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PHYSICS
10 - 12

What is physics?
Physics is the branch of science which deals with the properties and interaction of matter and energy.

Properties of matter
The properties of matter are called physical quantities.

Physical quantities are measurable features or properties of objects.

Types of physical quantities
There are two types of physical quantities:

- Basic quantities
- Derived quantities

1. **Base quantities**

These are quantities with only one SI unit.
SI units.(International system of units). This is a system of units which is universally agreed to be used in measurements of quantities worldwide.

Base unit	Symbol	For measuring
Metre	m	Length
Kilogram	Kg	Mass
Second	s	Time
Ampere	A	Electric current
Kelvin	K	Temperature
Mole	mol	Amount of substance
Candela	cd	Luminous intensity

2. **Derived quantities**

These are quantities which are expressed by combining two or more base units.

Derived quantity	SI unit	Symbol
Speed	Metre per second	m/s
Acceleration	Metre per second squared	m/s^2
Density	Kilogram per cubic metre	Kg/m^3
Force	Newton	Kgm/s^2
Energy	Joule	Kgm^2/s^2
Electricity	Coulomb	As

Conversion of units

Measure of distance
10mm = 1cm

100cm = 1m
1000m = 1Km
1Km = 100000cm = 1000000 mm

Measure of mass
1Kg = 1000g
1tonne = 1000Kg = 1000000g

Measure of time
60 seconds= 1 minute
60 minutes = 1 hour
24 hours = 1 day-night
7 days= 1 week
4 weeks = 1 month
12 months = 1 year = 360 days

Examples

1. Convert the following to the stated units.
(a) 200 kg to g,
(b) 30cm to m

Solution

(a) 1Kg $\rightarrow$ 1000g
200Kg $\rightarrow$x

$$x = \frac{200\text{Kg x } 1000\text{g}}{1\text{Kg}}$$

x = 200000g

(b) 100cm $\rightarrow$ 1m
30cm $\rightarrow$ x

$$x = \frac{30\text{cm x } 1\text{m}}{100\text{cm}}$$

x = 0.3m

Activity one

1. Convert the following to the stated units
   (a) 8.0Km to m
   (b) 0.8cm to m
   (c) 500m to Km
   (d) 13m to mm

Rounding off numbers
When considering whole numbers:

- Zeros at the end of the number are not significant. Note that zeros at the end of the whole number are place holders so that the other digits do not lose their place values

- Zeros between non – zero digits are significant

When rounding off decimal numbers:

- Zeros at the end of a decimal number are significant
- Zeros between non – zero digits are significant
- Zeros at the beginning at of a decimal number are not significant.
  When decimal numbers are rounded off, the number of decimal places to be rounded off must be specified

Scientific notation

Scientific notation is also called standard form.
Scientific notation is a method of expressing a number in the form: a x 10^n, where $1 \leq a < 10$ and n is an integer.
This is where numbers are expressed in the power of ten

Examples

1. Express the following in standard form
   (a) 3000000
   (b) 4200
   (c) 600
   (d) 0.0016
   (e) 0.235
   (f) 0.2001
   (g) 0.2000

Solution

(a) 3×10^6
(b) 4.2×10^3
(c) 6×10^2
(d) 1.6×10^{-3}
(e) 2.35×10^{-1}
(f) 2.001×10^{-1}
(g) 2×10^{-1}

Exercise

1. Write down the standard form of;
   (a) 6423
   (b) 5200
   (c) 60003
   (d) 0.03
   (e) 0.3002
   (f) 0.004010

Examples

1. Round off the following numbers according to the specifications:
   (a) 683 to the nearest ten
   (b) 683 to nearest hundred
   (c) 786 to the nearest ten
   (d) 9.3 to the nearest whole number
   (e) 5.7 to the nearest whole number
   (f) 9.9 to the nearest whole number

Solution

(a) 680
(b) 700
(c) 790
(d) 9
(e) 6
(f) 10

Rounding off decimal numbers

Examples

1. Round off the following according to the decimal places specified
   (a) 6.83 correct to one decimal place
   (b) 1.057 correct two decimal places
   (c) 0.0863648 correct to two decimal places
   (d) 0.95 correct to one decimal place

Solution

(a) 6.8
(b) 1.06
(c) 0.09
(d) 1.0

Exercise

1. Round off the following according to the decimal places specified.
   (a) 4.38 correct to one decimal place
   (b) 2.065 correct to two decimal places
   (c) 0.004689 correct to three decimal places.

Fundamental quantities

There are three fundamental quantities upon which all measurements are based. These are;

- Length
- Time
- Mass

Length

Symbol: L
SI unit: metre, m
Definition: Length is distance between two or more points.

Instruments used to measure length

- Rule
- Vernier calipers
- Micrometer screw gauge

The rule

Accuracy: 1mm
Quantity measured: Length

Common types of rules

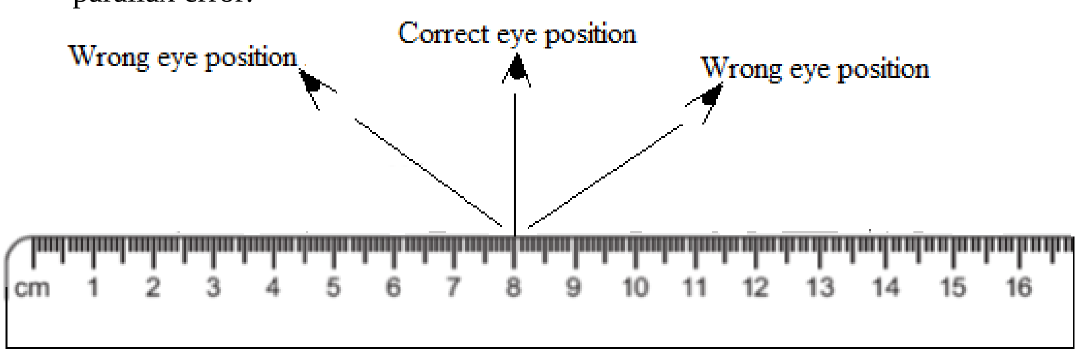
- metre rule (100cm rule)
- 30cm rule
- 15cm rule

Meter rule

The metre rule is used to measure length of more than 1mm.
It is usually graduated in centimeters.
It has sub- divisions in millimeters.

Correct useof a rule

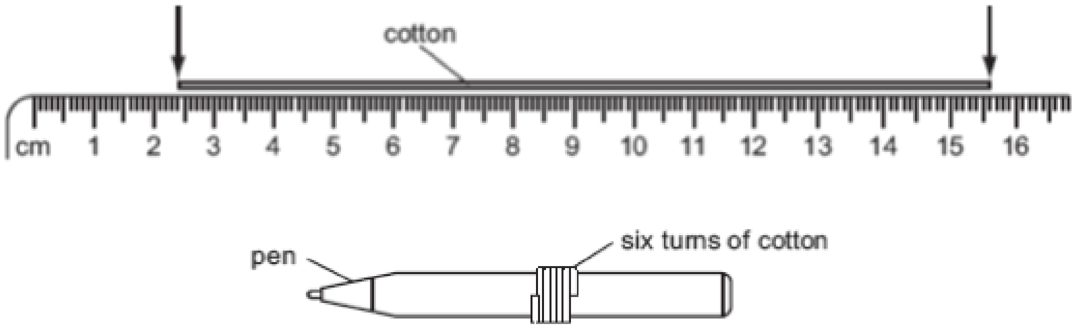
1. The eye should be placed vertically above the point to be measured to avoid parallax error.



2. If a rule has no zero edge, it means you cannot use this point. Therefore, to take a reading, start slightly inwards say at 1cm and remember to subtract from the final reading.

Example

1. A piece of cotton is measured between two points on a ruler.



When the length of cotton is wound closely around a pen, it goes round six times. What is the length of the cotton?

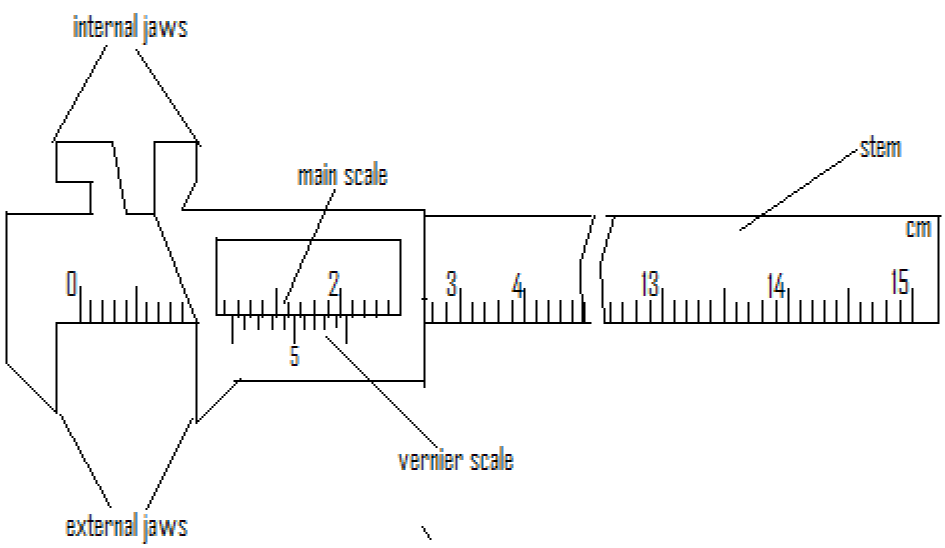
Solution

Length of cotton = 15.6cm – 2.4cm
=13.2cm

Vernier Calipers

Accuracy:0.01cm
Quantity measured: Length
Use: It is used to measure the length of solids where an ordinary rule cannot be used. The Vernier calipers can also be used to measure the diameter of balls and cylinders.

Structure of the vernier calipers



Main scale

The main scale is on the stem and fixed.
It is marked in centimeters, cm.

Vernier scale
The vernier scale is movable and slides on the main scale.
It is marked in millimeters, mm.
It has an accuracy of up to $\frac{1}{10}$thof a millimeter
The vernier scale has ten divisions that correspond to nine divisions of the main scale.

Internal jaws
They measure internal diameter of objects.

External jaws
They measure external diameter of objects.

How to read vernier calipers

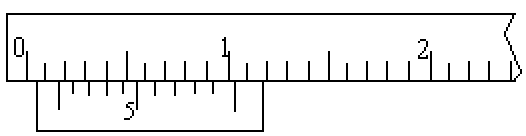
1. Find the value on the main scale that appears just before the zero of the vernier scale in centimeters, cm.
2. Find the value of the line on the vernier scale that coincides with a line on the main scale and multiply it by 0.01cm in order to convert it into cm.
3. Add main scale reading and vernier scale reading.

Precautions when using vernier calipers

1. Zero the instrument before taking a reading
2. Clean the instrument so that it is free from dust particles.

Example

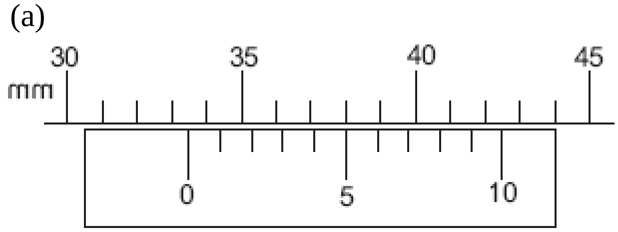
1. State the readings shown in the diagram of Vernier calipers below.



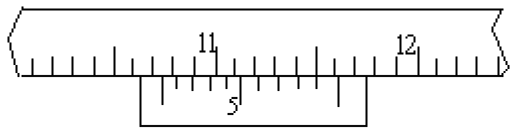
Main scale reading = 0.10cm
Vernier scale reading =3 x 0.01cm = 0.03cm
Vernier calipers reading = 0.10cm + 0.03cm
= 0.13cm

Activity four

1. Find the readings registered by the vernier calipers below.
(a)



(b)



<u>Micrometer screw gauge</u>

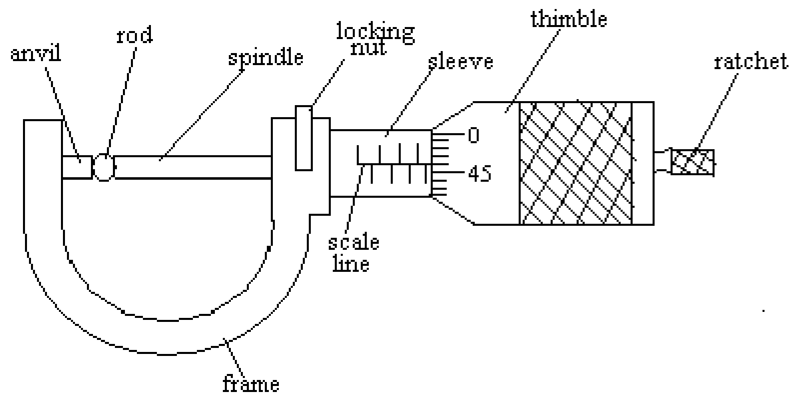
Accuracy: 0.01mm

Quantity measured: Length

Use: It is used to measure smallest size of length such as;

- the thickness of a hair,
- the diameter of a wire,
- the thickness of a piece of paper,
- the thickness of a coin,
- the thickness of a razor blade.

<u>Structure of the micrometer screw gauge</u>



<u>Important parts of the micrometer screw gauge</u>

1. **<u>Sleeve</u>**

This is the part that bears the sleeve scale.

The sleeve scale is graduated in millimeters, mm.
The sleeve scale measures correct to 0.5mm

2. **Thimble**

This is the part that bears the thimble scale.
The thimble scale measures correct to a 100th of a millimeter or 0.01mm.
A thimble scale has 50 divisions and each division represents 0.01mm.

3. **Anvil and Spindle**

These two parts hold the object that is being measured by the instrument.

4. **Ratchet**

This is a part used to move the spindle towards or away from the anvil in order to hold the object.

Measurement using the micrometer screw gauge

The two parts or scales are considered, namely;

- thimble scale
- sleeve scale

How to read the micrometer screw gauge

1. Find the value on the sleeve scale which appears just before the edges of the thimble. The value above the horizontal line gives the whole numbers.
   The value below the horizontal line but in front of the whole number obtained is a mark of 0.5mm and is added to the whole number.
2. Find the value on the thimble scale which is in line with the horizontal line of the sleeve scale and multiply it by 0.01mm.

Note

If there isn't any mark in line, but the horizontal line or point is in between the mark, the highest mark is taken and then multiplied by 0.01mm.

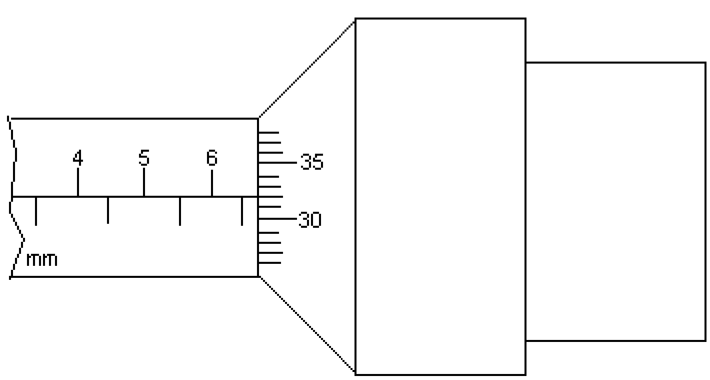
3. Add the sleeve scale reading and thimble scale reading.

Precautions when using a micrometer screw gauge.

1. Zero the instrument before making any measurement.
2. Clean the anvil and spindle before making any measurement.
3. Turn the ratchet gently.

Example

1. State the measurement shown in the diagram of the micrometer screw below.

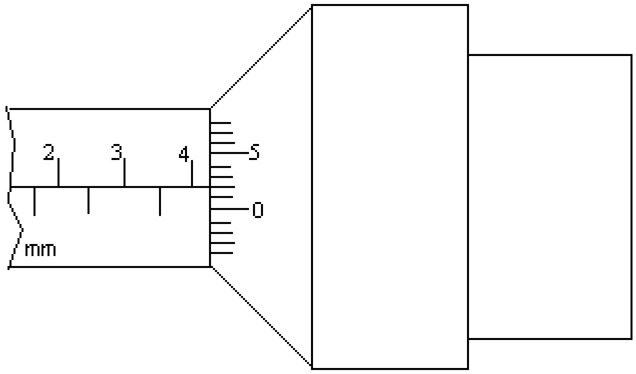


Sleeve reading = 6.5mm,
Thimblereading = 32 x 0.01mm
= 0.32mm

Micrometer reading = 6.5mm + 0.32mm
= 6.82mm .

Activity five

1. State the measurement shown in the diagram of the micrometer below



Time

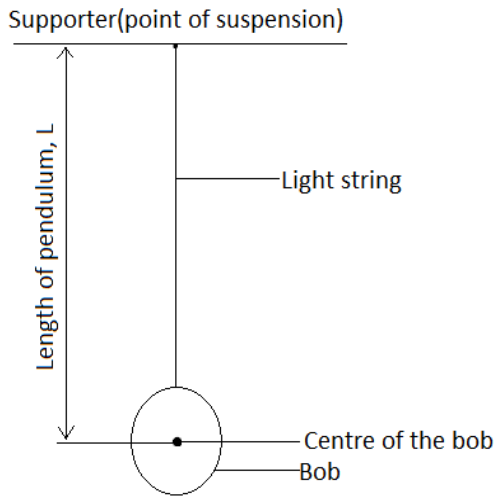
Symbol: t
SI unit: Second, s
Definition: It is the measure of how long matter occupies a given space
A time measurement enables us to determine the interval between the beginning and the end of an event.

Instruments for measuring time

- Simple pendulum
- Stop watch
- Ticker tape timer
- Oscilloscope (C.R.O)

The simple pendulum

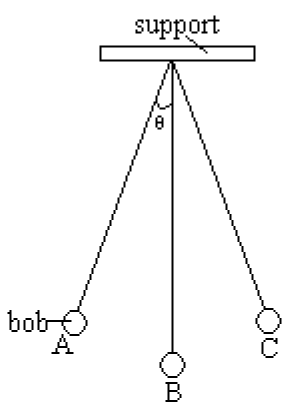
A simple pendulum is a small heavy bob suspended by a light inextensible string.
This consists of a string tied to a horizontal support. A bob is suspended at the lower end of the string.

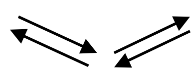


Terms used to describe a simple pendulum

Oscillation

An oscillation is a complete to and fro movement of the bob. It is also called a cycle or vibration or swing.





Note:

A swing from;

(a) A to B= $\frac{1}{4}$ or 0.25 oscillations.

(b) A to C= $\frac{1}{2}$ or 0.5 oscillations

(c) A to C and back to B =$\frac{3}{4}$ or 0.75 oscillations

(d) A to C and back to A = 1 complete oscillation

Amplitude

Symbol: A

SI unit: metre, m

Definition: Amplitude is the maximum displacement of the bob from the rest position.

Length of the pendulum

Symbol: L
SI unit: metre, m
Definition: Length of the pendulum is the distance from the supporter (point of suspension) to the centre of the bob.

Period of a pendulum

Symbol: T
SI unit: Second, s
Definition: Period of the pendulum is the time taken by the bob to make a complete oscillation.

Factors affecting the period of the pendulum

- Length of the pendulum, L
- Acceleration due to gravity, g

(a) Length of the pendulum, L

Period of the pendulum becomes;

(i) longer if the length of the pendulum is increased
(ii) shorter if the period of the pendulum is reduced

(b) Acceleration due to gravity, g

When;

(i) gravity is high, period reduces
(ii) gravity is low period increases

Period **does not** depend on the**mass or material** of the bob.

Relationship between period and time

- t = n x T
- $T=\frac{t}{n}$
- $n =\frac{t}{T}$

Note

- t = time interval in seconds, s
- n = number of oscillations (swings/cycles/times)
- T = period of the pendulum in seconds, s

Frequency

Symbol: f
SI unit: Hertz, Hz
Definition: Frequency is the number of oscillations in one second.

Relationship between frequency and period

- $\text{period} = \frac{1}{\text{frequency}}$

$T = \frac{1}{f}$

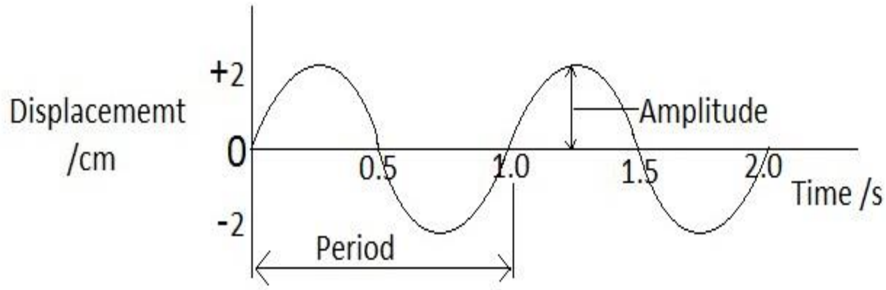
- frequency = $\frac{1}{\text{period}}$

$f = \frac{1}{T}$

- frequency = $\frac{\text{number of oscillations}}{\text{time}}$

$f = \frac{n}{t}$

<u>Displacement- time graph for a simple pendulum</u>



<u>Note</u>

- Amplitude = 2cm
- Period of the pendulum = 1.0s
- When length of the pendulum increases, period also increases but frequency reduces.
- When length of the pendulum reduces, period also reduces but frequency increases.

