles
- When the car goes out of control while driving, you would prefer to hit something soft than something hard. It is because by hitting soft material you extend your time of impact ,thereby reducing the impact force

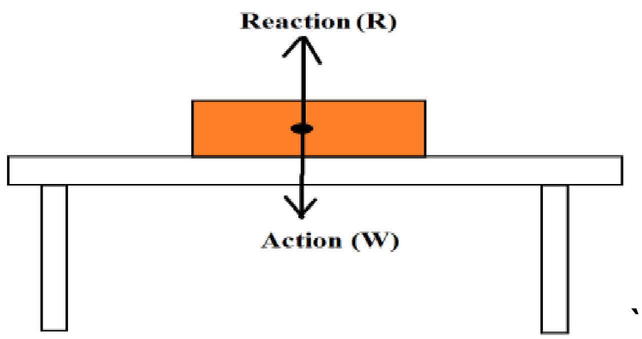
Individual Task – 1

1. A net force of 15 N is exerted on an encyclopedia to cause to accelerate at a rate of $3ms^{-2}$ .Determine the mass of the encyclopedia (**ANS: m = 5 kg**)
2. **A** trolley of mass 400 g has a velocity of 600 cm/s. Calculate the momentum of the trolley (**ANS: p = 2.4 kgm/s)**
3. Suppose that a sphere is accelerating at rate of 2 m/s^2 .If the net force is tripled and the mass is halved, then what is the new acceleration of the sphere? (**ANS: acceleration will increase by six times)**
4. Determine the momentum of a 1000 kg truck moving Northwards at a velocity of 20 m/s **(ANS: p = 20000 kgm/s ------northward)**

5. An athlete has a westward momentum of 5000 kgm/s. If the athlete has a mass of 75 kg, at what velocity is he moving? (**ANS: v = 66.7 m/s^{-1}**)
6. **A** cricket ball of mass 180 g travelling at 25 m/s is hit towards the bowler at 15 m/s .The impact lasts for 0.04 s. (**ANS: I = 7.2 Ns, F = 180 N to the left)**
   Find: (a) the impulse (b) the average force applied
7. An unbalanced force of 12 N acts on a mass of 2 kg. Calculate
   a) The resulting acceleration (**ANS: a = 6 m/s^2)**
   b) The force that would give a body of 10 kg the same acceleration **(ANS: F = 60 N)**

Newton's Third Law of Motion

- Consider the block when kept on a top of a table it cannot move either downward or upward due to equal action (weight of block) and reaction (the force pulls the block upward).
- Newton's third law is also known as the **law of reciprocal actions** or **law of action and reaction**



- Since two forces are equal Isaac Newton establish a law **which state that**:

"To *every action there is an equal and opposite reaction"*

Question:

1. Newton pair forces are equal in size and opposite in direction and yet they do not cancel each other out. Explain
   ANS: Forces can only cancel each other out if they act on the same object, Newton pair forces act on different objects

Application of Newton's Third Law

The following are some practical examples involving Newton's 3rd law of motion

- **Walking:** When a person walks on the ground ,he or she exerts a force on the ground and in turn ground exerts an equal force on the person

- If a car is accelerating forward , it is because its tyres are pushing backward on the road and the road is pushing forward on the tryres
- A block resting on a table exerts normal reaction which is equal to the weight of the block
- The person firing the gun will feel the recoil (push back) when the bullet leaves the gun
- 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
- A falling object exerts upward force on the earth as much as the earth is exerting a downward force on the object
- A hammer driving a nail into block of wood
- When the air is released from balloon it rushed out (action) tend to give reaction balloon so it acquire the motion
- An airplane pushes back on the air and the air pushes forward on the plane.

Apparent weight of man in lift (elevator)

- Suppose a man of mass **m** is standing on a weighing machine placed in lift or elevator
- The man exerts on the floor a force vertically downward which is the weight of the man (**W)**
- On the other hand, the floor exerts an equal force **R** on the man in the upward direction (**Newton's 3rd Law of motion) . Therefore R = W**
- **S**ince the two forces are acting on the man ,Then the difference of the two forces will determine in which direction the net force acts

(a) When the lift is at rest

Acceleration is zero and net force is zero

$$\boldsymbol{R - mg = 0} \qquad\qquad \therefore \boldsymbol{R = mg}$$

(b) When the lift is moving with constant velocity

Again in this case acceleration is zero (**a = 0 m/s^2)**

$$\boxed{\therefore \boldsymbol{R = mg = actual\ weight\ of\ man}}$$

(c) When the lift is moving upward with acceleration, $\boldsymbol{a}$

- Here the net force is acting in the upward direction

$$\boldsymbol{Net\ force = R - mg} \quad \rightarrow \quad \boldsymbol{ma = R - mg}$$

$$\therefore \boldsymbol{R = ma + mg = m\,(a + g)}$$

$\therefore \boldsymbol{R} > W\ (=\ mg)$

- Therefore, apparent weight (R) is greater than the actual weight W (= mg) of the man.**The man can feel it if he walks on the floor of lift (elevator),he will need more effort to walk naturally**

(d) When the lift is moving downward with acceleration a

- Net force is acting downward

$$\boldsymbol{Net\ force = mg - R} \quad \rightarrow \quad \boldsymbol{ma = mg - R}$$

$$\boxed{\therefore \boldsymbol{R = mg - ma = m\,(g - a)}}$$

$$\therefore \boldsymbol{R} < W\ (=\ mg)$$

- Therefore the apparent weight (R) of the man is less than the actual weight W(= mg) of the man .**The man will feel lighter as he walks about on the floor of the lift (elevator)**

(e) For free fall.

- **If the** lift (elevator) cable breaks , then the lift(elevator) will fall freely and $\boldsymbol{a =\ g}$

  From: $\boldsymbol{R = mg - ma = m\,(g - a) =\ 0}$
- **Therefore the apparent of the man will become zero**

(f) When the lift moves downward with $\boldsymbol{a} >\ g$

- In this case $\boldsymbol{R =\ m\,(g - a)}$ becomes negative
- Therefore the apparent weight of the man becomes negative and this indicates that the man will rise from the floor of the lift (elevator) and stick to the ceiling of the lift (elevator)

Individual task – 2

1. **A** 80 kg man stands in a lift .Calculate the force he exerts on the floor of the lift when the lift is (Assume g = 9.8 m/s^2)
   a) Stationary (**ANS: F = 780)**
   b) Ascending upward at 2 m/s^2 (**ANS: F = 940 N)**
   c) Moving with a constant velocity (upward) 4 m/s (**ANS: F = 780 N)**

Conservation of Linear Momentum

Collision

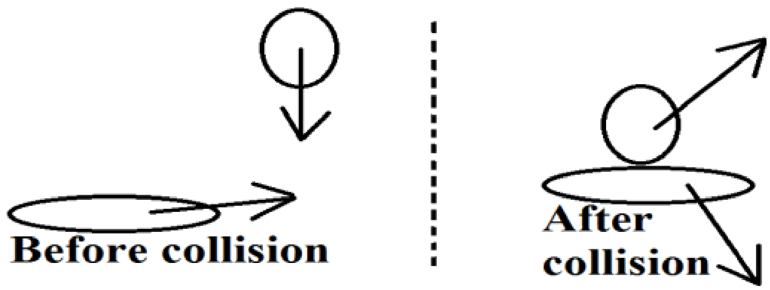
- Is an occurrence where momentum or kinetic energy is transferred from one object to another