<u>Determining (measuring) period of the pendulum</u>

- Set the pendulum oscillating
- Note the time, t, and the number of oscillations, n.
- Calculate the period, T, using the formula;
  $T = \frac{t}{n}$

<u>Measuring time interval using a simple pendulum</u>.

- Set the pendulum oscillating.
- Note the number of oscillations, n.

- Calculate time by using the formula;
  $t = n \times T$

Note

- A number of runs are done and the average is taken to minimize error.

Experiment

Aim: To determine the relationship between the length (L) and period (T) of the pendulum

Apparatus

- Bob
- Clamp and stand
- String
- Stop watch

Method

Measure and record the length of the string from the point of support to the centre of the bob.
Pull the bob to one side with angular amplitude of less than 10^{o}.
Release the bob so that it starts swinging.
When the bob reaches the maximum displacement, start the stop watch and start counting
Record the time taken for 20 complete oscillations
Repeat the experiment with different lengths (L). Record values in the table.

Results

	Length of string (cm)	Time taken for 20 complete oscillations (s)	Period (s)
1	30cm		
2	20cm		
3	10cm		

Conclusion

Period of the pendulum depends on the length of the pendulum and acceleration due to gravity.

Examples

1. In an experiment to measure the period of the pendulum, the time taken for 50

complete oscillations was found to be one minute. What is the period of the pendulum?

Data	Solution
T =? t = 60 seconds n = 50	$T = \frac{t}{n}$ $T = \frac{60s}{50}$ T = 1.2s

2. What is the period of a pendulum that makes 50 cycles in 9s?

Data	Solution
T =? t = 9s n = 50	$T = \frac{t}{n}$ $T = \frac{9s}{50}$ T = 0.18s

3. A pendulum has period 0.6s. Calculate the time it takes to make 75 cycles?

Data	Solution
t =? n = 75 T = 0.6s	t = n x T t = 75 x 0.6s t = 45s

4. How many cycles are made by a pendulum whose period is 1.2s in 30s?

Data	Solution
n =? T = 1.2s t = 30s	$n = \frac{t}{T}$ $n = \frac{30s}{1.2s}$ n = 25 cycles

5. A pendulum makes 96 cycles in 4.8s.What is its frequency?

Data	Solution
f =? n = 96 t = 4.8s	$f = \frac{n}{t}$ $f = \frac{96}{4.8s}$ f = 20Hz

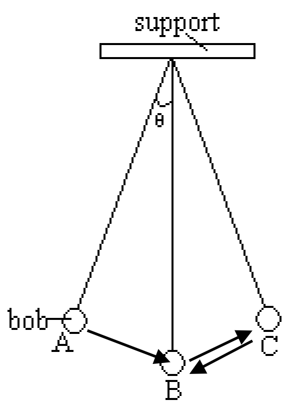
6. A pendulum's frequency is 15Hz.How many cycles does it make in 3.6s?

Data	Solution
n =? f = 15Hz t = 3.6s	n = f x t n = 15Hz x 3.6s n = 54 cycles

7. What is the time taken for a pendulum of frequency 25Hz to make 40 cycles?

Data	Solution
t =? n = 40 f = 25Hz	$t = \frac{n}{f}$ $t = \frac{40}{25Hz}$ t = 1.6s

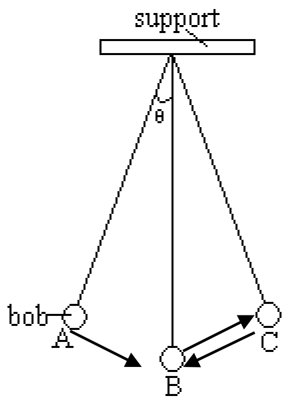
8. The figure below shows a simple pendulum that oscillates between position A and C.



a) If it takes 2 seconds for the bob to move from A to C and back to B, find the number of oscillations.
b) Calculate the period of the pendulum.
c) Calculate the frequency of the pendulum

	Data	Solution
a	A to C back to B	n = 0.75 oscillations
b	T =? t = 2s n = 0.75	$T = \frac{t}{n}$ $T = \frac{2s}{0.75}$ T = 2.67s
c	f =? T= 2.67s	$f= \frac{1}{T}$ $f = \frac{1}{2.67s}$ f = 0.37Hz

9. The diagram below shows an oscillating pendulum.

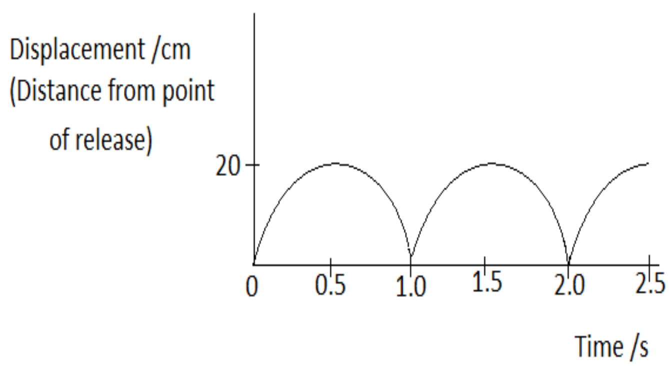


If the period of the pendulum is 0.4s, find the time taken for the pendulum to swing from;

a) A to C
b) A to B
c) A to C and back to B

	Data	Solution
a	t =? n = 0.5 oscillations T = 0.4s	t = n x T t = 0.5 x 0.4s t = 0.2s
b	t =? n = 0.25 oscillations T = 0.4s	t = n x T t = 0.25 x 0.4s t = 0.1s
c	t =? n = 0.75 oscillations T = 0.4s	t = n x T t = 0.75 x 0.4s t = 0.3s

10. The bob of a simple pendulum is pulled to one side and released. The motion during its swing is shown in the graph.

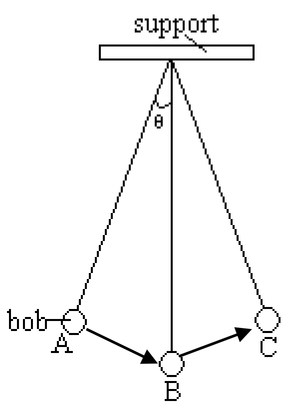


(a) What is the value of the period of the pendulum?
(b) Calculate the frequency of the pendulum
(c) What would you do in order to change the periodic time of the same pendulum to 1.5s?

	Data	Solution
a		T = 2.0s
b	f =? T = 2.0s	$f = \frac{1}{T}$ $f = \frac{1}{2.0s}$ f = 0.5Hz
c		By reducing the length of the pendulum.

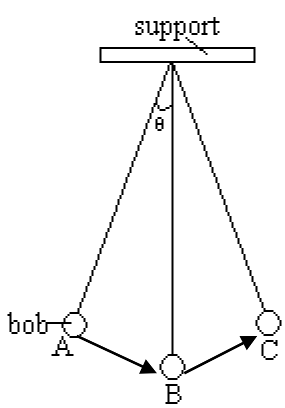
<u>Activity six</u>

1. Find the period of the pendulum if it oscillates 15 times for 45 seconds.
2. The diagram below shows an oscillating pendulum.



a) If it takes 3 seconds for the bob to move from A to C, find the period of the pendulum.
b) Find the time taken for 12 complete oscillations.

3. The bob of the pendulum shown below takes 0.25s to swing from A to C.

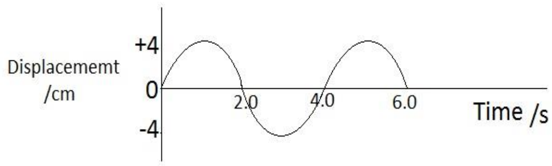


a) If A and C are extreme points, determine;
   (i) the period of the pendulum
   (ii) the frequency of the pendulum
b) State whether the frequency of oscillations will increase, decrease or remain the same if;
   (i) the length of the string is increased
   (ii) the mass of the bob is increased

(iii) The distance between A and C is increased.

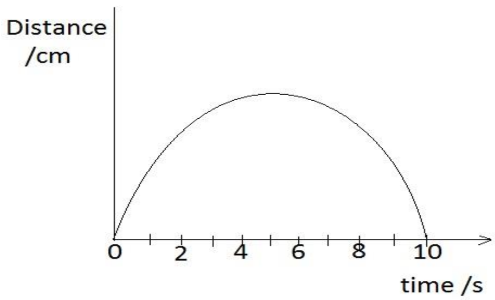
4 Briefly describe how the period of the pendulum would be measured.

5 Study the displacement- time graph for a simple pendulum.



(a) What is value of the period of the pendulum?
(b) State the maximum displacement of the pendulum.
(c) Naosa carried out an experiment to determine the time Kakula took to finish drinking one litre of castle using a simple pendulum. The period of the pendulum was 1.5 seconds and its length was 0.8m.
(i) Calculate the time taken for Kakula to finish drinking one litre of castle if the number of oscillations were 50.
(ii) State what will happen to the frequency of pendulum if the length was;
(a) reduced to 0.5m
(b) Increased by 0.5m.

6 The graph below is for a pendulum bob which was pulled to one side and then released to swing. Assume that there is no friction of any sort as the bob swings.

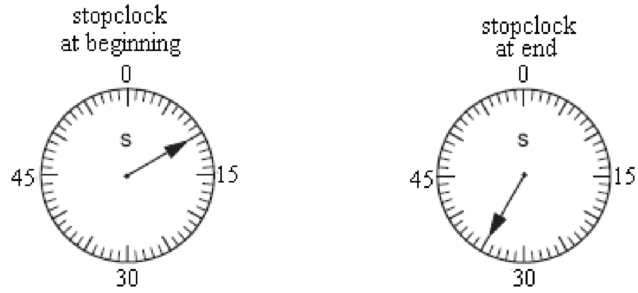


(a) What do you understand by period of the pendulum?
(b) After how long does the pendulum bob reach the maximum distance of travel?
(c) If the pendulum bob swings at the rate of 5m/s, how far from the starting position is it at 8 seconds later from the time it started swinging?
(d) Explain why this pendulum would be suitable for keeping or measuring time.

Stop clocks

Exercise

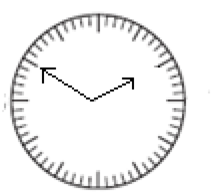
1. The diagrams show the times on a stop clock at the beginning and at the end of an experiment.



How long did the experiment take?

A 10 s B 25 s C 35 s D 45 s

2. One side of the main bedroom has a modern clock while the opposite side had a large dressing mirror. A child enters this room and sees the image of the clock in the mirror as shown below.



What is the correct time shown by the actual clock?

A 10:10 hours B 11:10 hours C 13:50 hours D 14:50 hours

Scalar and vector quantities

Scalar quantity

It is a quantity which has magnitude (size) with no direction

Scalar quantities can easily be added and subtracted.

Examples of scalar quantities

- Distance
- Speed
- Mass
- Volume
- Temperature

Vector quantity

It is a quantity which has both magnitude (size) and direction.
Vector quantities are mainly represented graphically or an arrow with a point (→)

Examples of Vector quantities

- Displacement
- Velocity
- Acceleration
- Force
- Weight
- Momentum

Kinematics

Kinematics is the science of describing the motion of objects using words, diagrams, numbers, graphs, and equations. Kinematics is a branch of mechanics.
Mechanics is the study of the motion of objects.

Motion

Motion is the change of position of an object in a given direction.

Types of motion

1. **Linear motion**

This is the movement of an object along a straight line or path e.g. a car travelling along a straight road.

2. **Motion Circular (Rotational motion)**

This is the movement in a circle about the centre or an axis e.g. a spinning wheel or rotating fan.

3. **Oscillatory motion**

This is the movement where an object moves to and fro about a fixed position e.g. the swinging of the bob of the pendulum.

4. **Random motion**

This is the movement of an object in a disorderly manner e.g. in the case of gaseous particles.

Linear motion

Four parameters are required to describe motion in a straight line. These are;

- Distance or displacement
- Speed or velocity
- Acceleration
- Time

Distance

Symbol: s
SI unit: metre, m
Definition: Distance is the length between two or more points. It can also be defined as

the actual path travelled by an object from its initial position to the final position.

Displacement

Symbol: s
SI unit: metre, m
Definition: Displacement is the distance travelled in a specified direction.

Similarity between distance and displacement

1. The SI unit for both distance and displacement is the metre, m.

Differences between distance and displacement

1. Distance is a scalar quantity while displacement is a vector quantity.
2. Distance is the length between two points while displacement is the distance travelled in a specified direction.

Examples

1. A car moves 15Km to the East and 13Km to the North.

(a) Find the distance and displacement of the car.

Solution

(i)Distance = 15Km + 13Km
= 28Km

(ii)Displacement = 15Km East and 13Km North.

2. The circumference of a round bout is 50m and the car turns it once.
   (a) Find the distance and displacement of the car.

Solution

(i)Distance = 50m

(ii)Displacement = 0m because the car came back to the starting point.

3. A boy walks forward 25m and backward 15m.
   (a) Find the distance and displacement of the boy.

Solution

(i)Distance = 25m + 15m
= 40m

(ii)Displacement = 25m – 15m

= 10m forward

Speed
Symbol: V
SI unit: metre per second, m/s (or ms^{-1})
Definition: Speed is the rate of change of distance with time.

Formula: Average speed = $\frac{\text{total distance covered}}{\text{total time taken}}$

$$v = \frac{s}{t}$$

Note
1m/s = 3.6Km/h

Examples

1. Express
(a) 72Km/h in m/s
(b) 10m/s in Km/h

Solution

(a) $= \frac{(72 \text{ x } 1000)\text{m}}{(60 \text{ x } 60)\text{s}}$
=20m/s

OR

3.6Km/h → 1m/s
72Km/h → x
$x = \frac{72\text{Km/h X } 1\text{m/s}}{3.6\text{Km/h}}$
x = 20m/s

(b) 1m/s → 3.6Km/h
10m/s→ x
$x = \frac{10\text{m/s x } 3.6\text{Km/h}}{1\text{m/s}}$
x = 36Km/h

2. A car travels from Lusaka to Mongu 600Km away in 8hours. Find the average speed of the car in Km/h.

Data	Solution
v =? s = 600Km t = 8h	$v = \frac{s}{t}$ $v = \frac{600\text{Km}}{8\text{h}}$ v = 75Km/h

3. A cheetah runs at a speed of 20m/s in 50 seconds. Calculate how far it will travel in this time.

Data	Solution
s =? v= 20m/s t = 50s	s = v x t s = 20m/s x 50s s = 100m

4. A bus takes 40 minutes to complete its 24Km route. Calculate its average speed in m/s.

Data	Solution
v =? s = 24Km = 24000m t = 40min = 2400s	$v = \frac{s}{t}$ $v = \frac{24000m}{2400s}$ v = 10m/s

Velocity
Symbol: V
SI unit: metre per second, m/s (or ms^{-1})
Definition: Velocity is the rate of change of displacement with time.

Formula: Average velocity = $\frac{\text{displacement}}{\text{time taken}}$

$$v = \frac{s}{t}$$

Similarity between speed and velocity
1. Both speed and velocity are measured in metres per second, m/s.

Differences between speed and velocity
1. Speed is a scalar quantity while velocity is vector quantity.
2. Speed is the rate of change of distance with time while velocity is the rate of change of displacement with time.

Note
Speed is called velocity when it has direction and velocity is called speed when it has no direction.

Example
1. Car 1 moves 10m/s east and car 2 moves 10m/s north. Find the speed and velocity of the two cars.

Solution
(a) Both car 1 and 2 have the same speed of 10m/s
(b) Car 1 has a velocity of 10m/s east while car 2 has a velocity of 10m/s north.

Acceleration
Symbol: a
SI unit: metre per second squared, m/s^2 (or ms^{-2})
Definition: Acceleration is the rate of change of velocity with time.

Formula: Average acceleration = $\frac{\text{Final velocity} - \text{initial velocity}}{\text{time taken}}$

$$a = \frac{V-U}{t}$$

Types of acceleration

1. **Positive acceleration**

This is when velocity is increasing with time.
It is always given a positive sign.

2. **Negative acceleration**

This is when velocity is decreasing with time. It is also called retardation or deceleration
It is always given a negative sign

3. **Uniform acceleration**

This is when the rate of velocity is constant
Under uniform acceleration, velocity is changing continuously but at the same rate.
Uniform acceleration is also called constant acceleration

4. **Non uniform acceleration**

This is the acceleration in which the rate of change of velocity is not constant.
The rate of change of velocity keeps on changing.

Note

1. Negative acceleration is called retardation or deceleration
2. When speed or velocity is constant, acceleration, a = $0m/s^2$
3. From rest, initial velocity, u = 0m/s
4. Moving at/travelling at/moving with, initial velocity, u = given velocity in m/s
5. To rest, final velocity, v = 0m/s

Examples

1. A car starting from rest increases its velocity uniformly to 15m/s in 3 seconds. What is the acceleration?

Data	Solution
a =? v = 15m/s u = 0m/s t = 3s	$a = \frac{v-u}{t}$ $a = \frac{15m/s - 0m/s}{3s}$ $a = \frac{15m/s}{3s}$ $a = 5m/s^2$

2. A car slows down from 36m/s to rest in 12s. Calculate the retardation.

Data	Solution
a =? v = 0m/s u = 36m/s t = 12s	a = $\frac{0m/s-36m/s}{12s}$ a = $\frac{-36m/s}{12s}$ a = $-3m/s^2$

Equations of uniformly accelerated linear motion

1. v = u + at
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$
4. $s = \frac{(v+u)t}{2}$

Examples

1. A car travelling at 10m/s accelerates at $2m/s^2$ for 3 seconds. What is its final velocity?

Data	Solution
v =? u = 10m/s t = 3s a = $2m/s^2$	v = u + at v = 10m/s + ($2m/s^2$ x 3s) v = 10m/s + 6m/s v = 16m/s

2. A car starts from rest accelerates at $3m/s^2$.How far does it travel in4 seconds?

Data	Solution
s =? u = 0m/s t = 4s a = $3m/s^2$	$s = ut + \frac{1}{2}at^2$ $s = 0m/s \ x \ 4s + \frac{1}{2}x \ 3m/s^2 \ x \ (4s)^2$ s = 24m

3. A car accelerates from rest to a velocity of 8m/s over a distance of 200m. How long does it take to accelerate from rest to 8m/s?

Data	Solution
t =? s = 200m v = 8m/s	t = $\frac{2s}{v+u}$

u = 0m/s	$t = \frac{2 \text{ x } 200m}{8m/s+0m/s}$ t = 50s

4. A car accelerates uniformly from rest until it reaches a velocity of 10m/s in 5s. How far does it travel during the 5s?

Data	Solution
s =? v =10m/s u = 0m/s t = 5s	$s = \frac{(v+u)t}{2}$ $s = \frac{(10m/s+0m/s)5s}{2}$ s = 25m

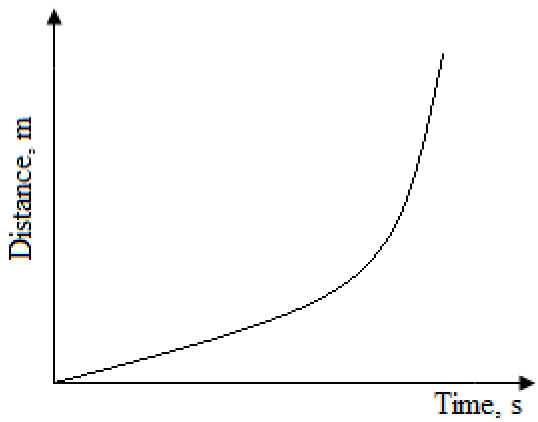
<u>Activity seven</u>

1. A car travelling at 20m/s accelerates at the rate of $2m/s^2$ for 30 seconds. Calculate;
   (a) the final velocity of the car
   (b) the distance travelled by the car.

Time graphs

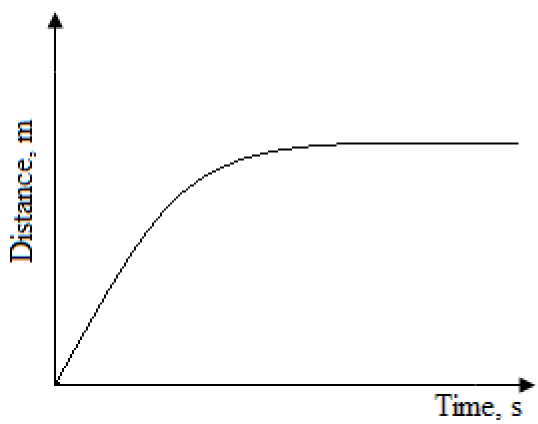
Distance-time graphs

A distance time - graph is a graph where distance is plotted against time.
The diagrams below represent the distance time graphs for the motion of an object.



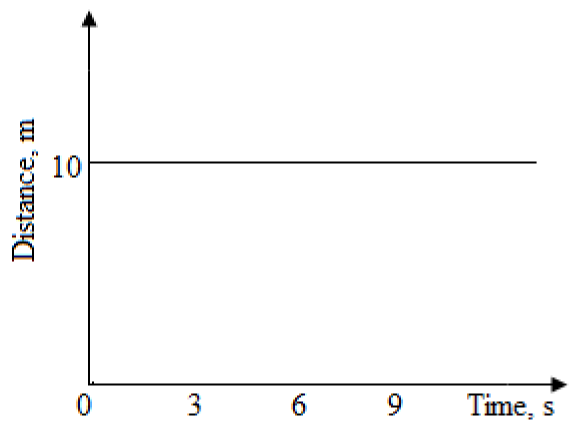
Description

The object was accelerating.



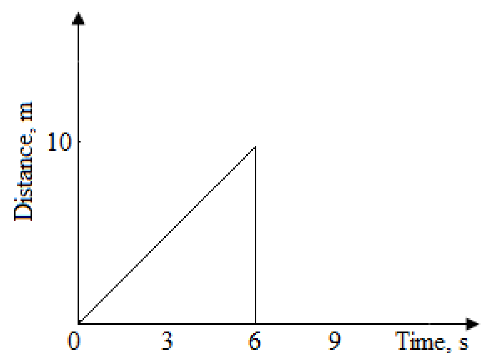
Description

The object was decelerating or retarding



Description

The object stopped moving.(was at rest)
The horizontal straight line indicates zero speed



Description

The object was moving with constant velocity. It travelled a distance of 10m in 6s.
The slope on the distance-time graph represents velocity.

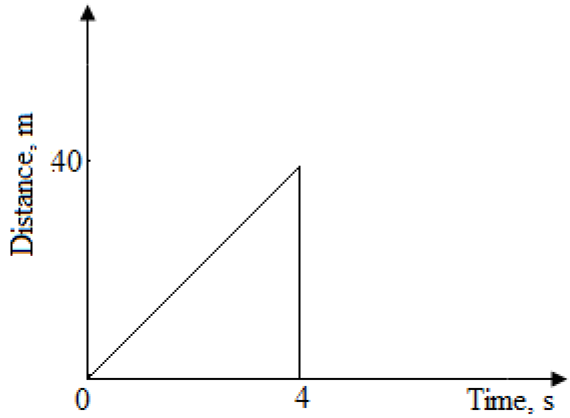
Velocity = $\frac{\text{distance}}{\text{time}}$

Example

1. An object travelled a distance of 40m in 4 seconds.
   (a) Sketch the distance- time graph to interpret the information above.
   (b) Calculate the velocity of an object.

Solution

(a)



(a) Velocity $= \frac{\text{distance}}{\text{time}}$

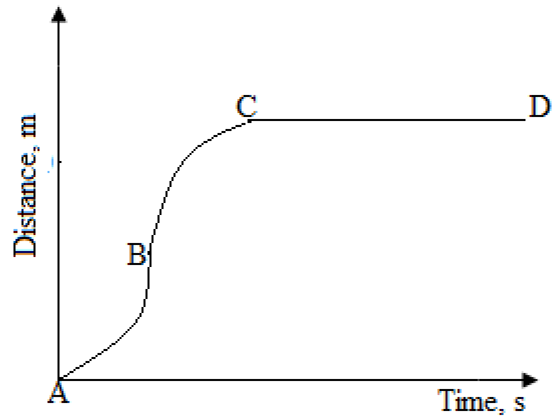
$v = \frac{s}{t}$

$v = \frac{40m}{4s}$

v = 10m/s

Activity eight

1. The diagram below shows the distance-time graph of an object.

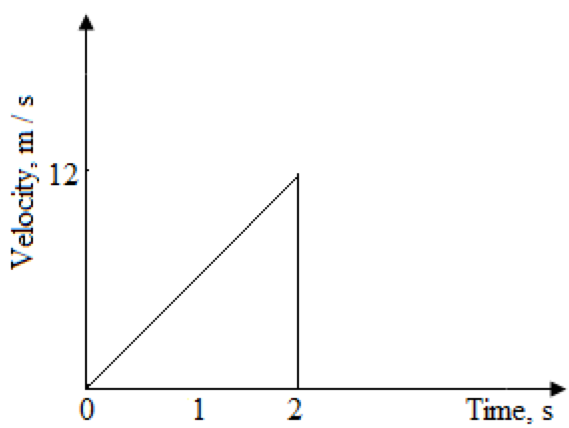


Describe the motion of an object from;

(a) A to B
(b) B to C
(c) C to D

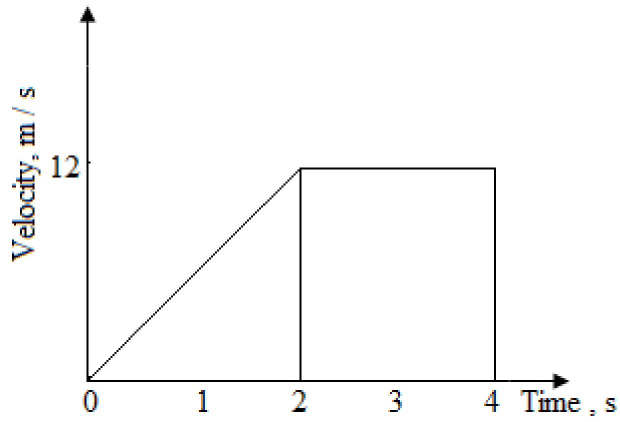
Velocity (speed)-time graphs

Velocity-time graph is a graph where velocity is plotted against time.
The diagrams below show the velocity-time graphs for the motion of an object.

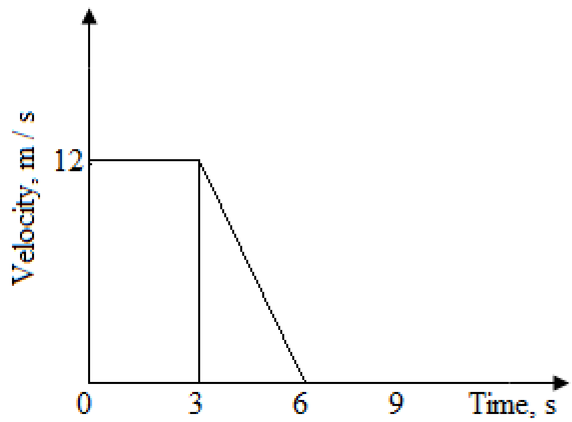


Description

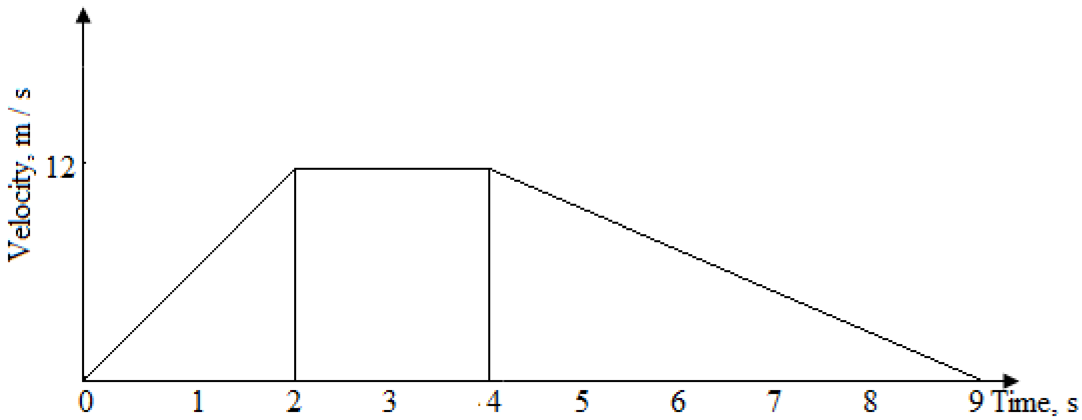
The object was moving from rest with constant acceleration to a velocity of 12m/s in 2s.
The slope indicates constant acceleration.



Description
The object was moving from rest with constant acceleration to a velocity of 12m/s in 2s. It then moved with constant velocity of 12m/s in 2s.



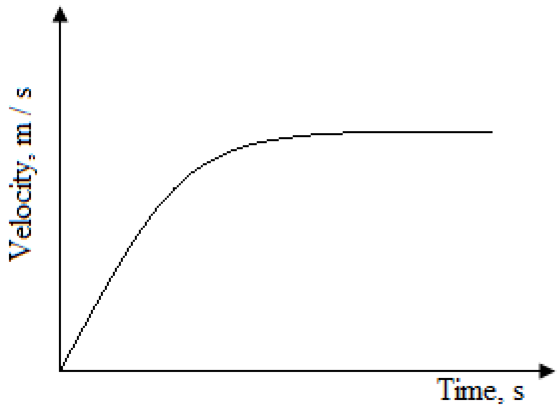
Description
The object was moving at a constant velocity of 12m/s in 3s and then decelerated uniformly to rest in 3s.



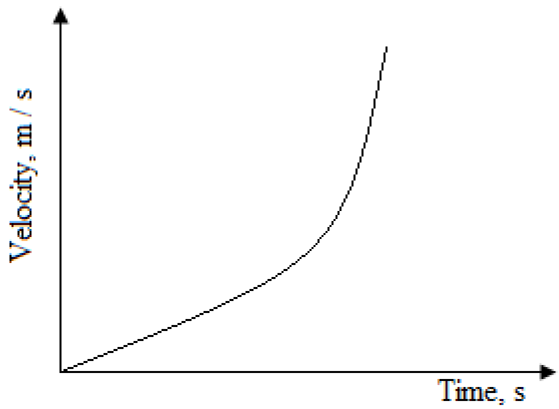
Description

The object was moving from rest with constant (uniform) acceleration to a velocity of 12m/s in 2s and then it moved with constant velocity of 12m/s in 2s and finally decelerates uniformly to rest in 5s.

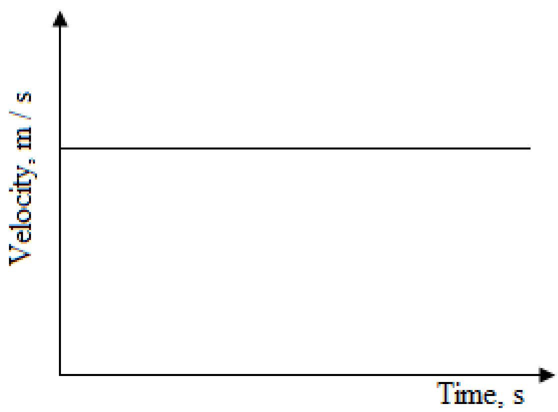
Summary of velocity-time graphs



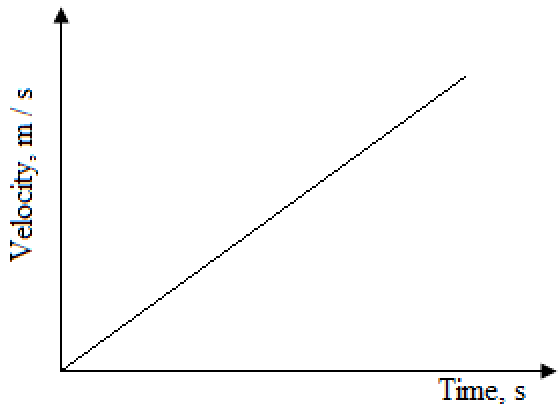
Description
Non-uniform acceleration



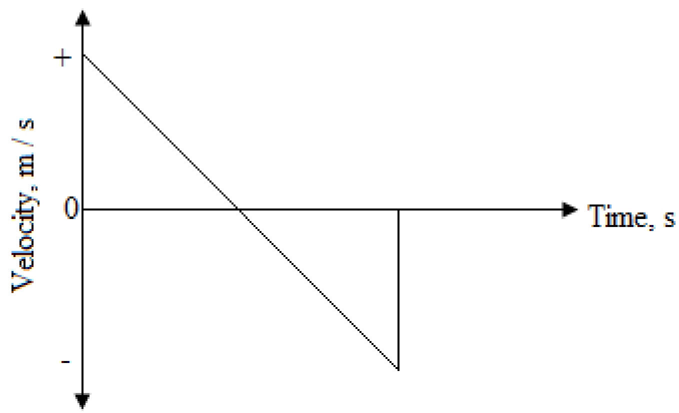
Description
Non-uniform deceleration or retardation



Description
Constant velocity
Horizontal line represents zero acceleration



Description
Increasing (uniform) velocity
Constant or uniform acceleration



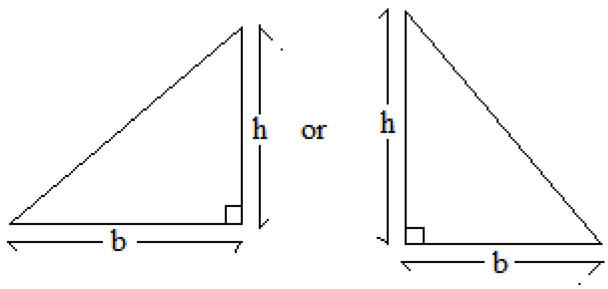
Description
Negative velocity shows that the object was dropping or falling.
Constant (uniform) deceleration

Note

1. The slope (gradient) on the velocity-time graph represents acceleration.

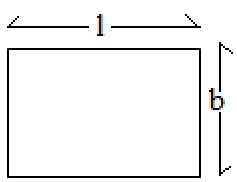
   a = $\frac{v-u}{t}$

2. The area under the velocity-time graph represents the distance covered.
   For a;
   (a) triangle,



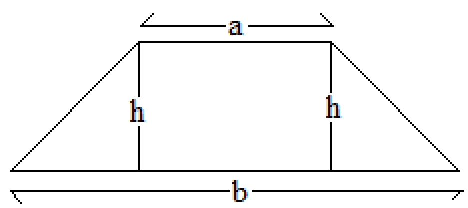
Distance, s = $\frac{1}{2}$bh

(b) rectangle,



Distance, s = l x b

(c) trapezium,

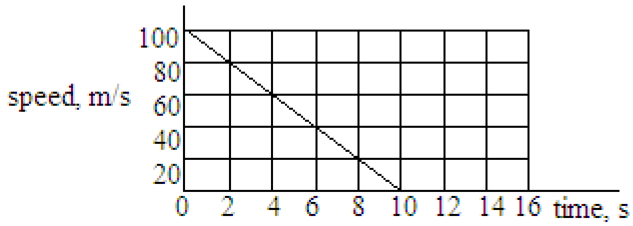


Distance, s = $\frac{1}{2}(a+b)h$

3. Velocity of a body must be changing when the body is accelerating

Example

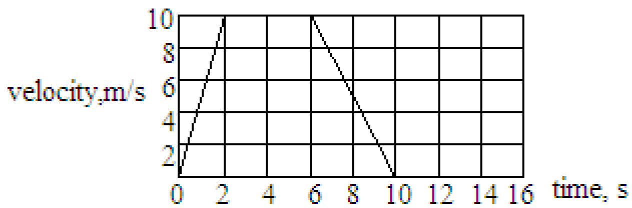
1. The diagram below shows a speed versus time graph for an arrow which was shot vertically upwards.



(a) At what speed was the arrow shot?
(b) How long did it take the arrow to reach its highest point?
(c) Determine how high the arrow rose.

	Data	Solution
(a)		v = 100m/s
(b)		t = 10s
(c)	s =? b = 10s h = 100m/s	$s = \frac{1}{2}bh$ $s = \frac{1}{2}$ x 10s x 100m/s s = 500m

1. The figure below shows a velocity-time graph for a car travelling along a straight road in 10s.



(a) Describe the motion of the car in 10s.
(b) Find the acceleration of the car in the first 2s.
(c) Find the acceleration of the car between 2 and 6 seconds of the journey.
(d) Calculate the acceleration of the car in the last 4s of its motion.
(e) Find the distance travelled by the car in the first 2s.
(f) Calculate the distance travelled by the car during the constant velocity (between 2 and 6 seconds)
(g) Find the total distance travelled by the car.

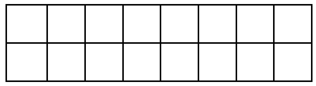
1	**Data**	**Solution**
(a)		The car was moving from rest with constant acceleration to a velocity of 10m/s in 2s and then it moved with constant velocity of 10m/s in 4s and finally decelerates uniformly to rest in 4s.
(b)	a =? v = 10m/s u = 0m/s t = 2s	a = $\frac{v-u}{t}$ a = $\frac{10m/s-0m/s}{2s}$ a = $5m/s^2$
(c)	a =? v = 10m/s u = 10m/s t = 4s	a = $0m/s^2$ because velocity is constant. or a = $\frac{v-u}{t}$ a = $\frac{10m/s-10m/s}{4s}$ a = $\frac{0m/s}{4s}$ a = $0m/s^2$
(d)	a =? v = 0m/s u = 10m/s t = 4s	a = $\frac{v-u}{t}$ a = $\frac{om/s-10m/s}{4s}$ a = $-2.5m/s^2$
(e)	s =? b = 2s h = 10m/s	s = $\frac{1}{2}bh$ s = $\frac{1}{2}$ $x\ 2s\ x\ 10m/s$ s = 10m
(f)	s =? l = 4s b = 10m/s	s = l x b s = 4s x 10m/s s = 40m

(g)	s =? a = 4s b = 10s h = 10m/s	$s = \frac{1}{2}(a + b)h$ $s = \frac{1}{2}(4s + 10s)10m/s$ $s = \frac{1}{2} x\ 14s\ x\ 10m/s$ s = 70m

Activity nine

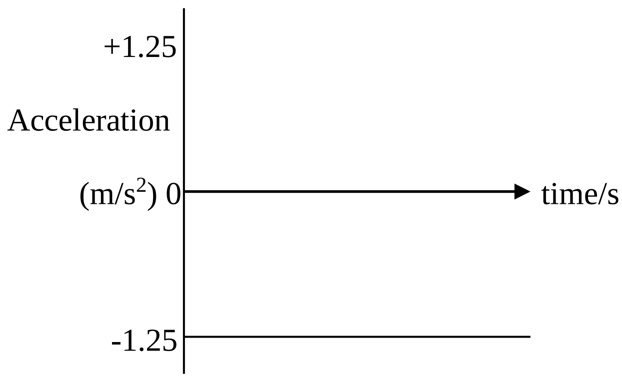
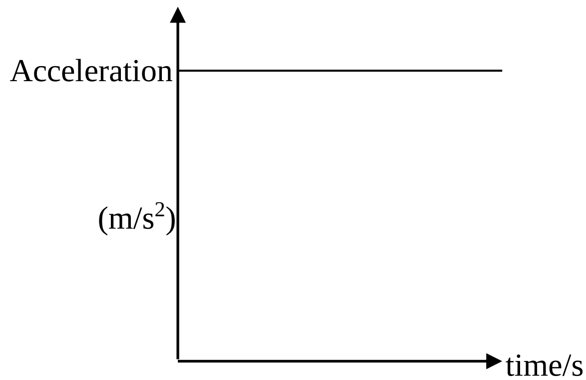
1. A car moving from rest acquires a velocity of 20m/s with uniform acceleration in 4s. It then moves with this velocity for 6s and again accelerates uniformly to 30m/s in 5s. It travels for 3s at this velocity and then comes to rest with uniform deceleration in 12s.
   (a) Draw a velocity-time graph
   (b) Calculate the total distance covered.
   (c) Calculate the average speed.
2. A car starting from rest accelerates uniformly to 20m/s in 5s. And it accelerates more to 40m/s in 2s and then decelerates until it stops 8s later.
   (a) Draw the speed-time graph
   (b) Calculate the retardation
   (c) Calculate the total distance travelled
   (d) Calculate the average speed.
3. A car accelerated uniformly from 10m/s to 20m/s. It travelled a distance of 50m during this time.
   (a) What the acceleration of the car?
   (b) How long does it take to travel this distance?
4. A car stating from rest accelerates uniformly at $5m/s^2$in 3s.
   (a) Calculate the final velocity
   (b) Calculate the distance covered.
5. A man drives a car at 5Km/h. He brakes and stops in 3s. Calculate the retardation.
6. A man rides a bicycle. He accelerates from rest to a velocity of 8m/s in 5s. What is the acceleration?
7. An object moving at a velocity of 10m/s comes to rest in 4s.
   (a) Sketch the velocity-time graph for the motion of this object.
   (b) Using your graph, calculate the acceleration of the object.
8. The table below shows the readings obtained by a group of pupils performing an experiment to determine variation of velocity with time for a car starting from rest.

Velocity, m/s	0	10	20	20	20
Time,s	0	2	4	6	8

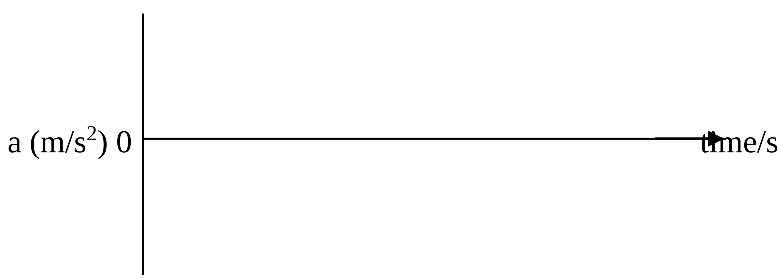


(a) On the axes above, draw the velocity-time graph.
(b) Calculate the acceleration of the car for the first 4 seconds.