Types of Collisions

- Elastic collisions
- Inelastic collisions

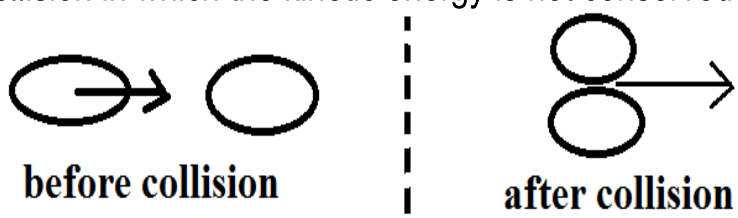
Elastic Collision

- **I**s a type of collision in which both kinetic energy and momentum are conserved after collision



Inelastic Collision

- **I**s a type of collision in which the kinetic energy is not conserved after collision



Difference between elastic and inelastic collision

Elastic collision	Inelastic collision
Both momentum and kinetic energy are conserved	**Only** momentum is conserved **(kinetic energy is changed into other energies such as heat and sound energy)**
Forces during collision are conservative and mechanical energy is not transformed into some other form of energy such as sound and thermal energy	Forces during collision are not conservative and mechanical energy is transformed into some other form of energy such as sound and thermal energy
Bodies move apart after collision	Bodies stick together after collision
Each body moves with individual velocity	**B**odies move with common velocity
An example of elastic collision is the movement of the swinging balls	**An e**xample of inelastic collision is an automobile collision

Principle of Conservation of linear Momentum

- It states that: **"when two or more bodies collide, their total momentum remains constant provided no external forces are acting"**

- Consider the case of firing a gun, as the bullet leaves the gun (reaction), the one holding it feels a backward force (reaction from the bullet of the gun)
- According to Newton's 3rd law of motion, these two forces are equal and opposite. Since these two forces act at the same time, the impulses (i.e. change in momentum) produced must be equal in magnitude and opposite in direction.
- Consider the collision of two balls moving in a straight line

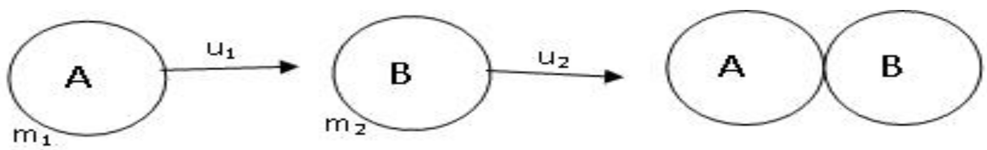


Fig: (a)
Fig: (b)

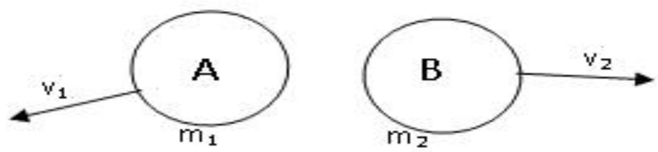


Fig: (c)

- The balls have the masses $\mathbf{m_1}$ and $\mathbf{m_2}$ and they are approaching each other with velocity $\mathbf{u_1}$ and $\mathbf{u_2}$ in fig (a)
- Then the balls have the velocities V_1 and V_2 after collision in fig (b)
- Let $\mathbf{F_1}$ and $\mathbf{F_2}$ be the forces acting on M_1 and M_2 during collision.
- By Newton's third law of motion the forces are equal and opposite since the two forces act during the same time t, the impulses produced are therefore equal and opposite $\therefore\ \boldsymbol{F_1 t = -F_2 t}$

- **But** $\boldsymbol{F_1 t = m_1 v_1 - m_1 u_1}$ **and** $\boldsymbol{F_2 t = m_2 v_2 - m_2 u_2}$

  From: $\boldsymbol{F_1 t = -F_2 t}$

  Thus: $\boldsymbol{m_1 v_1 - m_1 u_1 = -(m_2 v_2 - m_2 u_2)}$

  $$\boldsymbol{m_1 v_1 - m_1 u_1 = -m_2 v_2 + m_2 u_2}$$

  $$\boldsymbol{m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2}$$

  $$\boxed{\therefore\ \boldsymbol{m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2}}$$

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

NB:

- **If the two bodies are moving in opposite side (after or before collision), then minus sign (– ve) is introduced in the formula**

Example

1. 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 bullet, m_1 = 100 g, Mass of a gun, m_2 = 500 g

Initial velocity of a bullet, u_1 = 0 m/s Initial velocity of a gun, u_2 = 0 m/s

Final velocity of a bullet, v_1 = 100 m/s Final velocity of a gun, v_2=?

Solution

From: The Principle of conservation of linear momentum

$$\boldsymbol{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

$$500\ x\ 0 + 10\ x0 = 100\ x\ 10 + 500x\ v_2$$

$$0 = 1000 + 500V_2 \rightarrow \boldsymbol{v_2} = -\frac{1000}{500} = -2m/s$$

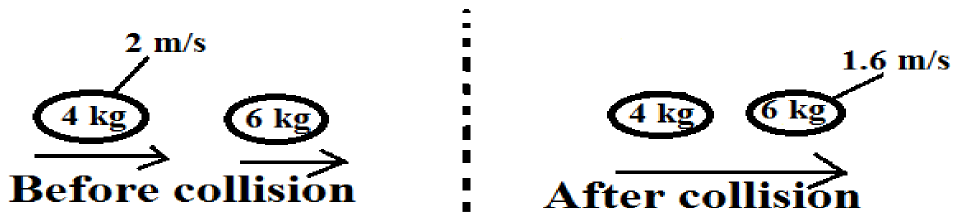
$\therefore$ ***the recoil velocity of the gun is* 2 *m/s*** **to the opposite side**

Individual task – 3

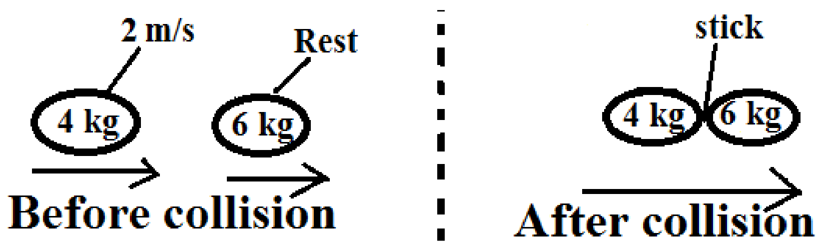
1. Trolley A of mass 6 kg is rolling across a smooth horizontal desk with a velocity of 0.8 m/s. The trolley collides with a stationery trolley B of mass 2 kg .After the collision the trolleys couple and move off together in the direction in which A was travelling .Calculate the velocity of the trolleys after the collision **(ANS: V_C = 0.6 m/s)**
2. A body of mass 8 kg moving with a velocity of 20 m/s collides with another body of mass 4 kg moving with a velocity of 10 m/s in the same direction .The velocity of the 8 kg is reduced to 15 m/s after collision .If the bodies do not stick together after the collision ,calculate the velocity of the 4 kg body
3. A 1000 kg cannon launches a cannon ball of mass 10 kg at a velocity of 100 m/s. At what speed does the cannon recoil? **(ANS: V_R = 1 m/s)**
4. During a shunting operation, a truck of total mass 15 metric tones (t) moving at 1 m/s, collides with a stationary truck of mass 10 t .If the two trucks are automatically connected so that they move off together , find their velocity . Also calculate the kinetic energy of the trucks (a) before (b) after collision. Explain why these are not equal (**ANS: V_C = 0.6 m/s, KE_B = 7.5 KJ, KE_A = 4.5 KJ)**
5. A 350 kg van moving at a velocity of 20 m/s crashes on a lorry of mass 600 kg that was at rest .Assuming the van and the lorry stick together upon impact, how fast will they come to a rest? (**ANS: V_C = 7.4 m/s)**
6. A 4 kg object is moving to the right at 2 m/s where 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
   (b) Velocity of 4 kg after the collision **(ANS: V = 0.4 m/s)**

(c) Total kinetic energy before and after collision **(ANS: $KE_B = KE_A = 8$ J)**

(d) Change in kinetic energy before and after collision **(ANS: $\Delta K.E = 0\ J$)**



7. Consider the diagram below and answer the questions that follows
   (a) What is their velocity after the collision **(ANS: $V_C = 0.8$ m/s)**
   (b) Total kinetic energy conserved (**ANS: Since $KE_B \neq KE_A$, Not conserved)**



Examples of conservation of linear momentum

1. **Recoil of a gun:** When a gun is fired ,the bullet moves with a large velocity and the gun moves with a small velocity in opposite direction to that of the bullet
2. When the bullet is fired ,the gun is always held close to the shoulder otherwise the shoulder may get hurt due to the recoil velocity of the gun
3. When a man jumps from a boat , the boat slightly moves away from the shore
4. **Rocket propulsion**: When the rocket is fired,fuel is burnt and very hot gases are formed. As the hot gases gain linear momentum to the rear on leaving the rocket, the rocket acquires equal linear momentum in the forward (i.e opposite direction) because linear momentum is conserved

Class Activity

1. **A car** of mass 600 kg moves with a velocity of 40 m/s .Calculate the momentum of the car (**ANS: P = 24,000 kgm/s)**
2. **Stones** of 8 kg and 4 kg move with velocities of 3 m/s and 6 m/s respectively .Compare their momentum **(ANS: Have the same momentum of 24 kgm/s)**
3. **A** cricket player catches a ball of mass 150 g moving with a velocity of 25 m/s. Find:
   a) the momentum of the ball (**ANS: P = 3.75 kgm/s ,F = 10.7 N)**
   b) the average force applied by the players hands to stop the ball in 0.35 s
4. **Find the** force required to accelerate a mass of 0.6 kg from 20 cm/s to 140 cm/s in 6 s (**ANS: F = 0.12 N)**
5. **Explain** the following terms:
   (a) momentum (c) elastic collision
   (b) inelastic collision (d) Impulse of a force
6. **A c**ar of mass 1200 kg travels along a straight horizontal road with a constant speed of 15 m/s. Calculate the momentum of the car (**ANS:P = 18 000 kgm/s)**
7. **A van** of mass 3 metric tons is travelling at a velocity of 72 km/h. Calculate the momentum of the vehicle. (**ANS: p = 6.0 x 10^4 kgm/s)**
8. **A hockey** player applies a force of 80 N to 250 g hockey ball for 0.1 s .Determine the impulse experienced by the hockey ball
9. **A** rocket pushes out exhaust gas at the rate of 150 kg/s. The velocity of the gas is 250 m/s. Calculate the forward thrust on the rocket
10. **A** fire fighter directs a horizontal jet of water onto a wall. The water strikes the wall at 6 m/s and bounces at 2 m/s. Find the force exerted on the wall if the mass of water hitting the wall is 30 kg per second
11. **Maryanne** , who has a mass of 50 kg is driving at a velocity of 35 m/s ,Suddenly ,she slams on the brakes to avoid hitting a pedestrian crossing the road .She is tightly held by the seatbelt which brings her body to rest in 0.5 s
    (a) What force does the seatbelt exert on her
    (b) If she had not been wearing the seatbelt and not had an airbag, then the wind screen would have stopped her head in 0.002 seconds .What force would the wind screen have exerted on her?
12. **Describe** any four applications of the law of inertia in everyday life
13. **Star**ting from the definition of Newton's 2^{nd} law of motion ,show that F = ma
14. **A** mass of 3.0 kg is moving at a velocity of 30 m/s. How long will a force of 15 N take to stop it?
15. **A person of mass** 60 kg jumps in air and lands with a speed of 6 m/s .If he bends his knees , he comes to rest in 0.8 s. Find the:
    (a) Deceleration of the person
    (b) Average force acting on the person

16. A 5 kg block moving at a velocity of 4 m/s strikes a 3 kg toy moving towards it at a velocity of 10 m/s. What will be the final velocity of the combined system after they experience an elastic collision

17. Suppose a 2 kg pistol containing a 10 g bullet is resting on a table. When it is accidentally fired, the bullet moves at a velocity of 150 m/s .What is the recoil velocity of the pistol?

18. A rocket expels gas at a rate of 0.5 kg/s. If the force produced by the rocket is 2000 N, What is the velocity with which the gas is expelled? (**ANS: v = 4000 m/s^2)**

19. A kick that lasts 0.03 s sends a ball of mass 0.65 kg with a velocity of 15 m/s northwards Find the

(a) Change of momentum of the ball

(b) Average force exerted on the ball

(c) Displacement of the ball in 2 s.

20. A football of mass 500 g attains a velocity of 17 m/s after being in contact with the player's boot for 0.03 s .Find the

(a) The average force exerted on the ball

(b) Impulse of the force

21. A body A of a mass 4 kg moves to the left with a velocity of 7 m/s. Another body B of mass 7 kg moves to the right with a velocity of 6 m/s. Calculate

a) **The momentum of** A **(ANS: P_A = -28 kgm/s)**

b) The momentum of B (**ANS: P_B = 42 kgm/s)**

c) The total momentum of A and B **(ANS: P_T = 14 kgm/s)**

22. (a) Find the average force required to stop a train weighing 200 tons travelling at 54 km/h in two minutes from the application of the brakes. **(ANS:F = 25 000 N)**

(b) what distance will the train travel in that time? (**ANS: d = 900 m)**

23. An object of mass 3 kg changes its velocity from 16 m/s to 30 m/s in 7.0 s. Calculate (a) the acceleration (b) the force applied on the object
(ANS: a = 2m/s^2 ,F = 6N)

24. State Newton's Laws of motion and explain how the second law may be used to define a unit of force ,the Newton

25. A breakdown truck tows a car of mass 1000 kg along a level road, and accelerates at 0.5 m/s^2. What is the tension in the towline? If the towline breaks when the car reaches a speed of 36 km/h , how far will the car travel before coming to rest if a breaking force of 5000 N is applied? **(ANS: T=500 N, S=10 m)**

26. A resultant force of 12 N acts for 5 s on a mass of 2 kg . What is the change in momentum of the mass? What would be the change in momentum of a mass of 10 kg under the same conditions? (**ANS: p= 60 kgm/s, p_2 = 60 kgm/s)**

27. A trailer of mass 1000 kg is towed by means of a rope attached to a car moving at a steady speed along a level road. The tension in the rope is 400 N .Why is not zero?. The car starts to accelerate steadily .If the tension in the rope is now 1650 N with what acceleration is the trailer moving? **(ANS: a = 1.25 m/s^2)**

28. A wooden trolley of mass 1.5 kg is mounted on wheels on horizontal rails. Neglecting friction and air resistance, what will be the final velocity of the trolley if a bullet of mass 2 g is fired into it with a horizontal velocity of 400 m/s along the direction of the rails? **(ANS: V = 0.53 m/s)**

29. An arrow of mass 100 g is shot into a block of wood of mass 400 g lying at rest on the smooth surface of an ice rink .If at the moment of impact the arrow is travelling horizontally at 15 m/s, Calculate the common velocity after the impact (**ANS: V_C = 3 m/s)**

30. State the law of conservation of momentum. Explain why the recoil velocity of a gun is much less than the velocity of the bullet