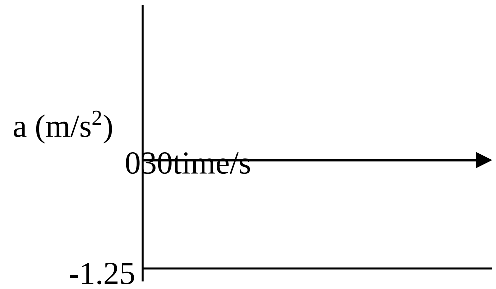
Acceleration-time graphs
Acceleration-time graph is a graph where acceleration is plotted against time.
The diagrams below represent the acceleration- time graphs

 **Description** Constant deceleration Decreasing velocity	 **Description** Constant acceleration Increasing velocity

Example
1. As it went past an observer standing by the road side, a bus decelerated at $1.25 m/s^2$. Thirty seconds later, the bus stopped.
   (a) How far from the observer has the bus moved when it stopped?
   (b) What was the speed of the bus as it went past the observer?
   (c) On the axis below, sketch an acceleration- time graph for the motion of the bus.

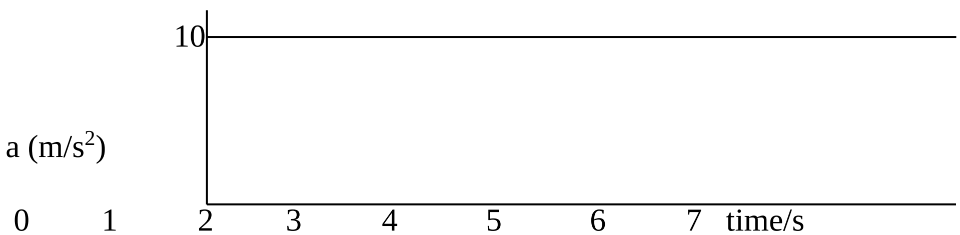


1	Data	Solution
(a)	s =? u = 0m/s t = 30s $a = -1.25 m/s^2$	$s = ut + \frac{1}{2}at^2$ $s = 0m/s \times 30s + \frac{1}{2} \times 1.25 m/s^2 \times (30s)^2$ $s = 0m/s \times 30s + \frac{1}{2} \times 1.25 m/s^2 \times 30s \times 30s$ s =562.5m

(b)	$u = ?$ $v = 0m/s$ $t = 30s$ $a = -1.25m/s^2$	$v = u + at$ $u = v - at$ $u = 0m/s - (-1.25m/s^2) \times 30s$ $u = 37.5m/s$
(c)		

Activity ten

1. Starting from rest at $t = 0s$, a car moves in a straight line with an acceleration given by the graph below.



(a) What is the speed of the car at $t = 3s$?

Acceleration due to gravity: free fall

Symbol: g

SI unit: metre per second squared, m/s^2

Definition: It is the acceleration of free falling objects.

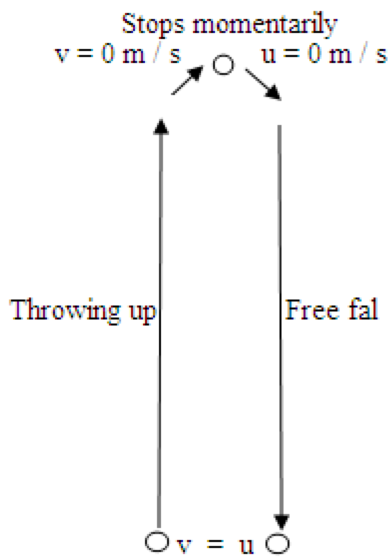
All objects accelerate uniformly downwards on the earth if air resistance is ignored. This is called acceleration due to gravity.

Objects fall because of the gravitational attraction between the objects and the earth.
If an object is dropped from the top of the building, it accelerates uniformly downwards.
If an object is released without applying force, it starts from rest. This is called free fall.

Free fall (dropping), $u = 0m/s$ $g = 10m/s^2$

If an object is thrown vertically upwards, it decelerates to the top. Then the object stops momentarily on the top and then it starts to fall freely.

Throwing up, $v = 0m/s$ $g = -10m/s^2$



The time taken for an object thrown vertically upwards to rise is equal to the time it will take to drop, $t_1 = t_2$
t_1: time taken from the ground to the top.
t_2: time taken from the top to the ground.
Total time, $t = t_1 + t_2$
The equations of motion can be applied to free falling objects using "g" instead of "a" and "h" instead of "s".

1. $v = u + gt$
2. $h = ut + \frac{1}{2}gt^2$
3. $v^2 = u^2 + 2gh$
4. $h = \frac{(v+u)t}{2}$

<u>Note</u>
g = acceleration due to gravity [$10\ m/s^2$]
h = height or distance [m].
<u>Examples</u>

1. A stone is thrown upwards with an initial velocity of 20m/s. Air resistance is ignored.
   (a) How far does it reach to the top?
   (b) How long does it take to the top?
   (c) What is its velocity just before reaching the ground?
   (d) How long does it take to the ground?

	Data	Solution
a	h=? u = 20m/s v = 0m/s g = -10m/s^2	$h = \frac{v^2-u^2}{2g}$ $h = \frac{0^2-20^2}{2\,x(-10)}$ $h = \frac{-400}{-20}$ h = 20m
b	t_1 =? u = 20m/s v = 0m/s g = -10m/s^2	$t_1 = \frac{v-u}{g}$ $t_1 = \frac{0-20}{-10}$ t_1 = 2s
c	u = v	v = 20m/s (Final velocity is equal to initial velocity, the velocity with which it was thrown)
d	t =? t_1 = 2s $t_1 = t_2$ = 2s	$t = t_1 + t_2$ t = 2s + 2s t = 4s

2. A body falls freely from rest. Air resistance is ignored.
   (a) What is its velocity after 1s?
   (b) How far does it reach in 1s?

2	Data	Solution
a	v =? u = 0m/s g = 10m/s^2 t = 1s	v = u + gt v = 0m/s + (10m/s^2 x 1s) v = 0m/s + 10m/s v = 10m/s
b	h =? u = 0m/s t = 1s g = 10m/s^2	$h = ut + \frac{1}{2}gt^2$ $h = om/s \text{ x } 1s + \frac{1}{2}$x10m/s^{2}x1sx1s h = 5m

3. A ball is thrown vertically upwards with a velocity of 10m/s.
   Calculate,
   (a) the maximum height that the ball reaches.
   (b) the total time the ball is in the air
   (c) the velocity with which the ball hits the ground.

3	Data	Solution
a	h =? u = 10m/s v = 0m/s g = -10m/s^2	$h = \frac{v^2-u^2}{2g}$ $h = \frac{0^2-10^2}{2x(-10)}$ $h = \frac{-100}{-20}$ h = 5m
b	t_1 =? $t_1 = t_2$ t =? h = 5m u = 10m/s v = 0m/s	$t_1 = \frac{2h}{v+u}$ $t_1 = \frac{2 \text{ x } 5m}{0m/s+10m/s}$ $t_1 = \frac{10m}{10m/s}$ t_1 =1s $t_1 = t_2$ = 1s $t = t_1 + t_2$ t = 1s + 1s t = 2s
c	u = v	v = 10m/s (Final velocity is equal to initial velocity, the velocity with which it was thrown.)

Activity eleven

1. A stone is released from the top of a building and takes 3s to reach the ground. The air resistance is ignored.
   (a) What was the final velocity of the stone?
   (b) How tall is the building?
2. A ball is thrown vertically upwards with an initial velocity of 40m/s.
   (a) Find the maximum height the ball reaches.
   (b) How long does the ball remain in the air? (assuming air resistance is ignored)

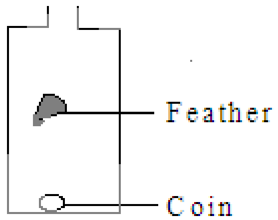
Terminal velocity
Terminal velocity is constant velocity reached by a falling object when the air resistance is equal to the weight of the object.
Every falling object experiences some air resistances which increase with speed. When a falling object acquires a high speed such that air resistance becomes equal to the weight of the object, the object stops accelerating and falls with constant velocity. This constant velocity is called terminal velocity.

Factors (conditions) that affect terminal velocity

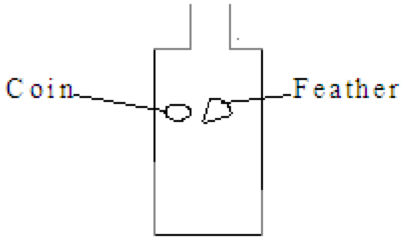
- Size of the object
- Shape of the object
- Weight of the object
- Mass of the object

An object of low density but large surface area reaches terminal velocity e.g. a feather.
A man who jumps out of a helicopter has a high terminal velocity, but when he opens the parachute to his advantage, terminal velocity reduces due to increased air resistance.

[A] If a coin and a feather are enclosed in a long tube which contains air and the tube is inverted, the coin falls much faster than a feather. A feather falls more slowly because it has a low density and large surface area.
Terminal velocity is reached where there is air.



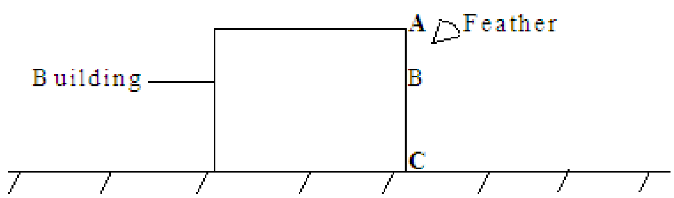
[B] If air is pumped out of the tube with a vacuum pump and the tube is inverted, both the feather and the coin fall at the same time and the same acceleration called acceleration due to gravity.
Terminal velocity is not reached in a vacuum.



Activity twelve

1. Give an example where a person uses terminal velocity to his advantage.
2. Explain a reason why a piece of paper falls more slowly than a stone, although both of them are on earth and are supposed to have the same acceleration of $10m/s^2$.

3. The figure below shows a feather, dropped from the top of a building which reaches terminal velocity at point B.



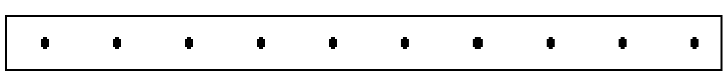
The velocity of the feather at B is 30m/s. If time taken for the feather to move from B to C is 3s, what is its velocity at C?

Recording motion using a ticker tape timer

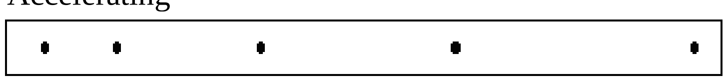
A ticker tape timer is a device that can be used to record motion of an object.
A ticker tape makes dots on a paper tape.
When a paper tape is pulled through the timer, a dot is marked on the tape every 0.02s.
In one second, 50 dots are made on the paper tape. This implies that a dot is made in $\frac{1}{50s}$ or 0.02s.

Implications (interpretations) of ticker tape dot pattern

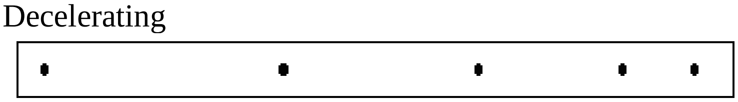
Constant speed



Accelerating



Decelerating

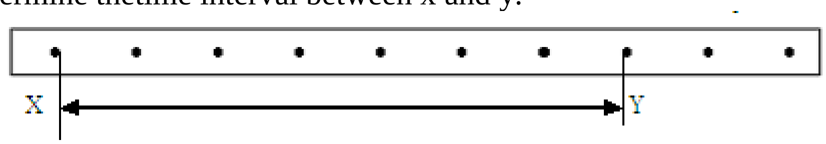


Determining time from the ticker tape

Time = number of dot spaces x 0.02s

Example

1. Determine thetime interval between x and y.



Solution

t = number of dot spaces x 0.02s

t = 7 x 0.02s

t = 0.14s

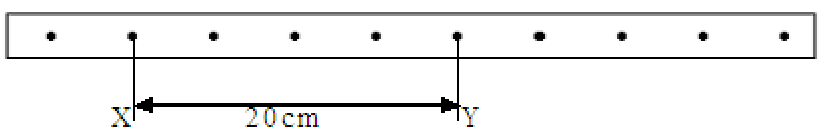
Determining speed from ticker tapes

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

$v = \frac{s}{t}$

Example

1. From the ticker tape shown below, work out the speed.



Solution

t = number of dot spaces x 0.02s

t = 4 x 0.02s

t = 0.8s

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

$v = \frac{s}{t}$

$v = \frac{0.2\text{m}}{0.8\text{s}}$

v = 2.5m/s

Mass

Symbol: m
SI unit: Kilogram, Kg
Definition: Mass is the quantity of matter contained in a substance.
The mass of an object is also the measure of its inertia.
Measuring instruments: beam balance.
Mass of an object is constant (same) everywhere the object is taken e.g. if the stone on earth is 75Kg, its mass on the moon will also be 75Kg.

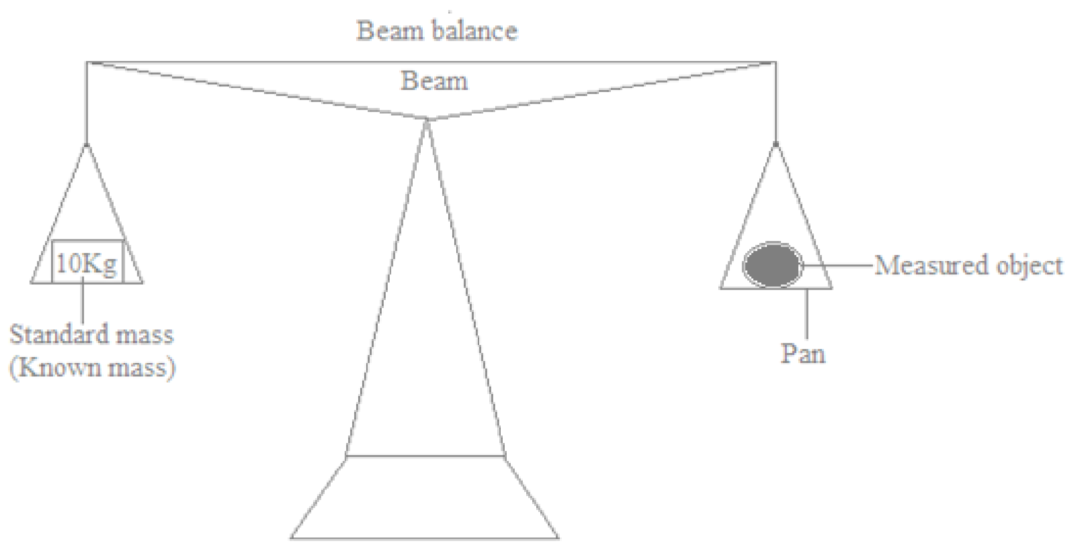
Conversion of units

1 Kg = 1000g
1 tonne = 1000Kg
1 tonne = 1000000g

Measurement of mass

Comparing masses using a beam balance

When measuring the mass of a substance, we compare the mass of the measured object with standard masses (known masses)



Procedure

1. Place the standard mass (e.g. 10kg) on one pan.(Standard mass of a substance of mass 10kg is needed)
2. Place the measured object on the other pan until the object and standard mass balances.
3. When the two balances, it means they have the same mass or weight.

Precautions

1. Clean the pans and beams
2. Adjust the zeroing screw so that the pointer coincides with the zero mark.
3. Read the mass of the known mass object when the beam is balanced.

Determining the mass of a liquid

Experiment

Aim: To find the mass of the liquid, m

Apparatus

- Triple beam balance
- Beaker
- Liquid

Method

Place a dry empty beaker on the beam balance and record its mass, m_1.
Pour the liquid into the beaker. Measure and record the mass of the liquid and beaker, m_2.
Find the mass of the liquid using the formula; $m = m_2 - m_1$.

Conclusion

Mass of liquid = mass of beaker and liquid – mass of empty beaker

Precaution

1. The beaker should be cleaned and dried before the experiment.

Example

1. In an experiment to determine the mass of a certain volume of paraffin, the mass of the beaker was found to be 20g. When the paraffin was poured into the beaker, the mass increased to 42.5g. What was the mass of paraffin?

Solution

Mass of paraffin = mass of beaker and liquid – mass of empty beaker

$$m = m_2 - m_1$$
$$m = 42.5g - 20g$$
$$m = 22.5g$$

Exercise

1. Briefly describe how the mass of a liquid can be determined. Show how the final result can be calculated.

Determining the mass of air

Experiment

Aim: To find the mass of air, m.

Apparatus

- Bottle with air
- Beam balance
- Vacuum pump

Method

Place the bottle filled with air on the beam balance and record the mass, m_1

Remove the air from the bottle using the vacuum pump. Measure and record the mass of the empty bottle, m_2

Find the mass of the air using the formula; $m = m_1 – m_2$

Conclusion

Mass of air = mass of bottle with air – mass of empty bottle

Example

1. The mass of the bottle filled with air is 50.65g. When the air is removed from the bottle, the mass of the empty bottle is 50g. Calculate the mass of air.

Solution

Mass of air = mass of bottle filled with air – mass of empty bottle

$m = m_1 – m_2$

$m = 50.65g – 50g$

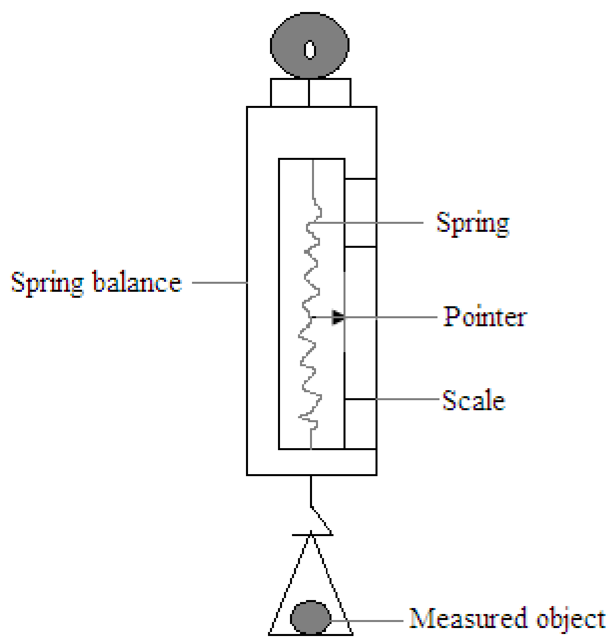
$m = 0.65g$

Activity thirteen

1. A bottle filled with air with mass 22g has a mass of 53.2g. Find the mass of the empty bottle.

Weight

Symbol: W
SI unit: Newton. N
Definition: Weight is the force of gravity acting on an object.
Measuring instrument: Spring balance.



The weight of an object varies from place to place i.e. from the earth to the moon.
Weight is less on the moon and more on the earth.
There is no weight in the outer space. (Weight is equal to zero newtons)

Factors that affect the weight of an object

- Mass of an object
- Acceleration due to gravity, g
- Distance of an object from the centre of the earth.

The greater the mass of an object, the greater its weight.
When g is high, weight is also high and when g is low, weight is also low.
On the earth's surface, g varies depending on how far the object is from the centre of the earth.
Nearer to the centre of the earth, g is high and further away from the centre of the earth, g is low.

As the object is moved further away from the centre of the earth, weight reduces because g keeps reducing.
A place at the south or North Pole where g is zero, weight is also zero.
As the object is moved closer to the centre of the earth, g increases and weight also increases.

Example

1. Explain why;
   (a) The weight of the miner increases as he goes along a deep mine?
   (b) The weight of the space craft reduces as it moves upwards?
   (c) The rocket's weight is zero?

Solution

(a) Because g increases as the miner goes closer to the centre of the earth and this results in an increase in the weight.
(b) Because g reduces as an object moves away from the centre of the earth and weight also reduces.
(c) Because in the space g is equal to zero and also results in weight to be zero.

Differences between mass and weight

1. Mass is the quantity of matter contained in a substance while weight is the force of gravity acting on an object.
2. Mass is a scalar quantity while weight is a vector quantity.
3. Mass is measured using a beam balance while weight is measured using a spring balance.
4. Weight varies slightly from place to place while mass does not change.
5. The SI unit for weight is the Newton, N, while the SI unit for mass is the kilogram, Kg. (A mass of 1Kg weighs approximately 10N)

Relationship between mass and weight

Weight = mass x acceleration due to gravity

$W = mg$

Where;
W = weight [N]
m = mass [Kg]
g = acceleration due to gravity [N/Kg]

Note

1. The value of g on earth is 10N/Kg
2. The value of g on the moon is 1.6N/Kg

Example

1. The mass of a man is 70kg. What is his weight on the moon?

Data	Solution
W =? m = 70kg g = 10N/kg	W = mg W = 70kg x 10N/kg W = 700N.