31. Two boys of masses 45 kg and 60 kg sit facing one another on light frictionless trolleys holding the ends of a strong taut cord between them .The lighter boy tug s the cord and acquires a velocity of 2 m/s. What is the initial velocity of the other boy? What happens to their motion when they collide?
(ANS: U = 1.5 m/s, they will either stop or rebound with velocities such that their total momentum will be zero)

32. A bullet of mass 12 g strikes a sold surface at a speed of 400 m/s. If the bullet penetrates to a depth of 3cm , calculate the average net force acting on the bullet while it is being brought to rest (**ANS: F = 32 000 N)**

33. Explain the terms; velocity and momentum. What is the relation between force and momentum ?

34. A rocket of total mass 5000 kg, of which 4000 kg is propellent fuel is to be launched vertically. If the fuel is consumed at a steady rate of 50 kg/s, what is the least velocity of the exhaust gases if the rocket will just lift off the launching pad immediately after firing? (**ANS: 1000 m/s)**

35. A girl of mass 50 kg stands on roller skates near a wall. She pushes herself against the wall with a force of 30 N. If the ground is horizontal and the friction on the roller skates is negligible, determine her acceleration from the wall. (**ANS: a = 0.6 m/s^2)**

36. A resultant force of 12 N acts on a body of mass 2 kg for 10 seconds. What is the change in momentum of the body? (ANS: $\Delta \boldsymbol{p} = \mathbf{12}\ \boldsymbol{Ns}$)

37. A girl of mass stands inside a lift which is accelerated upwards at a rate of 2 m/s^2 .Determine the reaction of the lift at the girls' feet. (**ANS: R = 600 N)**

38. The cork of a bottle of mass 4g is ejected with a velocity of 10 m/s in 0.1 s. Find the force exerted on the bottle. **(ANS: F= 0.4 N)**

39. A man whose mass is 70 kg stands on a spring weighing machine inside a lift .When the lift starts to ascend its acceleration is 2.5 m/s^2.What is the reading of the weighing machine? What will it read: (**ANS: m = 87.5 kg)**
   (a) When the velocity of the lift is uniform (**ANS: m = 70 kg)**
   (b) As it comes to rest with a retardation of 5.0 m/s^2. (**ANS: m = 35kg)**

40. A stationary bomb of mass 5 kg explodes into one part A of mass 2 kg flying off with a velocity of 60 m/s and another part B of mass 3 kg flying off with a certain velocity in the opposite direction. Calculate the,
(a) velocity of part B **(ANS: v = -40 m/s)**

(b) total kinetic energy produced by the explosion (**ANS:K.E = 6000 J)**

41. **An** inflated balloon contains 2.0g of air which is allowed to escape from a nozzle at a speed of 4.0 m/s .Assuming that the balloon deflects at a steady rate in 2.5 s, what is the exerted on the balloon. (**ANS: F = 0.0032 N**)
42. **A** vertical spring of unstretched length 30 cm is rigidly clamped at its upper end. When an object of mass 100 g is placed in a pan attached to the lower end of the spring its length becomes 36 cm. For an object of mass 200 g in the pan the length becomes 40 cm . Calculate the mass of the pan. Name and state the clearly the law you have assumed. **(ANS: m = 50 g)**
43. **A** body of mass 0.25 kg moving with a velocity of 12 m/s is stopped by applying a force of 0.6 N. Calculate the time taken to stop the body. Also calculate the impulse of this force. **(ANS: t = 5 s, Impulse = - 30 N)**
44. A 1200 kg car initially moving at 20 m/s strikes a tree and comes to rest in a distance of 1.5 m. Find the average stopping force the tree exerts on the car (**ANS: F = 1.6 x 10^5 N)**
45. A hunter has a machine gun that can fire 50 g bullets with a velocity of 150 m/s .A 60 kg tiger springs at him with a velocity of 10 m/s .How many bullets must the hunter fire per second into the tiger in order to stop him in his **track**
 (ANS: n= 80 bullets)
46. **A** ball of mass 10 g hits a hard surface vertically with a speed of 5 m/s and rebounds with the same speed. The ball remains in contact with the surface for 0.01 s. Find the average force exerted by the surface on the ball **(F = 10N)**
47. **A** shell of mass 30 kg is fired at a velocity of 600 m/s from a gun of mass 7000 kg
 (a) What is the recoil velocity of the gun? (**ANS: v_R = 2.57 m/s)**
 (b) Briefly explain the significance of the answer obtained in (a) above
48. A 450 kg van moving at a velocity of 30 m/s crashes on a truck of mass 3000 kg that is at rest .Upon impact the two vehicles moved some distance while stuck together
 (a) What is the common velocity of the motion after the impact?
 (b) If after the impact the two vehicles moved together for 10 seconds ,calculate the distance they moved
49. **A 30 kg** shell is flying at 48 m/s. When it explodes, its one part of 18 kg stops while the remaining part flies on. What is the velocity of the latter? **(v= 120 m/s)**
50. **A** cart of mass 500 kg is standing at rest on the rails. A man weighing 70 kg and running parallel to rail track with a velocity of 10 m/s jumps onto the cart on approaching it. Find the velocity with which the cart will start moving
 (ANS: v = 1.23 m/s)
51. **A mass** of 3 kg moving with a velocity of 4 m/s collides with another mass of 2 kg which is stationary. After collision the two masses stick together. Calculate the common velocity for the two masses (**ANS: V_C = 2.4 m/s)**

52. **A 5 kg mass moving** with a velocity of 10 m/s collides with a 10 kg mass moving with a velocity of 7 m/s along the same line. If the two masses join together on impact, find their common velocity if they were moving

(a) In opposite direction (ANS: V_C = 1.33 m/s to the left)

(b) In the same direction (ANS: V_C = 8 m/s to the right)

53. **A** bus of mass 3000 kg travelling at a velocity of 20 m/s collides with a stationary car of mass 600 kg. The two then move together at a constant velocity for 30 s .Find:

(a) The common velocity

(b) The distance moved after impact

(c) The impulsive force

(d) Kinetic energy before and after collision

54. A resultant force of 25 N acts on a mass of 0.5 kg starting from rest. Find:

(a) Find the acceleration in m/s^2 (**ANS: a = 50 m/s^2)**

(b) The final velocity after 20 s (**ANS: v = 1000 m/s**)

(c) The distance moved in metres (**ANS: s = 10 000 m)**

55. **A** bullet of mass 15 g travelling at 400 m/s becomes embedded onto a block of wood of mass 300 g which is at rest. Calculate the initial speed of the block immediately after collision.

56. **A** bullet of mass 0.006 kg travelling at 120 m/s penetrates deeply into a fixed target and is brought to rest in 0.01 s. Calculate:

(a) The distance of penetration of the target (**ANS: s = 0.6 m**)

(b) The average retarding force exerted on the bullet (**ANS: F = 72 N)**

57. 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? (**ANS: F = 31 N)**

58. **Differentiate** between elastic and inelastic collision

59. A rugby player of mass 75 kg, running east at 8 m/s ,tackles another player of mass 90 kg and who is running directly towards him at 5 m/s. If the two players cling together after the tackle, what will be their common velocity?

60. 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 (**ANS: a = 125 m/s^2)**

b) Force exerted on the nail by hammer (**ANS: F = 375 N)**

c) Time of impact (**ANS: t = 0.04 s)**

d) The impulse (**ANS: I = 15 Ns)**

61. A mass of 2.0 kg, travelling at 1.5 m/s catches up and collides with another ball of mass 3.0 kg travelling at 0.8 m/s in the same direction. If they stick and move together , calculate

(a) The velocity after collision for each ball

(b) The change in momentum for each ball

62. A small car of mass 500 kg is involved in a head – on collision with a heavy car of mass 4 000 kg travelling at 20 m/s. The small car is thrown onto the bonnet of the heavy car which continues after impact tat 4 m/s in the original direction .How fast was the small car moving?

63. A truck of mass 3 000 kg moving at 3 m/s collides head on with a car of mass 600 kg .The two stop dead on collision .At what velocity was the car travelling?

64. If a 2 kg ball travelling north at 6 m/s collides with 4 kg ball travelling in the same direction at 4 m/s ,the velocity of 4 kg ball increased to 5.5 m/s to the north , what happens to the 2 kg ball?

65. A car of mass 600 kg travels at 20 m/s towards a stationary pick – up of 1200 kg. After colliding the two stick and move together .Find their common velocity

66. An object of mass 20 kg collides with a stationary object of mass 10 kg. The two objects join together and move at a velocity of 5 m/s. Find the original velocity of the moving object

67. A monkey has a mass of 50 kg and it climbs on a rope which can stand **maximum tensional force(T) of 600 N**. when you expect the rope to break if Monkey:

a) Climb up with acceleration of 6 m/s2 **(ANS: R= 800 N, it will break**)

b) Climb up with uniform speed of 5 m/s (**ANS: R =500 N, it will not break)**

c) Fall down the rope will acceleration due to gravity (**AS: R= 0 N, it will not break)**

d) Fall down the rope will acceleration of 4 m/s^2 **(ANS:R = 300N,will not break)**

(**NB: Where R>T, the rope will break and for R<T, The rope will not break**)

68. 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 **(ANS: s = 2.15 m below)**

69. Give an explanation to the following:

(a) A gun recoils when it is fired

(b) A fireman moves backwards when a water hose he is aiming at a fire is suddenly turned on

70. Explain why action and reaction forces never cancel each other

71. A 10 kg object on Jupiter would weigh 260 N. What is the acceleration due to gravity on Jupiter?

72. If you see an object that is not moving, Can you conclude that there are no forces acting on it? Explain your answer

73. What is net force required to keep a 5 kg object moving with a constant velocity of 10 m/s?

74. What is net force required to keep a 5 kg object moving with a constant acceleration of 10 m/s^2?

75. Outline the types of inertia

76. A 4 kg object is acted upon by three horizontal forces: Force 1 is 20 N to the right, force 2 is 8 N to the left. If the acceleration of the object is 0.75 m/s^2 to the left, what is the magnitude and direction of force 3?

77. A 12 kg object is acted upon by an upward force of 150 N. What is the magnitude and direction of its acceleration?

78. A 0.2 kg helium balloon is acted upon by an upward buoyant force of 4 N. If released from rest, what is the time required for the balloon to reach an altitude of 200 m?

79. A model car of mass 2 kg is travelling in a straight line .If its velocity increases from 3 m/s to 9 m/s in 4 s, what is the resultant force on it?

80. A bullet of mass 10 g was fired into a block of wood of mass 390 g lying on a smooth surface .The wood then moves a at a velocity of 10 m/s

- **(a) What** was the velocity of the bullet?
- **(b) What was the K.E** before and after the collision?

81. A 0.2 kg ball is travelling at 20 m/s to the left when it is struck by a bat. After being struck the ball has a velocity of 25 m/s to the right. If the ball and bat were in contact for 0.3 s, what was the average force exerted on the ball?

82. Object A has a mass of 5 kg and a velocity of 10 m/s .Object B has a mass of 10 kg and a velocity of 5 m/s

- **(a)** Which object has the greatest momentum?
- **(b)** Which object has the most kinetic energy?

83. A railway truck of mass 2.4 t is shunted on to a stationary truck on a level track and collides with it at 4.7 m/s. After collision the two trucks move on together with a common speed of 1.2 m/s .Find:

- **a) The** mass of the stationary truck
- **b)** The original kinetic energy of the first truck
- **c)** The total kinetic energy of both trucks after collision. Account for the apparent loss in kinetic energy

84. A rocket taking off vertically, pushes out 25 kg of exhaust gas every second at a velocity of 100m/s. If the total mass of the rocket is 200 kg,

- **(e)** what is the resultant upward force on the rocket? (**ANS: F= 2500 N)**
- **(f)** What is the upward acceleration of the rocket? **(ANS: a = 12.5 m/s^2)**
- **(g) Ca**lculate the acceleration of the rocket in (a) above when it has burned off 100 kg of fuel **(ANS: a = 25 m/s^2)**

85. Briefly explain the following statements

- **(a)** A person doing high jump prefers to land on sand or plastic foam instead of the ground.
- **(b)** A car tends to skid on muddy roads

86. A Car of mass 1 200 kg is brought to rest by a uniform force of 300 N, in 80s. What was the speed of the car?

87. A stationary bomb of mass 5 kg explodes into one part A of mass 2 kg flying off with a velocity of 60 m/s and another part B of mass 3kg flying off with a certain velocity in the opposite direction .Calculate the,

- **(a) Velocity** of part B
- **(b) Total** kinetic energy produced by the explosion.

TOPIC: 08 Temperature

- **T**emperature is the degree of coldness or hotness of a body
- The SI unit of temperature is **Kelvin, K**. Other unit is **Celsius**, (**^{0}C)** or **Fahrenheit**,(**^{0}F)**
- Kelvin scale is also known as **absolute or thermodynamic scale.**
- The following formula may be useful when converting temperature from one unit to another:-

$$K = 273 + \theta°C$$

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

Whereby: ($\theta°C$) $is\ the\ temperature\ in\ celsius$

Difference between heat and temperature

Heat	Temperature
Is a form of energy possessed by a body due to its temperature change	**I**s the degree of hotness or coldness of a body
Its SI unit is Joule (J)	Its SI unit is Kelvin (K)
It cannot be measured directly	It can be measured by a thermometer
It can be transferred from one body to another	It cannot be transferred

- **S**imilarities between Heat and temperature

  →Heat and temperature all relate to the energy of a body

Measurement of Temperature

- Temperature is measured by using a **thermometer**
- The measurement starts with the establishment of any of the following **temperature scale.**
  - **Fahrenheit scale (^{0}F)**
  - **Celsius scale (^{0}C)**
  - **Kelvin scale (K)**
- The units of both the Celsius scale and Fahrenheit scale are called **degree**
- The SI units of Kelvin scale is **Kelvin**
- The freezing point of water in **Celsius scale** is 0 ^{0}C while its boiling point is 100^0 C
- Absolute zero temperature: Is the theoretical value of temperature where it is assumed that a substance has zero volume

  OR **Is the temperature at which the molecules of a material have zero kinetic energy**

Example:

1. Convert 600 ^{0}F into the ^{0}C scale

Solution:

$\boldsymbol{From: Temperature\ in}$ ^{0} **C =** $\frac{5}{9}\ x\ (F-32)$

θ ^{0} **C =** $\frac{5}{9}\ x\ (F-32) = \frac{5}{9} x\ (600-32) = \frac{5}{9}\ x\ 568 = 315.6$ ^{0}**C**

2. **C**onvert 398 K to degree Celsius.