2. The weight of an on object is 300N.
   (a) What is its mass on earth?
   (b) What is its (i) mass and (ii) weight on the moon?
   (c) What is its (i) mass and (ii) weight in the outer space?

	Data	Solution
A	m =? W = 300N g = 10N/kg	$m = \frac{W}{g}$ $m = \frac{300N}{10N/kg}$ m = 30Kg
b(i)	Mass does not change	m = 30kg
(ii)	W =? m = 30kg g = 1.6N/kg	W = mg W = 30kg x 1.6N/kg W = 48N
c (i)	Mass does not change	m = 30kg
(ii)	g = 0N/kg m = 30kg	W = mg W = 30kg x 0N/kg W = 0N

Activity fourteen

1. A stone of mass 20kg is placed on earth where gravitational strength is 10N/kg.
   (a) Find the weight of the stone on earth.
   (b) What is the weight of the same stone on the moon?
2. A block of mass 5000g is found at a place on earth where g is 10N/kg.
   (a) Find its weight at this place.
   (b) What is its mass when it is taken down into the mine?
3. An astronaut with a mass of 75kg on earth travels to the moon whose gravitational strength is 1.6N/kg.
   (a) What is meant by mass?
   (b) What is the mass of an astronaut on the moon?
   (c) What is his weight on the moon?
4. State the differences between mass and weight

Centre of gravity (Centre of mass)

Centre of gravity of an object is the point through which its whole weight appears to act. Centre of gravity can also be defined as a point within an object where its total mass seems to originate from.

How to determine the centre of gravity of an irregular object

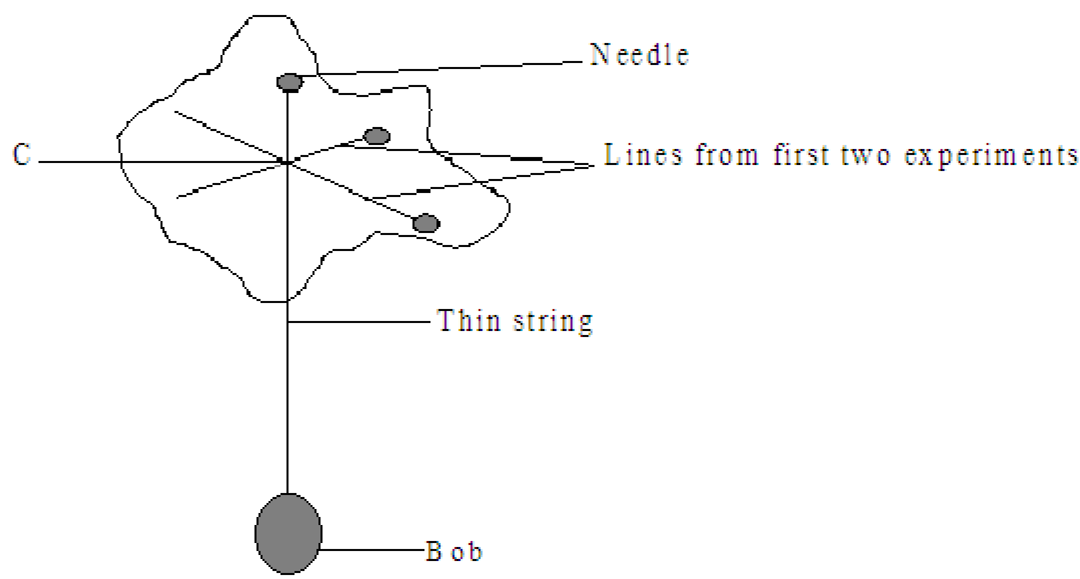
Aim: To find out (locate) the centre of gravity of an irregularly shaped object (plane lamina)

Apparatus

- String
- Plane lamina/ paper
- Pen/pencil/ruler with a knife edge
- Pin
- Bob

Method

Make a small hole near the edge of a flat plane lamina
Hang the plane lamina by a needle and make sure that it can swing freely.
Hang the plumb line from the same needle and again make sure that it is also free to turn
Mark the position of the plumb line on the plane lamina (to do this accurately, make a point near the bottom edge of the plane lamina over which the string passes)
Draw a straight line from the needle to this point to represent the position of the plumb line [the centre of gravity lies some where along this line]
Make two other holes near the edge of the plane lamina so that all the three holes are as far as possible.
Repeat the experiment and draw two other lines.



Observation

The irregular shaped plane lamina balances at point C.

Conclusion

Since the centre of gravity lies on each of the lines, their intersection locates the centre of gravity.

Stability

Stability of an object is defined as the ability of an object to regain its original position after it has been displaced slightly.

Stability can also be defined as a condition in which an object is not moving and cannot fall.

A stationary object can either be stable or unstable

Something stable is an object which cannot easily fall when slightly pushed or tilted.

Something unstable is an object which can easily fall when slightly pushed or tilted.

Conditions (factors) for stability

- Low centre of gravity
- Wide base

1. **Low centre of gravity**

The position of centre of gravity affects the stability of an object.

The centre of gravity should be as low as possible.

2. **Wide base**

The base area should be as large as possible

The wider the base, the more stable an object will be.

The mass of an object should be concentrated at the base.

Equilibrium

Equilibrium is a condition of an object in which the sum of all forces acting on it is zero e.g. resultant force is zero

Objects which are in equilibrium are;

(a) those that are stationary i.e.at rest

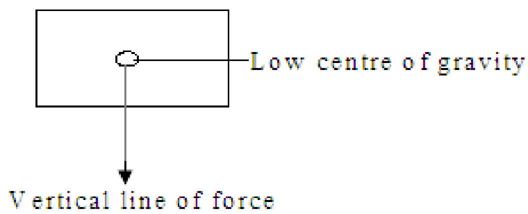
(b) those that are moving with constant velocity

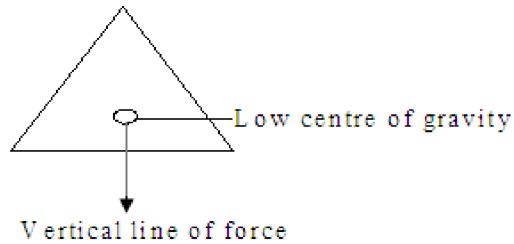
A stationary object can either be in a stable equilibrium, unstable equilibrium or neutral equilibrium.

1. **Stable equilibrium**

An object is said be in stable equilibrium if when slightly pushed or tilted goes back to its original position.

Examples





The objects above are more stable because they have;

(a) Low centre of gravity and
(b) Wider base

Objects in stable equilibrium do not easily fall when slightly pushed because the vertical line of force from the centre of gravity does not easily fall on the other side of base.

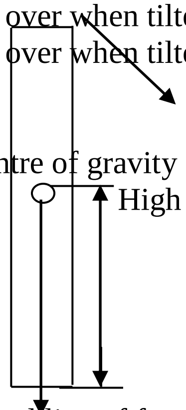
2. Unstable equilibrium

An object is said to be in unstable equilibrium if when slightly pushed or tilted falls off i.e.it does not go back to its original position.

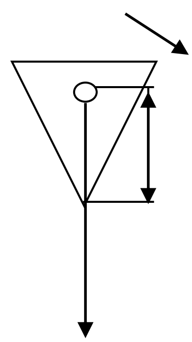
Examples

Topples over when tilted
Topples over when tilted

High centre of gravity



High centre of gravity



Vertical line of force Vertical line of force

The objects above are unstable because they have;

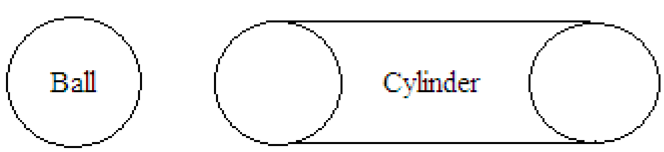
(a) High centre of gravity
(b) Smaller or narrow base

Objects in unstable equilibrium fall off easily because when slightly pushed or tilted, the vertical line of force easily falls off on the other side of the base.

3. Neutral equilibrium

An object is said to be in neutral equilibrium if it stays in its new position after it has been pushed slightly.

Example



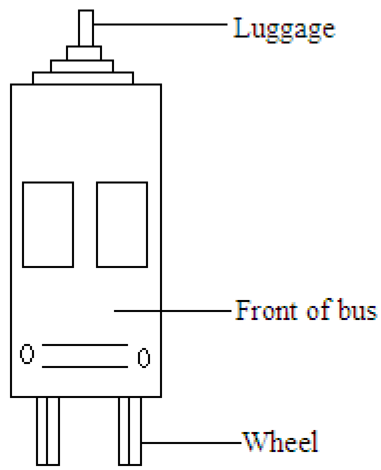
When a ball and a cylinder are rolled, they come to rest in a new stable equilibrium.

Note

It is not advisable to put a heavy luggage on the roof of a minibus because it can topple over at the corner when it is moving fast.

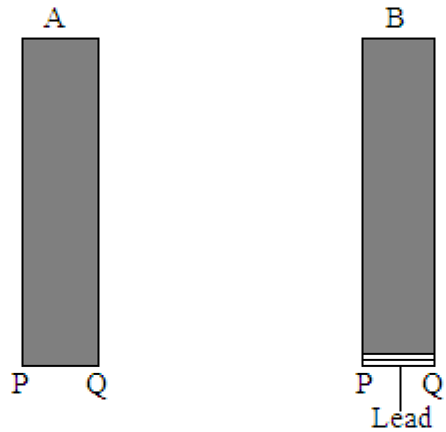
Activity

1. The figure below shows a bus



(a) State three modifications that should be made in the design of the bus to make it more stable.

2. The diagram below shows two identical rectangular wooden blocks A and B. Block B has a layer of lead attached to its base. The blocks were tilted about edges PQ as shown in the diagram below.



Explain why A topples over at a smaller angle of tilt than B

(a) State two conditions which can help to prevent a truck toppling over when tilted.

3. What two factors will make an object stable?

Volume

Symbol: V

SI unit: cubic metre, m^3

Definition: Volume is the amount of space occupied by an object.

Other units for volume

Cubic centimeters, cm^3

Mililitres, ml

Litres, L

Relationship of units

$1ml = 1cm^3$

$1L = 1000ml = 1000cm^3$

$1m^3 = 1000L = 1000000cm^3$

Note

In the laboratory, we usually use cubic centimeters because the cubic metre is a very large unit.

Instruments for measuring volume of liquids

Measuring cylinder

It measures various volumes of liquids

Pipette

It measures a fixed amount of volume of liquid according to its capacity

Burette

It measures the required volume up to its capacity

Flasks
They give or measure approximate fixed volumes

Volume of regular solids
An irregular solid is an object whose sides can be measured easily.

Procedure
Measure the length of an object using a ruler or vernier calipers or micrometer screw gauge
Use the appropriate formula to find the volume.

Object	**Formula**
Cuboid (rectangle)	V = l x b x h V = A x h
Cube (square)	$V = l^3$
Sphere (circle)	$V = \frac{4}{3}\pi r^3$
Cylinder (wire or pipe)	$V = \pi r^2 h$ V = A x h
Cone	$V = \frac{1}{3}\pi^2 h$
Pyramid	$V = \frac{1}{3}bh$
Prism	$V = \frac{1}{3}bh$

Examples

1. Find the volume of the block which has the following measurements; length = 10cm, breadth = 6cm, height = 3cm.

Data	Solution
V =? l = 10cm b = 6cm h = 3cm	V = l x b x h V = 10cm x 6cm x 3cm $V = 180cm^3$

2. Find the volume of a cube of sides 4cm.

Data	Solution
V =? l = 4cm	$V = l^3$ V = l x l xl V = 4cm x 4cm x 4cm $V = 64cm^3$

3. Calculate the volume of the sphere of radius 6cm.

Data	Solution
V =? $\pi = \frac{22}{7}$ r = 6cm	$V = \frac{4}{3}\pi r^3$ $V = \frac{4}{3} \times \frac{22}{7} \times 6cm \times 6cm \times 6cm$ $V = 905cm^3$

Activity sixteen

1. Calculate the volume of the pipe of cross section area $30cm^2$ and 50cm long.
2. Find the volume of a wire of diameter 0.2cm and height 7cm.

Volume of liquids

Liquids take the shape of the container in which they are placed.
If a container is filled to its capacity, its volume can be determined by pouring the contents into the measuring cylinder.

How to read volumes of liquids

When a liquid is poured into a measuring cylinder, it forms a curved surface on the upper part of the liquid.
The curve could be concave or convex depending on the properties of the liquid.
The curved surface is called meniscus and is caused by the attraction between the liquid particles and the container.
When the meniscus is convex (i.e. curving upwards) it is read from the top and when it is concave (i.e. curving downwards) it is read from the bottom.

Precautions

1. Place the measuring cylinder on the horizontal flat surface

Volume of irregular solids

An irregular solid is an object whose sides cannot be measured easily.
An irregular solid has no specific dimensions e.g. a stone
The volume of small solids is measured by the **displacement method** using;

- A measuring cylinder
- An over flow can

(a) Using a measuring cylinder

Experiment

Aim: To find the volume of the stone, V

Apparatus

- Measuring cylinder
- Water
- Stone
- Thin string

Method
Pour water into a measuring cylinder and record the initial water level, V_1
Tie a piece of thin string around a small stone and slowly lower the stone into the measuring cylinder until it is fully submerged. Record the final water level, V_2
Find the volume of the stone using the formula, $V = V_2 – V_1$

Conclusion
Volume of water displaced by the stone is equal to the volume of the stone.

(b) Using an over flow can

Experiment

Aim: To find the volume of the stone, V

Apparatus
- Over flow can
- Water
- Measuring cylinder
- Tripod stand
- Small stone
- Thin string

Method
Place an over flow can on a tripod stand
Pour water into an over flow can until it begins to flow from the spout.
Leave the can until the water stops over flowing (dripping)
Place an empty measuring cylinder under the spout
Tie a piece of thin string around a small stone and slowly lower the stone into the can until it is fully submerged.
Water from the can is collected in a measuring cylinder. Water collected in the cylinder is the volume of the stone.

Conclusion
The water collected in the measuring cylinder is called displaced water and its volume is equal to the volume of the stone lowered in the can.

Precautions
1. Use a thin string to reduce the amount of water displaced by it.

2. Use a solid that does not react or dissolve in the liquid.
3. Lower the irregular solid gently to avoid the splashing of the liquid.
4. Place the measuring cylinder on the flat or horizontal surface
5. Tap the measuring cylinder to remove any amount of air bubbles.
6. Place the eye level with the flat surface of the liquid [in case of water, read from the bottom of the meniscus]

Example

1. $100cm^3$ of water is poured into a measuring cylinder. A block of copper wire is gently lowered into the measuring cylinder and the water level rises to the 183cm mark.

(a) What is the volume of the copper block?

(b) If the height of the block is 10cm, what is the cross sectional area?

	Data	**Solution**
a	$V = ?$ $V_2 = 183cm^3$ $V_1 = 100cm^3$	$V = v_2 - v_1$ $V = 183cm^3 - 100cm^3$ $V = 83cm^3$
b	$A = ?$ $V = 83cm^3$ $h = 10cm$	$A = \frac{V}{h}$ $A = \frac{83cm^3}{10cm}$ $A = 8.3cm^2$

Volume of a small irregular floating solid

Experiment

Aim: To find the volume of an irregular floating solid, V

Apparatus

- Cork (floating object)
- Stone
- Water
- Thin string
- Measuring cylinder

Method

Pour water into the measuring cylinder.
Tie a thin string around a small stone and gently lower the stone into the measuring cylinder until it is fully submerged. Record this initial water level, V_1.

Then tie a floating object together with the stone and then lower them into the same measuring cylinder. Water level rises and record the this final water level, V_2
Find the volume of the floating object using the formula, $V = V_2 – V_1$

Conclusion
Volume of floating object = final volume – initial volume

Note
The stone is used to make the floating object to sink or submerge
Anything that sinks can be used in place of a stone.

Density
Symbol: ρ
SI unit: kilogram per cubic metre, kg/m^3
Definition: Density is defined as mass per unit volume of a substance
Formula: Density = $\frac{\text{mass}}{\text{volume}}$

$$\rho = \frac{m}{v}$$

Relationship of units
$1kg/m^3 = 0.001g/cm^3$
$1g/cm^3 = 1000kg/m^3$

Example
1. Convert
   (a) $3kg/m^3$ into g/cm^3
   (b) $5g/cm^3$ into kg/m^3

Solution
(a) $0.001g/cm^3 \rightarrow 1kg/m^3$
$x \rightarrow 3kg/m^3$

$$x = \frac{0.001g/cm^3 \text{ x } 3kg/m^3}{1kg/m^3}$$

$x = 0.003g/cm^3$

(b) $1g/cm^3 \rightarrow 1000kg/m^3$
$5g/cm^3 \rightarrow x$

$$x = \frac{5g/cm^3 \text{ x } 1000kg/m^3}{1g/cm^3}$$

$x = 5000kg/m^3$

Simple determination of density

Find the mass of an object using a beam balance
Find the volume of an object
Find the density of an object using the formula;

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{v}$$

Density of irregular solids

Experiment

Aim: To find the density of an irregular object, ρ

Apparatus

- Measuring cylinder
- Beam balance
- Stone
- Water
- Thin string

Method

Measure and record the mass of the stone, m
Pour water in the measuring cylinder and record the initial volume of water, V_1
Slowly, lower the stone into a measuring cylinder using a thin string and record the final volume of water, V_2.
Find the density of the stone by using the formula;

$$\rho = \frac{m}{V_2 - V_1}$$

Examples

1. A body of mass 500g was suspended in $100cm^3$ of water by a piece of cotton. The level rises to $150cm^3$. What is its density?

Data	Solution

ρ =? m = 500g V_1= 100cm^3 V_2 = 150cm^3	$\rho = \frac{m}{V_2 - V_1}$ $\rho = \frac{500g}{150cm^3 - 100cm^3}$ $\rho = \frac{500g}{50cm^3}$ ρ = 10g/cm^3

Activity

1. A material has density of 9.0g/cm^3 and volume 50cm^3. What is its mass?
2. A metal has mass of 225g and volume of 30cm^3. What is its density?

Density of liquids

Experiment

Aim: To find the density of a liquid, ρ

Apparatus

- Measuring cylinder
- Beam balance
- Liquid

Method

Measure and record the mass of an empty cylinder, m_1.
Pour the liquid into the measuring cylinder. Measure and record the mass of the cylinder and water, m_2.
Record the volume of the liquid in the measuring cylinder, V
Find the density of the liquid by using the formula;

$$\rho = \frac{m_2 - m_1}{V}$$

Example

1. A container of mass 200g and contains160cm^3 of liquid. The total mass of the container and liquid is 520g. What is the density of the liquid?

Data	Solution
ρ =?	$\rho = \frac{m_2 - m_1}{V}$

$m_1 = 200g$ $m_2 = 520g$ $v = 160cm^3$	$\rho = \frac{520g - 200g}{160cm^3}$ $\rho = \frac{320g}{160cm^3}$ $\rho = 2.0g/cm^3$

Activity

1. A stone of mass 20g and density $0.5g/cm^3$ was immersed into water in a measuring cylinder whose initial volume was $30cm^3$. Find the final volume of the water in the measuring cylinder.

2. What is meant by the density of a substance? State constituent units in which the various quantities you have mentioned could be measured.
   (a) A tin containing $5000cm^3$ of paint has a mass of 7.0kg.
   (i)If the mass of the empty tin including the lid is 0.5kg, calculate the density of the paint.

(ii)If the tin is made of a metal which has a density of $7800kgm^{-3}$, calculate .
the volume of metal used to make the tin and the lid.

Relative density

Alternative term: Specific gravity

Symbol: ρ_r

Definition: Relative density is the ratio of the mass of a substance to the mass of water.
It is also the ratio of the density of a substance to the density of water

Formula: Relative density = $\frac{\text{mass of liquid}}{\text{mass of water}}$

Relative density = $\frac{\text{density of a substance}}{\text{density of water}}$

Units: Relative density has no units.

Note

Density of water = $1g/cm^3$ or $1000kg/m^3$

Example

1. Find the relative density of a liquid of mass 300g if it has the same volume as 100g of water.

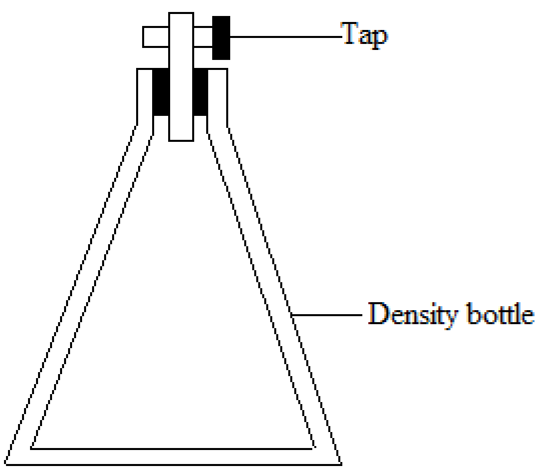
Data	**Solution**
ρ_r=? Mass of liquid = 300g Mass of water = 100g	$\rho_r = \frac{\text{mass of liquid}}{\text{mass of water}}$ $= \frac{300g}{100g}$ = 3

Activity

1. The density of mercury is 13600kg/m^3. The density of water is 1000kg/m^3. Calculate the relative density of mercury.

Density bottle

A density bottle is used to determine the relative density of a liquid



Experiment

Aim: To find the relative density of a liquid using the density bottle.