Solution:

$\boldsymbol{From: Temperature\ in}$ ^{0} **C = Temperature in K – 273**

$\therefore$ $\boldsymbol{Temperature\ in}$ ^{0} **C = 398 – 273 = 125^0 C**

Individual task – 1

1. **After** being mixed with impurities, the melting of ice was found to be -22 ^{0} C. What is this temperature in Kelvin? (**ANS: θ ^{0} C = 251 K)**
2. **T**he temperature of the liquid nitrogen is 77 K. What is this temperature on the Celsius and Fahrenheit scale? (**ANS: -196 ^{0}C and -320 ^{0}F)**

A temperature scale is built from:

(a) At least two fixed points which are:-

- **Upper** fixed point
- **Lo**wer fixed point

(b) Fundamental interval

NB:

- ✓ **Upper fixed point** is the maximum temperature a reference object can attain without change of the desired state
- ✓ **Lower fixed point** is the minimum temperature a reference object can attain without change of the desired state
- ✓ **Fundamental interval** refers to the span of numbers between the upper fixed point and the lower fixed point

OR **Fundamental interval** Is the difference between the upper fixed point and the lower fixed point on a temperature scale.

$\therefore$ **Fundamental interval = Upper fixed point – Lower fixed point**

- **The U**pper fixed point (steam point): Is the temperature of the pure boiling water at normal atmospheric pressure

- **The** lower fixed point (ice point): Is the temperature of a pure melting ice at normal atmospheric pressure

- **To determine the temperature for a given height of the liquid above the lower fixed point ,the formula below is used:**

$$\boldsymbol{Temperature} = \frac{\boldsymbol{height\ of\ liquid\ above\ the\ L.F.P}}{\boldsymbol{Fundamental\ interval}} \times \boldsymbol{U.F.P\ in}\ (^0C)$$

Whereby L.F.P = Lower Fixed Point, U.F.P = Upper Fixed Point

Example

1. **T**he upper fixed point of a thermometer is 23 cm above the lower fixed point .If the upper fixed point is 90 ^{0}C while the lower fixed point is 25 ^{0}C ,What is the temperature when the mercury thread is 14 cm above the lower fixed point?

Solution:

The length of mercury thread above the lower fixed point = 14 cm
Fundamental interval = 23 cm
Upper fixed point = 90 ^{0}C
Lower fixed point = 25 ^{0}C

From: $\boldsymbol{Temperature} = \frac{\boldsymbol{height\ of\ liquid\ above\ the\ L.F.P}}{\boldsymbol{Fundamental\ interval}} \times \boldsymbol{U.F.P\ in}\ (^0C)$

$$\therefore \boldsymbol{temperature} = \frac{\mathbf{14}}{\mathbf{23}}\ \boldsymbol{x}\ \mathbf{90^0} = \mathbf{54.78^0}\boldsymbol{C}$$

Thermometers

- **A th**ermometer is a device that is used to measure the temperature of a system in a quantitative way
- The liquid which is enclosed in these types of thermometers is called **"thermometric liquid"**

Characteristics of Thermometric Liquid

(a) The liquid must be a good thermal conductor
(b) The liquid must be easily visible
(c) The liquid must have a wide range of temperature
(d) The liquid should not stick on to the walls of the container
(e) The liquid should be sensitive to minute temperature changes
(f) It should have a small specific heat capacity

NB:

- **T**he most common thermometric liquids are **mercury** and **alcohol**

Alcohol thermometer

Is a type of thermometer that uses a bulb filled with alcohol as the temperature sensor

Advantages of alcohol as a thermometric liquid:

a) Has a low freezing point of -115 ^{0}C
b) Its expansion is uniform (It expands more than mercury)
c) It is cheap and easily available
d) It is clear visible through glass
e) It is less toxic and less hazardous

Disadvantages of alcohol as a thermometric liquid

a) It cannot measure a high temperature, because its boiling point is low
b) Less durable (**alcohol evaporates)**
c) **It** makes wet the wall of the glass
d) **The** liquid should be dyed before filling the bulb

Mercury thermometer

Is a type of thermometer that uses a bulb filled with mercury as the temperature sensor

Advantages of mercury as a thermometric liquid:

a) It has a high boiling point (357°C) and low melting point (-39°C).
b) It is visible, because its color silvery shining
c) It does not stick to the wall of its place
d) It is a good thermal conductor
e) Its expansion is regular
f) It is very sensitive to temperature changes.

Disadvantages of Mercury as Thermometric Liquid

a) It is relatively expensive
b) It is toxic
c) Its freezing point is – 39 ^{0}C, hence is not suitable in reading very low temperature

Why water is not used as a thermometric liquid?

a) Its expansion is not linear
b) It has high freezing point and low boiling point
c) It has high specific heat capacity
d) It is transparent (colorless)
e) It is poor conductor of heat
f) It wets glass and sticks to the sides of the glass.

Types of thermometer

- Mercury in glass thermometer
- Alcohol in glass thermometer
- Bimetallic thermometer
- Thermocouple thermometer (works on Emf)
- Thermistor thermometer (Resistance thermometer)

NB:

- **Thermometric property**
  Is a physical property of matter on which a thermometer is based on.

OR **Is the property of a material that varies with the temperature of it**

OR Is the property of a substance which changes uniformly with the uniform change in temperature

Liquid in Glass Thermometer

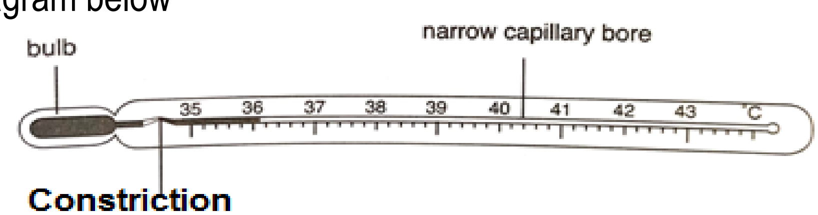
- Liquid – in glass thermometer are the most often used for temperature measurement
- A typical liquid in glass thermometer consists of a glass cylinder with a bulb at one end , a capillary tube inside the glass cylinder
- Examples of liquid in glass thermometers are **clinical thermometer, six's thermometer, laboratory thermometer**

Clinical thermometer (medical/doctors –thermometer)

- **Is** typically a mercury in – glass thermometer used to measure human body temperature
- **It** consists of
  (a) A thin walled bulb containing mercury which warms quickly and makes the thermometer quick – acting
  (b) **A** narrow capillary bore for providing sensitivity of thermometer
  (c) **Narrow** constriction just above the bulb for maintaining the reading (Makes the reading not to change).It prevents the mercury in the bore from returning to the bulb.

Mode of Action

Consider the diagram below



A clinical thermometer

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:

- **Constriction**: **is a bend on the capillary tube** or a very thin bore found at the neck of a clinical thermometer
- **Short stem**: is the glass cover of a liquid – in – glass thermometer where the scale is calibrated
- Fine bore: is the space inside a capillary tube
- It is not advisable to sterilize a clinical thermometer in boiling water at normal atmospheric pressure **because the glass will crack (burst) due to excessive pressure created by expansion of mercury**

Limitation of Clinical Thermometer

- They do not reflect the core temperature of the body
- May spread infection if not properly sterilized
- They are delicate and can break easily

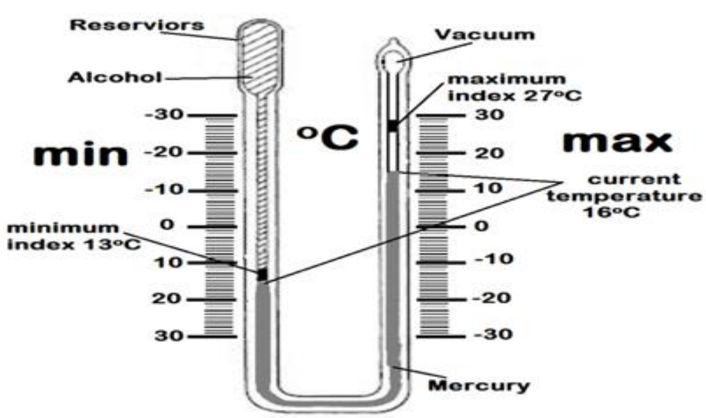
Precautions taken when using Clinical Thermometer