Method

Measure and record the mass of the density bottle, m_1.
Measure and record the mass of the density bottle containing the water, m_2.
Measure and record the mass of the density bottle containing the liquid under investigation, m_3.

Find the relative density by using the formula;

$\rho_r = \frac{m_3 - m_1}{m_2 - m_1}$

Conclusion

Relative density of liquid $= \frac{\text{mass of liquid}}{\text{mass of water}}$

NB: The density of a liquid is then found by multiplying relative density of the liquid by the density of water.

Density of liquid = relative density x density of water

Precautions when using a density bottle

1. The density bottle must be thoroughly dried.
2. The water outside the density bottle must be dried completely with a dry cloth
3. The density bottle must be held by the neck to avoid expansion of the liquid [if the bottle itself is held in the hands, the heat will cause expansion to the liquid]
4. Remove the water from the top of the stopper with a blotting paper.

Example

1. An empty relative density bottle weighs 25g. It weighs 65g when filled with a liquid and 75g when filled with water.

(a) Calculate the mass of the liquid
(b) Calculate the mass of water
(c) Calculate the relative density of the liquid
(d) Calculate the density of the liquid

Solution

(a) Mass of liquid = 65g -25g
= 40g
(b) Mass of water = 75g – 25g
= 50g
(c) Relative density of the liquid $= \frac{\text{mass of liquid}}{\text{mass of water}}$

Relative density of the liquid $= \frac{40\text{g}}{50\text{g}}$
= 0.8

(d) Density of liquid = relative density x density of water
= 0.8 x 1g/cm^3
= 0.8g/cm^3

Activity

1. In an experiment, the results below were obtained
Mass of empty bottle = 50.2g
Mass of bottle filled with ethanol = 130.2g
Mass of bottled filled water = 150.2g
(a) Calculate the mass of the liquid

(b) Calculate the mass of water
(c) Calculate the relative density of the liquid
(d) Calculate the density of the liquid

2. An empty relative density bottle has a mass of 25g. When filled with a liquid of relative density 0.92, its mass becomes 85g.
   Calculate
(a) The mass of the bottle when filled with water.
(b) The capacity of the bottle

3. An empty relative density bottle has a mass of 35g. When filled with water, its mass becomes 85.
   Calculate the
   (I) Mass of water
   (II) The volume of the bottle (take density of water to be $1g/cm^3$)

Density of air
Experiment

Aim: To find the density of air, ρ

Apparatus
- Beam balance / top pan balance
- Bottle / container with a top and tube

Note
A tube of the container can be connected to a suction pump which draw air in or suck air out of the container

Method
Measure and record the mass of the container filled with air, m_1.
Remove all the air from the container using a suction pump and then close the tap.
Measure and record the mass of the container without air. (empty container), m_2.
NB: The volume, V, of the container should be known.
Next, open the container and fill it with water. Close the container tightly and make sure all the air has been replaced by water
Measure and record the mass of the container filled with water, m_3.
Find the density of air by using the formula;

$$\rho = \frac{m_1 - m_2}{V}$$

Conclusion

$$\text{Density of air} = \frac{\text{mass of container with air} - \text{mass of empty container}}{\text{volume of the air}}$$

Note

Volume of container = Volume of air = Volume of water

The volume of air depends very much on the temperature and pressure of the surrounding. It is therefore important to take note of the temperature and atmospheric pressure during the experiment.

Example

1. Mr.Naosa D.K, a physics teacher at Kambule Technical Secondary School did an experiment to find the density of air and he obtained the following results:

   Mass of container = 265.12g
   Mass of container and air = 265.42g
   Mass of container and water = 515.12g
   Take density of water to be $1 g/cm^3$
   Calculate

(a) The mass of air
(b) The mass of water
(c) The volume of the container
(d) The density of air

Solution

(a) Mass of air = mass of container with air – mass of empty container
= 265.42g – 265.12g
= 0.3g

(b) Mass of water = mass of container with water – mass of empty container
= 515.42g – 265.12g
= 250g

(c) Volume of container = volume of water

$$\text{Volume} = \frac{\text{mass}}{\text{density}}$$

$$= \frac{250\text{g}}{1\text{g/cm}^3}$$

$= 250cm^3$

(d) Volume of air = volume of container

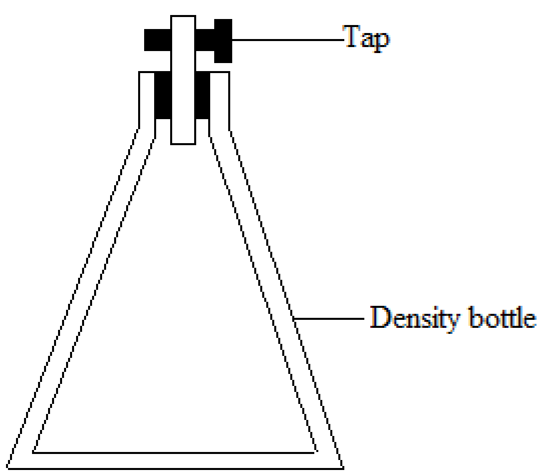
$$\text{Density of air} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{0.3\text{g}}{250\text{cm}^3}$$

$= 0.0012g/cm^3$

Activity

1. An experiment was carried out by Darlington Naosajunior to determine the density of air using the density of air contained in a thick walled bottled as shown below.



The following results were obtained:
Mass of empty bottle = 309g
Mass of bottle filled with air = 310g
Mass of bottle filled with water = 1050g

Take density of water to be $1g/cm^3$

(a) What was the mass of water?
(b) What was the initial volume of the bottle?
(c) What was the mass of air?
(d) Calculate the density of air.

Density of a mixture

Method

Add the mass of the components to find the total mass
Add the volume of the components to find the total volume
Find the density of the mixture by using the formula;

$$\text{Density} = \frac{\text{Total mass of mixture}}{\text{Total volume of mixture}}$$

Example

1. 30g of alcohol of volume $38cm^3$ is mixed in a jug with water of volume $20cm^3$ with mass 20g. Find the density of the mixture.

   Solution
   Total mass of mixture = 30g + 20g
   = 50g
   Total volume of mixture = $38cm^3 + 20cm^3$
   = $58cm^3$

   $$\text{Density} = \frac{\text{Total mass of mixture}}{\text{Total volume of mixture}}$$

   $$= \frac{50g}{58cm^3}$$

   $= 0.86g/cm^3$

Activity

1. 32g of kerosene of density $0.80g/cm^3$ is mixed with 8g of water.
(a) Find the total mass of the mixture
(b) Find the volume of kerosene
(c) Find the volume of water
(d) Calculate the total volume of the mixture
(e) Calculate the density of the mixture
2. $300cm^3$ of water is mixed with $300cm^3$ of pure alcohol. Calculate the density of the mixture if the relative density of alcohol is 0.79.

Note

- When impurities of pollutants are added to a substance, its density increases e.g. the density of water is $1g/cm^3$, but when salt is added to it, density increases depending on the amount of impurities.

- An egg sinks in pure water because an egg is denser than pure water and an egg floats in salt water because salt water is denser than an egg.

Force

Symbol: F
SI unit: Newton, N
Definition: Force is the push or pull exerted on an object
Measuring instrument: Spring balance.

Examples of forces

- Weight
- Friction
- Tension
- Up thrust
- Magnetic force
- Electric force
- Constant force

Effects of force on an object

1. Force can change the size and shape of an object
2. Force can change the motion of an object. Force can change the motion of an object in the following ways:

(a) It makes an object to start moving
(b) It makes an object accelerates either uniformly or non-uniformly i.e. makes an object accelerates uniformly if the force is constant and makes an object accelerates non uniformly if the force varies.
(c) It makes an object decelerates
(d) It makes an objectchange direction

3. Force can make an object to turn about the point (pivot). It can also make an object to rotate.

Newton's laws of motion

There are three basic laws of motion given by **Sir Isaac Newton**

Newton's first law of motion

The law states that: Any given body continues in its state of rest or uniform motion in a straight line unless it is compelled to change that by an external force exerted on it.
Newton's first law of motion is also called the law of **inertia.**
Inertia is the property of a body that resists a change to its motion.
Inertia is not a force but a property of an object.
Inertia depends on the mass of an object.
If something has a high resistance [high mass] to the change of motion, its inertia is said to be high.

Note

1. A wire car is easier to start and easier to stop

2. A heavy truck has high inertia and it is difficult to start moving and difficult to stop.

Every day effects of inertia

(a) When a fast moving bus stops suddenly, the passengers tend to be thrown forward to maintain their forward motion. Similarly, when a bus suddenly starts moving, the passengers are thrown backwards; they tend to remain behind due to inertia.

(b) When a block is placed on a smooth card on the table and the card is suddenly pulled away horizontally, the block remains behind.

Newton's second law of motion

The law states that: An unbalanced force acting on a body produces an acceleration in the direction of the force.

This acceleration is directly proportional to the force but inversely proportional to the mass of the body.

$a \propto F$ and $a \propto \frac{1}{m}$

Force = mass x acceleration

F = ma

Note

- $a = \frac{F}{m}$
- $m = \frac{F}{a}$

F = force [N]

m = mass [kg]

a = acceleration [m/s^2] or [N/kg]

Example

1. A horizontal force of 5N was applied to a brick of mass 2kg resting on a frictionless table. What was the acceleration of the brick?

Data	Solution
a =? F = 5N m = 2kg	$a = \frac{F}{m}$ $a = \frac{5N}{2kg}$ a = 2.5N/kg

Activity twenty three

1. A man pushes an 8kg luggage on the smooth floor. It starts from rest and reaches the final velocity of 15m/s in 5seconds.
   (a) Calculate the acceleration
   (b) What was the force acting on the luggage?

<u>Newton's third law of motion</u>

The law states that: To every action, there is an equal and opposite reaction.

<u>Resultant force</u>

Symbol: R_f

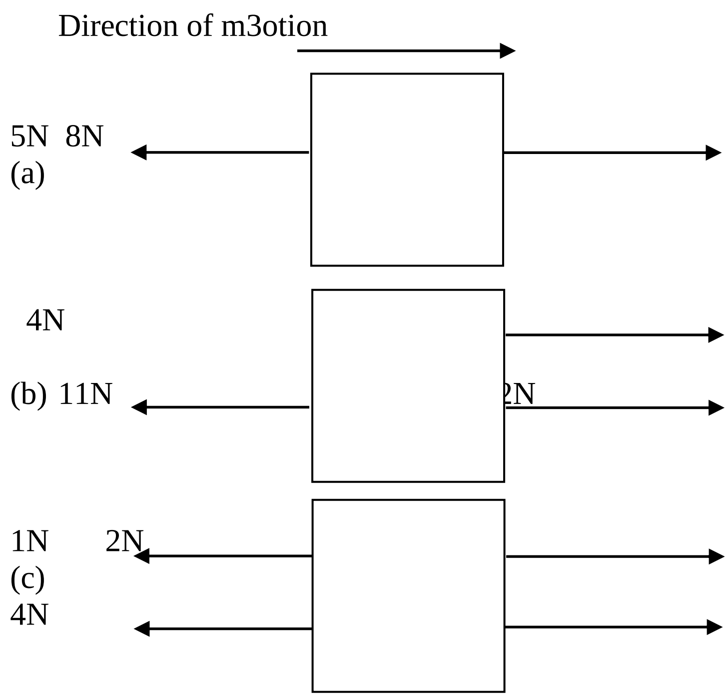
Definition: Resultant force is the sum of all forces acting on a body.

Formula: Resultant force = sum of forward forces– sumof backward forces

Or Resultant force = horizontal force -friction

<u>Example</u>

1. Find the resultant force of each of the following:



<u>Solution</u>

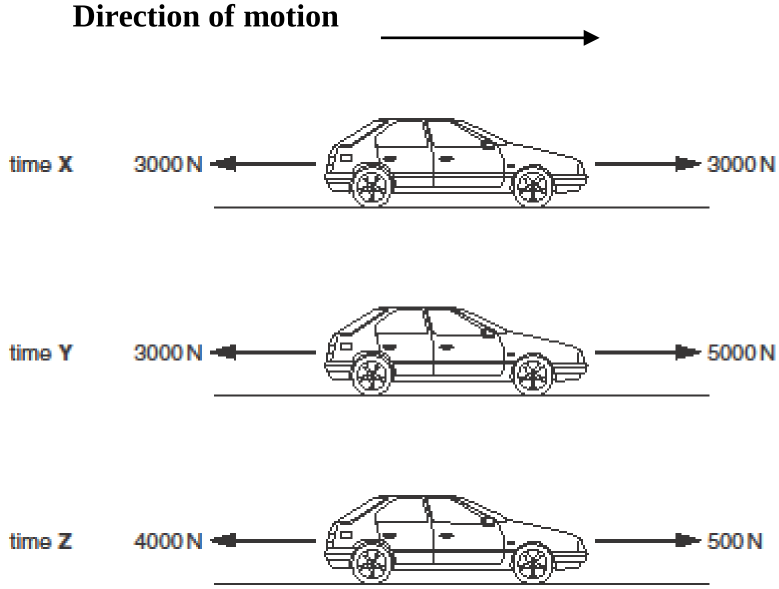
(a) R_f= 8N – 5N
= 3N

(b) R_f= (4N + 12N) – 11N
= 16N – 11N
= 5N

(c) R_f= (2N + 3N) – (1N + 4N)
= 5N – 5N
= 0N

2. The figure below shows the total forces acting forwards and backwards on a car at different times X, Y and Z during a journey.

Direction of motion



In each case, the car is moving forwards. The mass of the car is 1000kg.

(a) State the name of one of the forces that is acting in the opposite direction to the motion of the car.

(b) State whether the speed of the car is changing at time X.
Explain your answer.

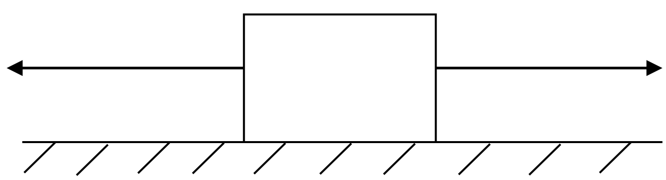
(c) State whether the speed of the car at time Y is increasing, decreasing or is constant.
Explain your answer.
(d) Calculate the acceleration of the car at time Y.

	Data	Solution
(a)		Friction
(b)	Forward force = Backward force	The speed is not changing Reason: Because the resultant force is zero (i.e. $R_f = 3000N - 3000N = 0N$)
(c)	Forward force > Backward force	Increasing Reason: Because the forward force is greater than the backward force.
(d)	a =? F = 5000N – 3000N = 2000N m = 1000kg	$a = \frac{F}{m}$ $a = \frac{2000N}{1000kg}$ $a = 2m/s^2$

Exercise

1. The figure below shows an object of mass 0.7kg resting on a horizontal surface.

6.0N



If the object is pulled to the left by a force of 6.0 N and to the right by a force of 2.5N and assuming that no other forces act on the object,
Calculate
(a) The resultant force
(b) The acceleration produced by the resultant force in (a)
(c) Explain why in practice the actual acceleration for the object may be lower than your answer in (b) above.

<u>Friction</u>
Friction is the force which opposes the motion of two touching surfaces.
Friction acts in the opposite direction to the motion of an object.

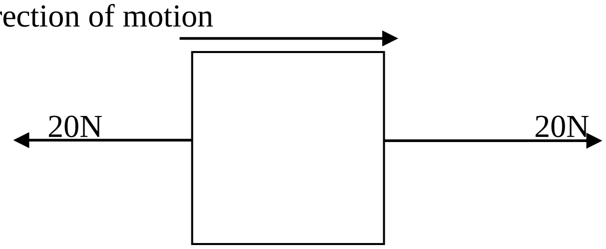
Application of friction

1. It enables us to walk without slipping
2. It enables us to hold or grip something
3. It helps a vehicle to run and stop.

Friction and its effects on motion

1. It causes an object to move with constant velocity. In this case, horizontal force (forward force) is equal to friction (backward force).e.g.

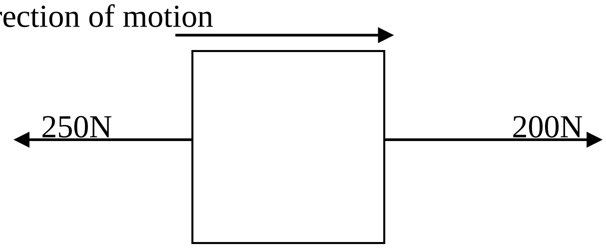
Direction of motion



R_f = 20N – 20N
= 0N

2. It causes an object to come to rest or decelerates. In this case, friction is greater than forward force. e.g.

Direction of motion



R_f= 200N – 250N
= -50N

3. It causes the change in the direction of motion

Problems (consequences) of friction

1. It produces unnecessary heat and reduces the efficiency of machines
2. It causes the wearing and tearing of surfaces in contact

How to reduce friction

1. Lubrication of surfaces in contact using grease or oil
2. Putting ball bearings between movable surfaces in contact

Exercise

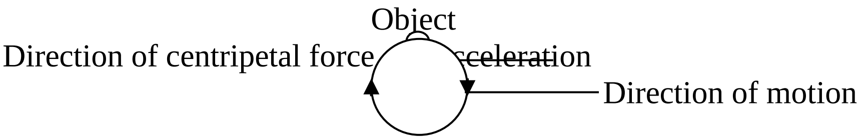
1. A man pushes a packing car having a total mass of 400kg across a floor at a constant speed of 0.5m/s by exerting a horizontal force of 100N.
   (a) How big was the force of friction acting on the car?

(b) What was the resultant force on the car?

Force and motion in a circular path
There are a number of objects which move round in circular motion.

Examples
1. The moon goes round the earth
2. The earth goes round the sun in an orbit
3. In the laboratory, a mass tied to a string can be made to swing round.

Centripetal force
Centripetal force is a force where the direction of the force is always directed towards the Centre of the circle.
The force of circular motion is always at right angles to the motion.



The acceleration caused by the centripetal force is called centripetal acceleration

Effects of force on the shape and size of an object
Force changes the shape and size of an object
The change of shape and size of an object is called deformation
Force can change the size and shape in the following ways;
(a) It compresses the object, hence reduces it in size
(b) It stretches the object, hence makes it longer
(c) It twists the object, hence changes its shape

Elastic material
It is a substance which regains its original shape and size when the force applied has been removed

Examples of elastic materials
- Spring
- Rubber

Elasticity
Definition: Elasticity is the ability of an elastic material to regain its original shape and size after the applied force has been removed

Elastic limit of the spring
Definition: Elastic limit of the springis the maximum force that can be applied to a spring without stretching it permanently

Original length
Alternative term: Neutral length

Definition: Original length is the length of the spring before being stretched
Formula: Original length = new length – extension

<u>New length</u>
Definition: New length is the length the spring reaches when it is stretched
Formula: New length = original length + extension

<u>Extension</u>
Definition: Extension is the difference between the new length and original length of the spring
Formula: Extension = new length – original length

<u>Experiment</u>

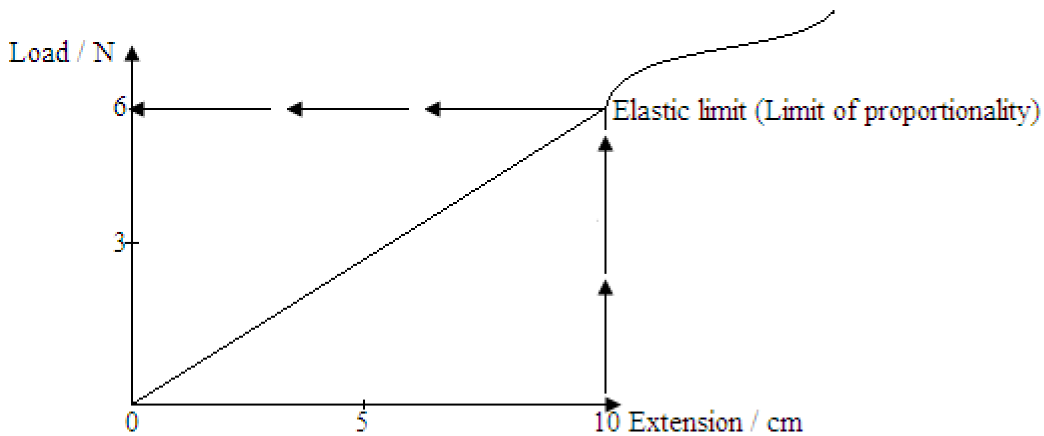
<u>Title:</u> Hooke's law

<u>Aim</u>: To find the relationship between loads and extensions on a spring

<u>Apparatus</u>
- Spring
- Loads (standard masses)
- Clamp and stand

<u>Method</u>
Support the spring vertically by means of a clamp and stand. Place a pan on the lower end of the spring.
Measure the original length of the spring
Hang a load (standard mass) on the lower end of the spring
Calculate the new length of the spring
Calculate the extension of the spring
Repeat the experiment by adding loads
Calculate the spring constant by using the formula;
Constant = $\frac{\text{Load}}{\text{Extension}}$, K = $\frac{F}{E}$

Graph of load against extension



Elastic limit = 6N

$$\text{Constant} = \frac{\text{Load}}{\text{Extension}}$$

$$\text{Constant} = \frac{6\text{N}}{10\text{cm}}$$

Constant = 0.6N/cm

Conclusion

The extension of the loaded spring is directly proportional to the force applied, provided the elastic limit is not exceeded. This is called Hooke's law.