- Don't drop or subject it to heavy shock
- Do not bend it or bite the bulb
- Do not use damaged or broken thermometer as it can cause injury
- Keep it away from unsupervised children
- Sterilize it after use to avoid contamination

Maximum and Minimum Thermometer (six's thermometer)

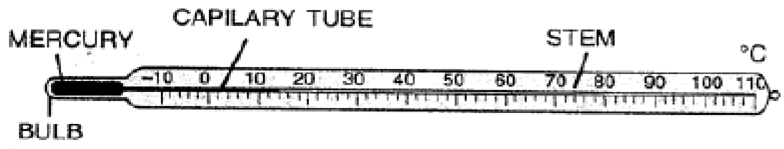
- **Is** a thermometer that is used to measure the maximum and minimum temperature of a place during a day
- **It consists** of a U – shaped capillary tube with two separate temperature readings ,and a small piece of steel called an i**ndex** (**marker**)
- **A** maximum thermometer uses mercury which pushes an index when the temperature rises and the mercury expands
- **A** minimum thermometer uses alcohol which contracts when the temperature falls.
- Maximum thermometer records highest temperature reached while minimum thermometer records lowest temperature

A six's thermometer



Laboratory thermometer

- Is a kind of thermometer designed mainly for scientific experiments which involve large temperature changes
- It consists of a bulb filled with mercury , a capillary tube attached to the bulb ,a glass cover (stem)



A laboratory thermometer

Difference between clinical thermometer and laboratory thermometer

Clinical Thermometer	Laboratory thermometer
Is the thermometer designed to measure the body temperature of humans and animals	Is the thermometer designed to measure the temperature of liquid and gas substance
Used at homes, hospitals and clinics	Used in laboratories
Its range of temperature is 35 ^{0} C to 43 ^{0}C	Its range of temperature is -10 ^{0}C to 110 ^{0}C
May be used by almost anybody	Mainly used in the scientific filed
It is small in size	It is large in size
Temperature can be read after removing the thermometer from body (armpit or mouth)	Temperature is read while keeping the thermometer in the substance

Class Assignment

1. The temperature of a body is 47 ^{0}C. What would this temperature be in the Fahrenheit scale?
2. With reasons, explain why mercury is more preferred to alcohol in liquid – in – glass thermometers.
3. Convert 212 ^{0}F into Kelvin scale
4. **Using a clearly labeled diagram, describe a clinical thermometer**
5. **De**fine the following terms:-
   a) Fundamental interval
   b) Temperature
   c) Thermometer
   d) Constriction
   e) Absolute zero temperature
   f) Thermometric liquid
6. Water, though readily available, is not preferred for use as a thermometric liquid. Explain

7. A human body temperature is 37 ^{0}C. What is this temperature in Fahrenheit and Kelvin scale?
8. What is 172K in the Celsius scale?
9. Name three types of thermometer
10. Convert – 40 ^{0}C to ^{0}F
11. The temperature of the surface of the sun is approximately 6000K .What is this temperature in ^{0}C and ^{0} F?
12. **On** a particular liquid – in – glass thermometer the distance between the 0 ^{0}C and 100 ^{0}C marks is 22.3 cm. What would be the distance between the 30 ^{0}C and 60 ^{0}C marks?
13. List advantages and disadvantages of mercury and alcohol as thermometric liquids
14. Explain the meaning of the following terms
    - **(c)** Lower fixed point.
    - **(d)** Upper fixed point.
    - **(e)** Fundamental interval.
15. List two advantages of mercury over alcohol as thermometric liquid.
16. A faulty thermometer has its fixed points marked 5 ^{0}C and 95 ^{0}C.What is the correct temperature in ^{0}C when this thermometer reads 59 ^{0}C
17. What are the advantages of alcohol(**ethano**l) over mercury
18. **The ice** and steam points on an ungraduated thermometer are found to be 192 mm apart. What temperature is recorded in ^{0}C when the length of the mercury thread is 67.2 mm above the ice point mark? (**ANS:**$\boldsymbol{\theta = 35^0}$ **C)**
19. **W**hy should a clinical thermometer not be sterilized in boiling water?
20. **If** the thermometer registers 103 at 100 ^{0}C and has no zero error ,what will it register at 50 ^{0}C (**ANS**: $\boldsymbol{\theta = 51.5^0}$ **C)**
21. **S**tate three desirable physical properties of a thermometric liquid
22. Sketch and label a clinical thermometer
23. Explain why a clinical thermometer should never be put in hot water?
24. Explain why it is fairly easy to see the very thin mercury column in a clinical thermometer.
25. What special features ensure that a clinical thermometer
    - **(h)** Records the maximum temperature
    - **(i)** Is sensitive
    - **(j)** Is quick in action
26. Heat and temperature are closely related but they are different. State how they are related and how they differ
27. What are the fixed points of a thermometer?
28. The temperature of the melting point of ice and that of steam above water boiling at 760 mmHg pressure are marked as 20 and 80 respectively on a certain thermometer .Calculate the thermometer reading when the temperature is 60^0 C (ANS: thermometer reading = 36 $\rightarrow \boldsymbol{temperature} = \frac{\boldsymbol{thermometer\ reading}}{\boldsymbol{range}} \times \boldsymbol{100^0 C}$)

29. In a mercury centigrade thermometer ,the distance between 0^0C point and 20^0 C point is 4 cm. What is the distance between 0^0 C point and 100^0 C point? **(L = 20 cm)**
30. Mention four reasons why mercury is a better thermometric liquid than ethanol.
31. Why is ethanol used in minimum thermometers but not in maximum thermometers?
32. Why do we often feel cold after perspiring freely?
33. Explain why a swimmer coming out of water on a windy day usually feels cold.
34. A thermometer is directly dipped into the beaker containing boiling water.
    (a) What does the thermometer measure?
    (b) What is the liquid in the thermometer?
    (c) What liquid would be used to measure a temperature of about – 80^0 C?
35. What does it mean by the term thermometric property?

TOPIC: 09 SUSTAINABLE ENERGY SOURCE

Sustainable sources of energy

- Are the natural resources that are used in the production of electricity without destroying the environment.

OR

- Is a form of energy whose usage meets the needs of the present generation without compromising its ability to meet the needs of the future generations

Types of Sources of Energy

- Renewable sources
- Non- renewable sources

Renewable Sources

- These are the energy sources which can be turned into use again after being used.
- Examples are **sun**, **water**, **wind** and **fossils**

Non- Renewable Sources

- These are the energy sources which cannot be turned into use again.
  For example **oil**, **natural gas** and **charcoal**

Sustainable Sources of Energy

This source occurs naturally and readily available, these include the following:-

- Hydroelectric energy
- Solar energy
- Wind energy
- Sea wave energy
- Geothermal energy
- Tidal energy

Hydroelectric Energy (water energy)

- Hydroelectricity is a form of renewable energy that uses the water stored in dams as well as flowing in rivers to create electricity in hydropower plants
  OR
- Hydroelectric energy is the generation of electricity using flowing water to drive a turbine which powers a generator.