Example

1. A load of 1N extends a spring by 5mm. What load extends it by 10mm?

Solution

1N → 5mm
x→ 10mm

$$x = \frac{1\text{N x } 10\text{mm}}{5\text{mm}}$$

x = 2N

2. Calculate the extension of a spring that would be produced by a 20N load if a 15N load extends the spring by 3cm?

Solution

15N → 3cm
20N → x

$$x = \frac{20\text{N x } 3\text{cm}}{15\text{N}}$$

x = 4cm

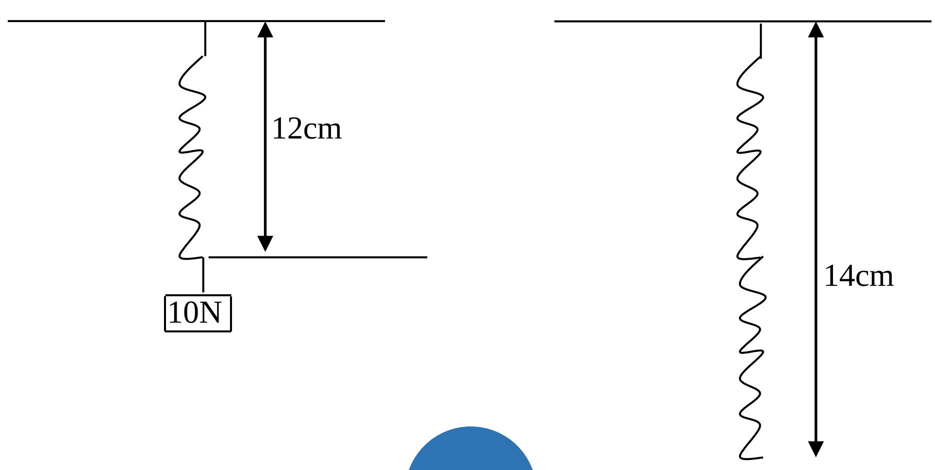
Exercise

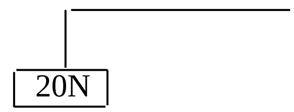
1. A load of 4N extends a spring by 10mm. What load would extend it by 15mm?
2. A steel spring obeys Hooke's law. A force of 8N extends a spring by 10mm. Calculate the extension of the spring that would be produced by a force of 10N
3. A spring of neutral length 3cm is extended by a force of 4N. What will be
   (a) the stiffness of the spring
   (b) its extension when a force applied is 12N
   (c) its length when a force applied is 12N
4. Use the data below to answerthis question;
   Original length = 20cm
   New length = 25cm
   Load = 50N
   (a) Find the extension of the spring
   (b) Calculate the elastic limit
   (c) Find the extension caused by the 100N load that the elastic is not exceeded
   (d) Find the new length when the spring is stretched by the 100N force.
5. In an experiment to verify Hooke's law, standard masses were placed on the pan which was attached to a suspended spring at the lower end. The corresponding lengths of the stretched spring were recorded as shown below.

Load/N	0.0	1.0	1.5	2.0	2.5	3.0	3.5	3.8	3.4	3.1
Length of the spring/mm	500	505	510	515	520	525	528	530	530	530
Extension/mm										

   (a) Complete the table by filling in the values of extension
   (b) Plot the graph of load against extension
   (c) Show clearly on the graph the elastic limit
   (d) Use your graph to determine the spring constant

6.



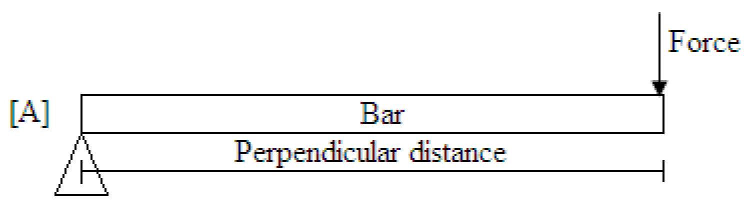


In the figure above, the length of the spring with 10N force hang on it is 12cm and with 20N is 14cm. What would be the length of the spring with 12N hang on it if the spring obeys Hooke's law?

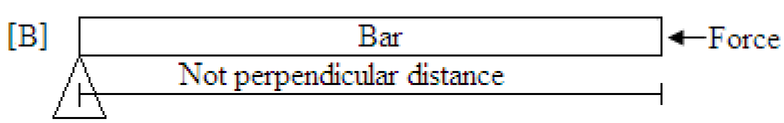
Moments
Symbol:Γ
SI: Newton metre, Nm
Definition: Moment is the turning effect of the force about the pivot
Moment of a force
Moment of a force about a pivot is the product of the force and perpendicular distance from the point to the line of action of the force.
Moment = force x perpendicular distance
Γ = F x d
Note
Γ = moment [Nm]
F = force [N]
d = perpendicular distance[m]

Perpendicular distance must be distance from the pivot to the force

Perpendicular distance must be at right angle to the force



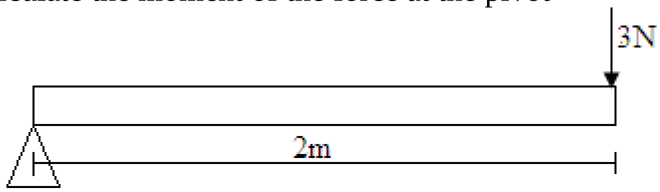
In this case, there is a moment because the force is perpendicular to the bar.
The force can produce the turning effect.



In this case, there is no moment because force is in the same direction of distance
The force doesn't produce the turning effect.

Example

1. Calculate the moment of the force at the pivot



Data	Solution
Γ =?	Γ= F x d
F =3N	Γ= 3N x 2m
d = 2m	Γ = 6Nm

Principle of moments

The law states that: For a body in equilibrium, the sum of clockwise moment is equal to the sum of anticlockwise moment about the same point.

Total anticlockwise moment = Total clockwise moment

Experiment

Title: Moments

Aim: To verify the principle of moment

Apparatus

- Long ruler (30cm or more)
- 3 string
- Loads

Method

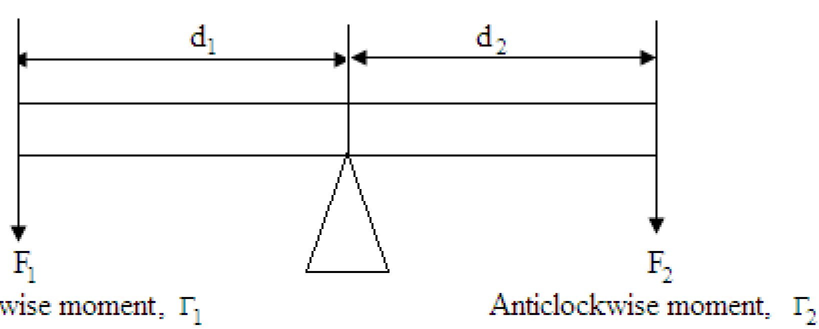
Hang a ruler by a string at the centre of mass and make it balanced

Hang some loads at a certain point from the pivot

Find the position where other loads are hanging to balance the ruler and measure the length from the pivot to the position.

Calculate the clockwise moment and the anticlockwise moment

Repeat the experiment with different pairs of loads and distances



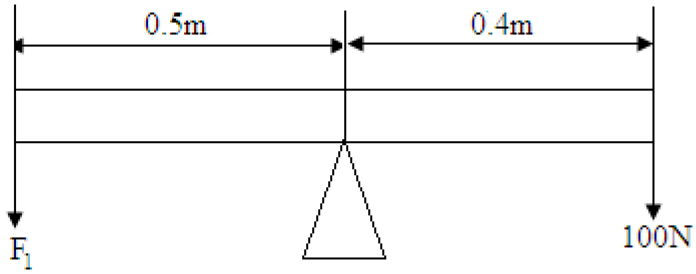
$\Gamma_1 = \Gamma_2$

F_1 x d_1= F_2 x d_2**Conclusion**

If a body is balanced, then the total clockwise moment is equal to the total anticlockwise moment.

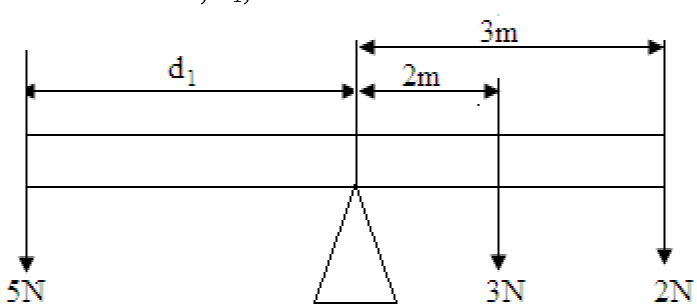
Example

1. Find the force, F_1, if the bar below is balanced



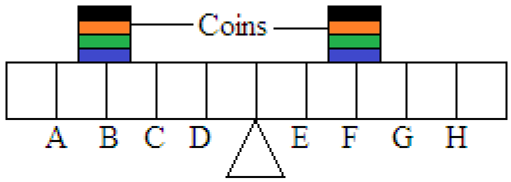
Data	Solution
$\Gamma_1 = \Gamma_2$ F_1 =? d_1 =0.5m F_2 = 100N d_2 = 0.4m	$F_1 \text{ x } d_1 = F_2 \text{ x } d_2$ F_1 x 0.5m = 100N x 0.4m F_1 x 0.5m = 40Nm $F_1 = \frac{40Nm}{0.5m}$ F_1 = 80N

2. Find the distance, d_1, if the bar below is balanced.



Data	Solution
$\Gamma_1 = \Gamma_2 + \Gamma_3$ d_1 =? F_1 = 5N d_2 = 2m F_2 = 3N d_3 = 3m F_3 = 2N	$F_1 \text{ x } d_1 = F_2 \text{ x } F_2 + F_3 \text{ x } d_3$ 5N x d_1 = 3N x 2m + 2N x 3m 5N x d_1 = 6Nm + 6Nm 5N x d_1 = 12Nm $d_1 = \frac{12Nm}{5N}$ d_1 = 2.4m

3. Below is the diagram of a uniform beam suspended on a pivot. Four coins of equal masses are put on points B and F as shown below.



(a) What happens to the beam if left to move freely?
Give a reason for your answer
(b) Which position on the beam would you put one coin to balance the beam? Mark the position with letter P

Solution

(a) The beam will tilt anticlockwise
Reason: The anticlockwise moments are more than the clockwise moments
(b) P should be at H

Determining mass using the principle of moments

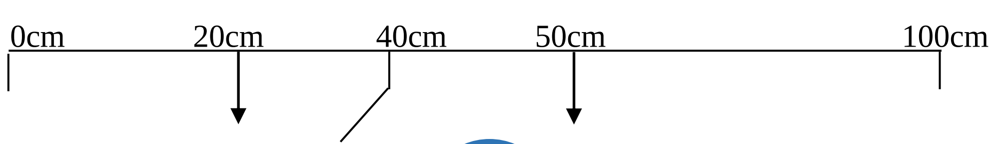
Hint

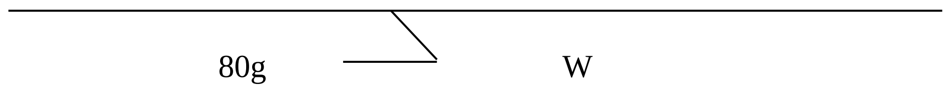
1. Weight of a body acts through its centre of gravity
2. Centre of gravity of a body with a uniform cross section is at mid points

Example

1. A meter rule pivoted at the 40cm mark is balanced by an 80g placed at the 20cm mark. Find the mass of the rule.

Solution





$20cm \times 0.8N = 10cm \times W$

$$W = \frac{20cm \times 0.8N}{10cm}$$

$W = 1.6N$

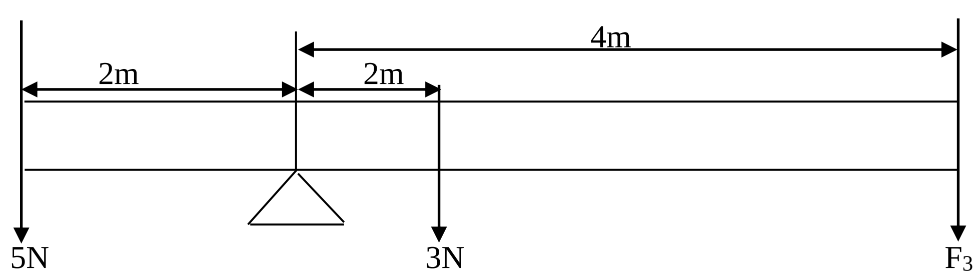
$$m = \frac{W}{g}$$

$$m = \frac{1.6N}{10N/kg}$$

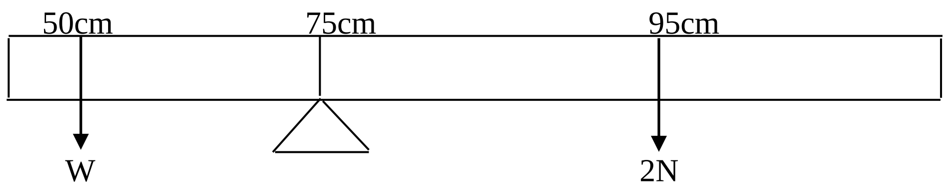
$m = 0.16kg = 160g$

Exercise

1. Calculate the force, F_3, if the bar below is balanced



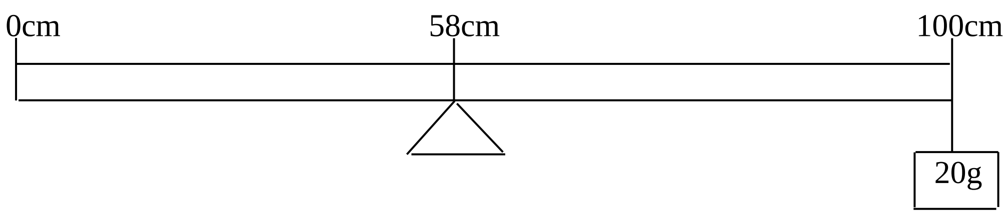
2. The diagram below shows a uniform rule, weight, W, pivoted at the 75cm mark and balanced by a force of 2N acting at the 95cm mark.



(a) Calculate the moment of the 2N force about the pivot
(b) Use the principle of moments to calculate the value of W.

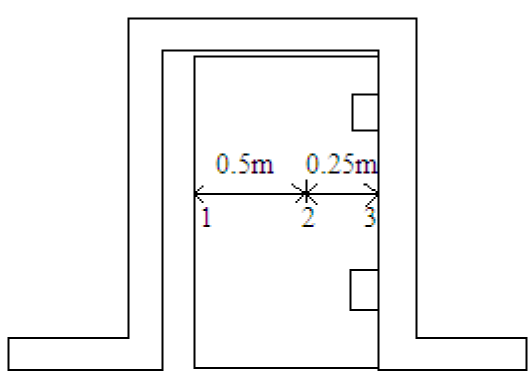
3. A metre rule hangs by a string at the 80cm mark and a mass of 140g hangs at 95cm mark. The weight of the ruler appears on the centre of mass.
   (a) Where is the pivot?
   (b) What is the weight of the 140g mass?
   (c) Calculate the weight of the ruler, W
   (d) Calculate the mass of the ruler

4. The diagram below shows the uniform metre rule balanced horizontally on a knife-edge placed at the 58cm mark when a mass of 20g is suspended from the end.



(a) Find the mass of the rule
(b) What is the weight of the rule (taking g = $10m/s^2$)
(c) A candle stand has a wide heavy base. Explain why the base has both heavy mass and wide area.

5. The figure below shows a door well secured on the door frame.



(a) What is meant by moment of force? Include SI units.

(b) Calculate the moment of force if a force of 10N is applied at point 1 to open or close the door.
(c) Explain why it is easier to open or close the door if the handle is fixed at point 1 than at point 2 or 3.

Simple machines
A machine is mechanical device which uses an effort to overcome a load
Effort
Symbol: E
SI unit: Newton, N
Definition: Effort is the applied force
Load
Symbol: L
SI unit: Newton, N
Definition: Load is the force which the effort overcomes
Load can also be defined as the force an object pulls or pushes on a machine.

Mechanical advantage
Symbol: M.A
Definition: Mechanical advantage is the ratio of the load to the effort
Formula: M.A = $\frac{\text{Load}}{\text{Effort}}$
Units: M.A has no units since it is a ratio whose units cancel each other.

Velocity ratio
Alternative term: Ideal mechanical advantage
Symbol: V.R
Definition: Velocity ratio is the ratio of the distance moved by the effort to the distance moved by the load

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

Units: V.R has no units since it is a ratio whose units cancel each other.

Efficiency of a machine

Symbol**:** η

Definitions

Efficiency is the ratio of the useful energy output to the energy input multiplied by 100%.
Efficiency is the ratio of the power output to the power input multiplied by 100%.

Formulae: $\eta = \frac{\text{Energy out put}}{\text{Energy in put}} \times 100\%$

$\eta = \frac{\text{Power out put}}{\text{Power in put}} \times 100\%$

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

<u>Note</u>

Efficiency of a machine can never be more than 100% because the energy out put (work done by a machine) is never more than energy in put (work done on the machine)

$\eta \leq 100\%$

Efficiency of a machine cannot be 100%

Reasons:

- Some energy is used to overcome friction
- Some energy is used to move parts of the machine

M.A≤ V.R

Generally, in an **ideal situation**, the efficiency of any machine is equal to100% and this just theoretical. This means that M.A = V.R or energy out put = energy in put.

1. Prove that M.A ≤ V.R

<u>Solution</u>

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

$\eta \leq 100\%$

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

$$\frac{1}{\cancel{1}00\%} \times \frac{M.A}{V.R} \times \cancel{1}00\% \leq \cancel{1}00\% \times \frac{1}{\cancel{1}00\%}$$

$$\frac{M.A}{V.R} \leq 1$$

M.A ≤ V.R, hence proved

2. Find the efficiency of an electric motor that is capable of pulling a 50kg mass through a height of 15m after consuming 30,000J of electric energy.

Solution

Energy out put = mgh

= 50kg x 10N/kg x 15m

= 7,500J

Energy in put = 30,000J

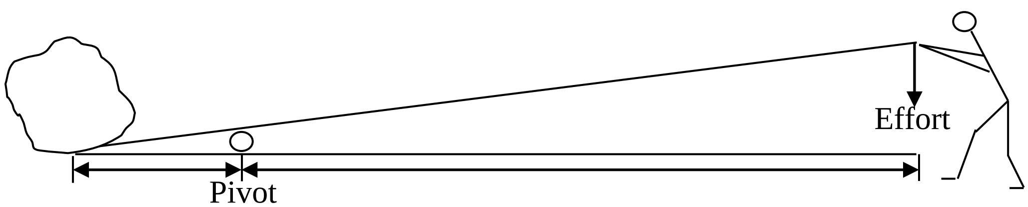
$$\eta = \frac{\text{Enrgy out put}}{\text{Energy in put}} \times 100\%$$

$$= \frac{7{,}500\text{J}}{30{,}000\text{J}} \times 100\%$$

$$= 25\%$$

Types of simple machines

A. Levers



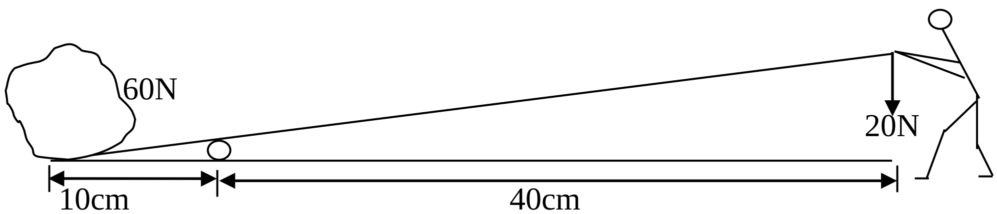
$$\text{V.R} = \frac{\text{Distance from pivot to effort}}{\text{Distance from pivot to load}}$$

Some examples of levers

- Wheel barrow
- Claw hammer
- Table knife
- Scissors
- Bore hole

Example

1. Study the diagram below and answer the questions that follow



Calculate

(a) The mechanical advantage
(b) The velocity ratio
(c) The efficiency

Solution

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

$\text{M.A} = \frac{60\text{N}}{20\text{N}}$

M.A = 3

(b) $\text{V.R} = \frac{\text{Distance from pivot to effort}}{\text{Distance from pivot to load}}$

$\text{V.R} = \frac{40\text{cm}}{10\text{cm}}$

V.R = 4

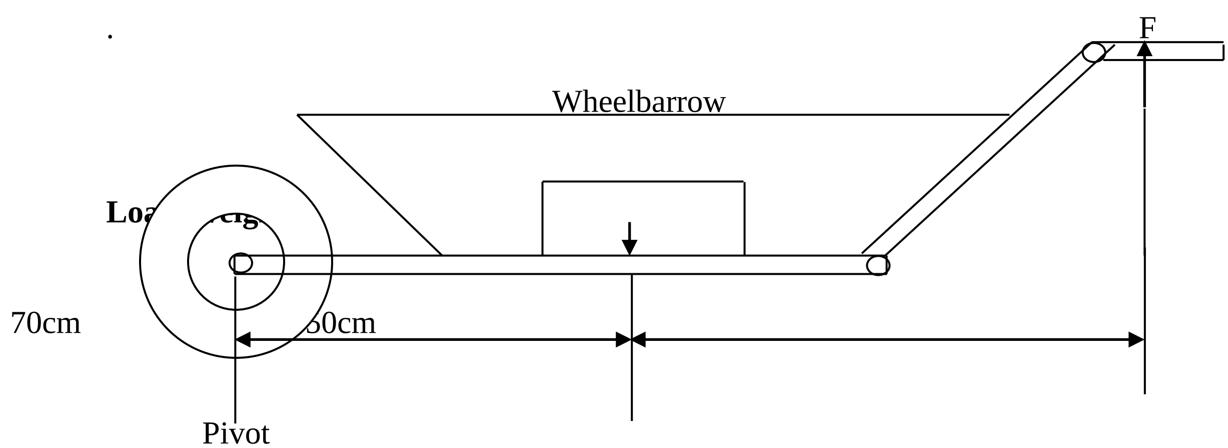
(c) $\text{Efficiency} = \frac{M.A}{V.R} \text{x } 100\%$

$\text{Efficiency} = \frac{3}{4} \text{x } 100\%$

Efficiency = 75%

2. A load is to be moved using a wheelbarrow. The total mass of the load and wheelbarrow is 60kg. The gravitational field strength is 10N/kg

.