Generation of Hydroelectricity

- Hydroelectric energy is formed from the force of falling (moving) water
- The capacity of this energy depends on the **available flow** and the **height** from which it falls
- When water comes from the dam which is constructed to hold water at a higher ground used to drive the **turbine in order to generate electricity**

Uses of water energy

- **U**sed for industrial work
- Used for lighting
- Used for heating and cooking
- Used for running hospital equipment

Advantage of Using Water Energy

- It is a renewable form of energy
- It is Clean and safe energy
- It is reliable source of energy
- It is operated at low cost
- Electricity can be generated constantly due to constant flow of water

Disadvantage of using water energy

- It is expensive to construct (install)
- The huge area is required hence can affect the ecology of the area
- Much of the energy produced is wasted in form of heat during transmission

Solar Energy

- S*olar energy is the radiant energy emitted by the sun*.
- Solar energy converted by solar cells (photovoltaic or photoelectric cells).
- Solar cell is a device that converts light energy into electric current using a **photoelectric effect**
- **photoelectric effect i**s a property of some materials to release electrons when hit with rays of light known as **photons**
- 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 sun is the ultimate source of much of the world's energy
- It provides the earth with light, heat and radiation
- All renewable energies ,other than geothermal energy and tidal(wave) energy, derive their energy from the sun

Advantage of Solar Energy

- **It** is renewable and unlimited
- **It** is non – polluting
- **It** has easy installation
- **It** is used for lighting purposes
- It is used for provision of electricity that is used by electric appliances
- It is used for drying clothes
- It is used for heating of water

- It is used to power torches, cars and calculators
- It is used by spaceships and satellites to convert sunlight into electricity
- It creates jobs by employing solar panel manufacturers, solar installers **etc**

Disadvantage of Solar energy

- **Lo**wer production in the winter months
- Devices that run on DC power directly are more expensive
- No solar power at night so there is a need for a large battery bank
- It is cost for initial purchasing of a solar system
- Uses a lot of space (the more solar panel as you need)

Wind Energy

- **Wind** is simply air in motion
- **Wind energy** is the form of solar energy caused by the uneven heating of the earth's surface by the sun
- Wind energy can be converted into electricity by building a tall tower with a large propeller on top called **wind mill (wind turbine).**
- **Wind mill** is a rotating machine that converts kinetic energy of wind into electrical energy

Advantage of Using Wind Energy

- It is renewable source of energy
- It is environmental friendly
- It has low running costs
- It can provide power to remote locations
- It is free (anyone can use it and never run out)

Disadvantage of wind energy

- **Noise**: some wind turbines tend to generates a lot of noise which can be unpleasant
- **Wind** turbines can cause death to wild animals (e.g birds, bats)
- **In**stallation is expensive

Sea Wave Energy

Sea water is the form of energy caused by disturbing water particles resulting progressive propagation from one point to another

Causes of Sea Wave Energy

Sea wave energy is as a result of wind blowing across the sea

Advantages of sea wave energy

- It is a renewable source of energy
- It is an environment friendly
- It is abundant and widely available
- It is easily predictable
- It is operated at low costs

Disadvantages of sea wave energy

- It has effects on marine ecosystem
- It is a source of disturbance for private and commercial vessels
- High cost of investment

Tidal Energy

- A Tide refers to the rise and fall of the sea level surface
- Tidal energy refers to the energy that is created by the rise and fall of the earth's sea level
- The amount of energy that is produced is determined by how high or low the tide rises or falls

Causes of Tides

- Tides are caused by the gravitational interaction between the earth and the moon

Advantages of tidal energy

- It is renewable energy source
- It is an environmentally friendly energy source
- Tides are very predictable thus highly reliable
- Cost of running is cheap
- It does not generate any unsafe, greenhouse gases or hazardous waste
- It functions without fuel requirement ,only functions with natural tidal energy

Disadvantages of Tidal Energy

- **It is** expensive to construct
- Limited locations: Tidal energy requires specific site characteristics
- Equipment maintenance can be challenging
- Weather effects: Bad weather and storm events along coastlines can damage tidal energy equipment

Geothermal Energy

- Geothermal energy is the energy generated by the flow of heat within the surface of the earth
- it is associated with area of frequent earthquakes and high volcanic activities
- The heat from the inside of the earth is used to heat water into steam. The steam is used to turn turbines and as the result this causes turbines to turn generator and produce electricity
- Geothermal energy exists in the form of :-
    a) **Volcanoes**
    b) **Hot Springs**
    c) **Geysers**

Three main uses of geothermal energy

- Heating
- Electricity generation
- Geothermal heat pumps

Advantages of geothermal energy

- It is renewable source of energy
- It is environmentally friendly
- It is reliable
- **It** reduces reliance on fossil fuels
- **It** create jobs and economic benefits

Disadvantages of geothermal energy

- During construction it can cause earthquakes (surface instability)
- Commercial geothermal power projects are expensive
- It can sometime run out of steam
- Suited to particular region
- It may release harmful gases through the holes drilled by constructors

Energy Cycle

- The sun is the ultimate the source of much of the world's energy.
- For instance, the solar cell generates electricity using light energy which has just arrived from the sun.
- 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.

- Wind is caused by the unequal heating of the earth by the sun. Wind energy therefore is a derivative of solar energy.
- 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 obtained from a wood fire originally comes from the sun.
- This is similar to the fossil fuels formed hundreds of millions of years ago. Plants died and became compressed to form coal.

Class Assignment

1. What are the advantages of utilizing tidal energy over utilizing geothermal energy?
2. Describe how hydro – electric energy is generated
3. "Though fossil fuels such as petroleum and coal are widely used, they are not sustainable." Give reasons to support the statement above.
4. Nuclear energy is not sustainable energy. Explain.
5. What are the benefits and drawbacks of hydroelectric energy?
6. "The sun is the ultimate source of the earth's energy". Explain this statement showing how the sun is the source of the other forms of energy
7. What is the role of a wind turbine?
8. ---------------------- is a form of energy that can be persistently used without running out
9. Name five sources of sustainable energy
10. State application of water energy
11. Sea wave energy is as a result of ------------------------ the sea
12. What is geothermal energy?
13. A ------------ is a device that converts light energy into electrical energy.
    (A)Wind mill (B) Inverter (C) Turbine (D) Solar cell
14. A form of energy that can be persistently used without running out is said to be:
    (A)Efficient (B) Renewable (C) Environmental friendly (D) Non – Renewable
15. Which is false?
    (a) Hydroelectric power stations are easy to set up?
    (b) Windmills are noisy?
    (c) Hydroelectric power plants degrade the environment
    (d) Windmills cannot be set up near the seabed
16. The energy due to the rising and falling in the level of water in the oceans or seas is known as:
    A. electric energy C. water energy
    B. Tidal energy D. wind energy
17. The most available sustainable sources of energy is:
    A. the sun B. wind C. Sea tides D. Water falls

18. Mention three sources of thermal energy in everyday life
19. State the energy conversion in a solar cell and give two practical uses of it.
20. Mention three renewable sources of energy
21. Sustainable energy sources are:
    A. Biogas, kinetic energy and petrol
    B. Biogas ,tidal energy and water energy
    C. Firewood, petrol and tidal energy
    D. Kerosene, nuclear energy and water energy
22. Which of these resources of energy is non renewable?
    A. Wave energy
    B. Bio fuels
    C. Radiant energy
    D. Fossil fuel
23. Match the items in list A with the items in List B

List A	List B
a) Geothermal energy b) Solar energy c) Wind energy d) Sea wave energy e) Water energy	(i) Energy from the sun (ii) Energy from firewood (iii) Energy from coal (iv) Hydroelectric energy (v) Energy from the nuclear of the atom (vi) Energy from hot rocks underground (vii) Energy from fossils (viii) Energy from charcoal (ix) Air current energy (x) Energy from batteries (xi) Tidal energy