What is the size of force, F, needed just to lift the loaded wheelbarrow?

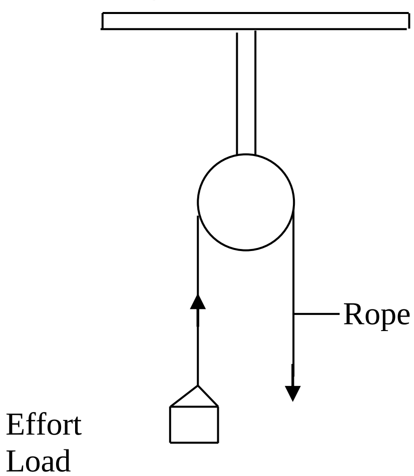
Data	Solution
F =? m = 60kg g = 10N/kg d_1 = 70cm d_2 = 120cm (70cm +50cm)	W = mg W = 60kg x 10N/kg W = 600N 600N x 70cm = F x 120cm $F = \frac{600N \times 70cm}{120cm}$ F = 350N

B. Pulleys

A pulley is a wheel with a grooved rim mounted on a block

Types of pulleys

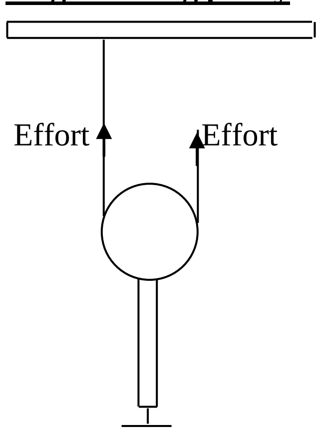
1. **Single fixed pulley**

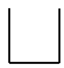


Load = Effort

M.A = 1

2. **Single moving pulley**



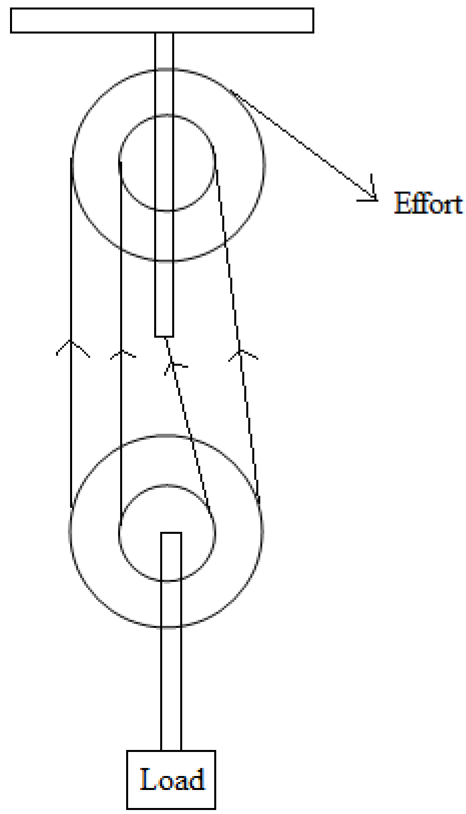


Load

Load is twice effort

M.A = 2

3**. Block and tackle**

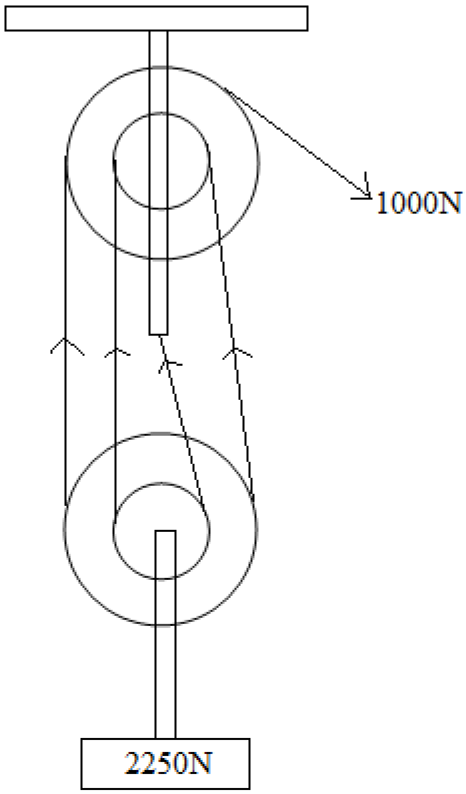


V.R = Number of lines or pulley wheels

V.R = 4

Exercise

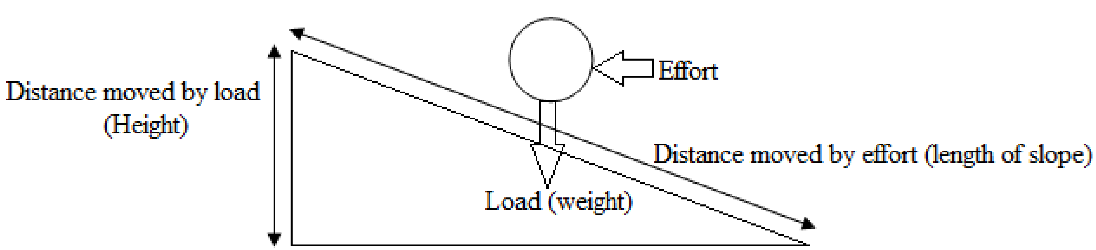
1. The diagram below shows the pulley system



Find

(a) The mechanical advantage
(b) The velocity ratio
(c) The efficiency

C. **Inclined plane**



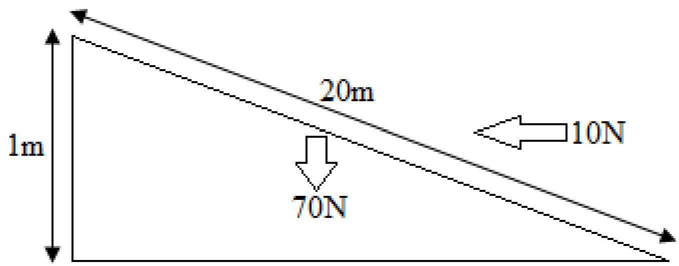
$$V.R = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

OR

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

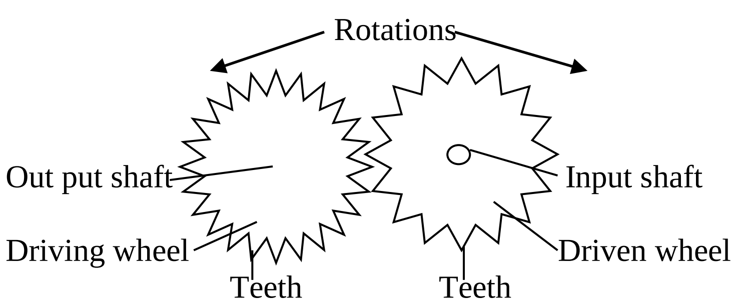
<u>Activity</u>

1. The diagram below shows an inclined plane.



Find
(a) The mechanical advantage
(b) The velocity ratio
(c) The efficiency

D. <u>Gears</u>

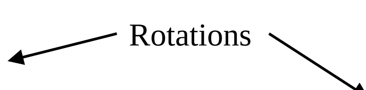


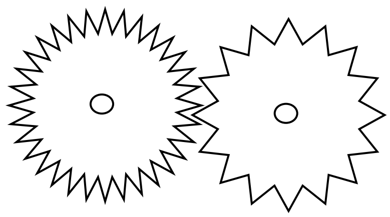
$$V.R = \frac{\text{Number of teeth in driving wheel}}{\text{Number of teeth in drven wheel}}$$

$$\text{Number of rotations in driving wheel} = \frac{\text{Number of rotations in driven wheel}}{V.R}$$

Exercise

1. The figure below shows the diagram of rotating gear wheels. The driving wheel has 36 teeth and the driven wheel has 12 teeth.





(a) Find the velocity ratio
(b) If the driven wheel makes 15 rotations, how many rotations would the driving wheel make

Work
Symbol: W
SI unit: Joule, J
Definition: Work isthe product of the force and the distance moved in the direction of the force.
Formula: Work = force x distance
W = F x d
W = weight x height
W = mgh

Note
W = work [J]
F = force [N]
d = distance [m]
h = height [m]
m = mass [kg]
g = acceleration due to gravity [$10m/s^2$] or [10N/kg]

Joule is the work done when the point of application of a force of 1 Newton moves through 1 metre in the direction of the force.
1 Newton-metre is equal to 1 joule of work.
Work is said to have been done when we push an object through a certain point or when we lift an object from the ground.

Relationship of units

1KJ = 1000J
1MJ = 1000KJ = 1000000J = 10^6J

NB: KJ = kilo joule
MJ = mega joule

Example

1. A force of 5N acts on a 2kg brick, moving it 8m horizontally from rest. Find the work done by the force.

Data	Solution
W =? F = 5N d = 8m	W = F x d W = 5N x 8m W = 40Nm W = 40J

2. A hawk picks a 2kg chicken and lifts it up to a branch of a tree 15m from the ground. How much work has it done on the chicken?
   g = 10N/kg

Data	Solution
W =? m = 2kg g = 10N/kg h = 15m	W = mgh W = 2kg x 10N/kg x 15m W = 300Nm W = 300J

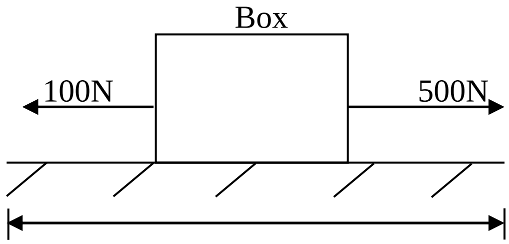
Exercise

1. A car of mass 1000kg is accelerated at 2m/s^2 from rest in 20 seconds.
   Calculate
   (a) The force acting on the car.
   (b) The final velocity
   (c) The distance travelled by the car
   (d) The work done by the car.

2. A crane lifts a weight of 200N through 50m. Find the work done by the crane.

3. A crane lifts a car of mass 500kg through 5m. Find the work done by the crane.

4. A person exerts a horizontal force of 500N on a box, which also experiences a friction force of 100N.



3m
How much work is done against friction when the box moves a horizontal distance of 3m?

Energy
Symbol: E
SI unit: Joule, J
Definition: Energy is the ability to do work.

Potential energy
Symbol: P. E or E_P
SI unit: Joule, J
Definition: Potential energy is the energy which the body possess by virtual of its position.
Formula: P.E = mgh

Note
P.E = potential energy [J]
m = mass [kg]
g = acceleration due to gravity [$10m/s^2$] or [10N/kg]
h = height [m]

Example

1. A 2kg object is raised to a heightof 5m. What is its potential emery?

Data	Solution
P.E =? m = 2kg	P.E = mgh P.E = 2kg x 10N/kg x 5m

g = 10N/kg h = 5m	P.E = 100Nm P.E = 100J

Exercise

1. A book which has a mass of 1.2kg is put on the desk of height 0.8m. Calculate the potential energy. (Take g to be 10N/kg)

2. A rock of mass 10kg is on top of the hill. Calculate the height of the hill if the potential energy of the rock is 5000J. (Take g to be 10N/kg)

Kinetic energy

Symbol: K.E or E_k

SI unit: Joule, J

Definition: Kinetic energy is the energy the body has due to its motion.

Formula: K.E = $\frac{1}{2}mv^2$

Note

K.E = kinetic energy [J]

m = mass [kg]

v = velocity [m/s]

Example

1. A 2kg stone is thrown vertically with a velocity of 5m/s. What is the kinetic energy?

Data	**Solution**
K.E =? m = 2kg v =5m/s	K.E = $\frac{1}{2}mv^2$ K.E = $\frac{1}{2}$ x 2kg x $(5m/s)^2$ K.E = $\frac{1}{2}$ x 2kg x 5m/s x 5m/s K.E = 25J

Exercise

1. A car of mass 500kg moves with a velocity of 20m/s. Find the kinetic energy.

2. A 60kg pupil runs 600m in one minute uniformly.
   (a) Calculate his velocity
   (b) Calculate his kinetic energy.

The law of conservation of energy

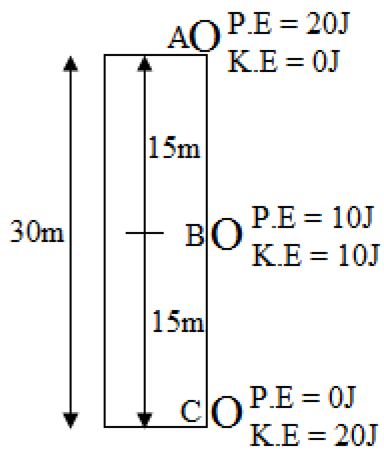
The law states that: Energy cannot be created or destroyed but can only be changed from one form to another.

Energy transformations

Each energy can be changed but the total energy is constant
When there is only P.E and K.E, then;
P.E + K.E = Constant

Applications

(I) Conservation of mechanical energy of a falling body



[A] Before a ball is released, its potential energy is 20J and the kinetic energy is 0J because it is not moving

[B] At the mid-point of its journey, the potential energy drops to 10J but the kinetic energy increases to 10J.At height 15m, P.E becomes equal to K.E.
The total energy is still 20J.

[C] Just before hitting the ground, the potential energy becomes 0J but the kinetic energy increases to 20J. All P.E becomes K.E
There is no change in the total energy throughout its falling.

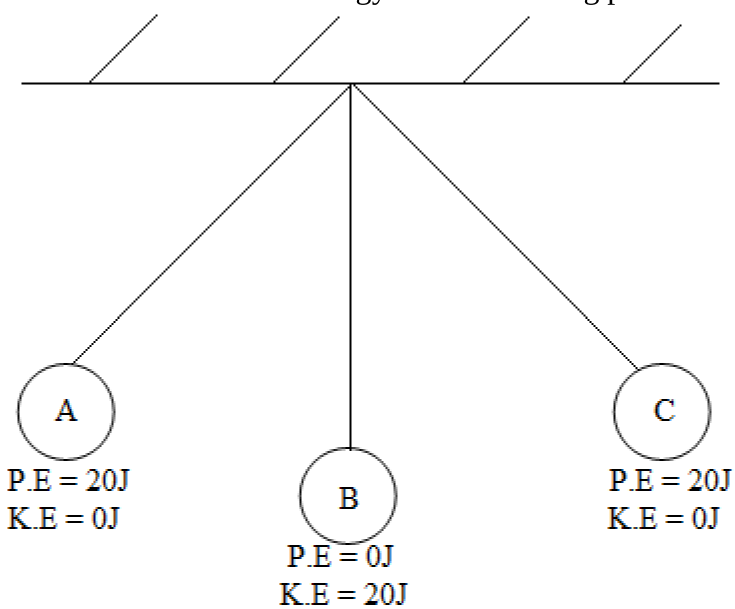
Example

1. A 2kg stone is dropped from the top of a 20m building.
   (a) What potential energy does it posses?
   (b) At what height does its potential energy becomes equal to its kinetic energy?
   (c) What is its kinetic energy just before it hits the ground?
   (d) With what velocity does it reach the ground?

1	Data	Solution
(a)	P.E =? m = 2kg g = 10N/kg h = 20m	P.E = mgh P.E = 2kg x 10N/kg x 20m P.E = 400Nm P.E = 400J
(b)		At height 10m
(c)	All P.E becomes K.E	K.E = 400J
(d)	v =? K.E = 400J	K.E = $\frac{1}{2}mv^2$ 400 = $\frac{1}{2}$ x 2 x v^2 v^2 = 400

	m = 2kg	$v = \sqrt{400}$ v = 20m/s

(II) Conservation of mechanical energy in an oscillating pendulum



[A] The pendulum bob is pulled to position A. Before it is released, its potential energy is 20J and kinetic energy is 0J because it is at rest.

[B] As the bob moves from A to B, it loses potential energy and gains kinetic energy of 20J because of reducing the height and increasing the velocity. It has maximum velocity at B

[C] Moving from B to C, the bob slows down losing kinetic energy but gaining potential energy. If air resistance is ignored, the height of A is the same as the height of C because the potential energies must be the same.

Example

1. A pendulum bob of mass 0.1kg is raised to a height of 0.4m above its lowest point. It is then released.
   (a) What is its potential energy at this height?
   (b) What is its kinetic energy at its lowest height?
   (c) What is its maximum velocity?

1	**Data**	**Solution**
(a)	P.E =?	P.E = mgh

	m = 0.1kg g = 10N/kg h = 0.4m	P.E = 0.1kg x 10N/kg x 0.4m P.E = 0.4Nm P.E = 0.4J
(b)	All P.E becomes K.E	K.E = 0.4J
(c)	v =? m = 0.1kg K.E = 0.4J	$K.E = \frac{1}{2}mv^2$ $0.4 = \frac{1}{2} \times 0.1 \times v^2$ $v^2 \times 0.1 = 0.4 \times 2$ $v^2 \times 0.1 = 0.8$ $v^2 = \frac{0.8}{0.1}$ $v^2 = 8$ $v = \sqrt{8}$ v = 2.83m/s

(III) Charging a cell phone
(From electrical energy to chemical energy)

(IV) Using a cooker
(From electrical energy to thermal energy)

(V) Generation of electrical energy at a hydro - electric power station
(From mechanical energy to electrical energy)

Exercise

1. A 25kg bag of mealie meal is lifted from the ground to the top of a wall 1.8m high in 0.6 seconds.
   (a) What type of energy has the mealie meal bag gained?
   (b) If the bag is released from the wall, with what velocity does it strike the ground?
   (c) Calculate the power which developed
   (d) On striking the ground, into what form is the energy of the bag converted?

2. A tin of mass 64g fell from a height of 11.25m.
   (a) Work out the speed of the tin at the moment it struck the ground.
   (b) Calculate the kinetic energy of the tin when it was just hitting the ground.

Power

Symbol: P
SI unit: watt, W

Definition: Power is the rate of doing work.

Formula: Power = $\frac{\text{Work done}}{\text{time taken}}$

$$P = \frac{W}{t}$$

$$P = \frac{mgh}{t}$$

P = power [W]
W = wok [J]
t = time [s]
m = mass [kg]
g = acceleration due to gravity [10m/s^2] or [10N/kg]
h = height [m]

Example

1. A machine can lift 200kg to a height of 100m in 20 seconds. Find the useful power of the machine.

Data	Solution
P =? m = 200kg g = 10N/kg h = 100m t = 20s	$P = \frac{mgh}{t}$ $P = \frac{200\text{kg x } 10\text{N/kg x } 100\text{m}}{20\text{s}}$ P = 10,000W

2. A boy whose mass is 40kg finds that he can ran up a flight of 45 steps each 16cm high in 5 seconds. Calculate the power.

Data	Solution

P =? m = 40kg g = 10N/kg h = 45 x 16cm = 720cm = 7.2m t = 5s	$P = \frac{mgh}{t}$ $P = \frac{40kg \ X\ 10N/kg\ X\ 7.2m}{5s}$ $P = \frac{2880J}{5s}$ P = 576W

Exercise

1. A force of 1000N is needed to push a mass of 30kg through a distance of 40m to raise an inclined plane to a height of 5m.

Calculate

(a) The weight of the object
(b) The mechanical advantage
(c) The velocity ratio
(d) The efficiency of the inclined plane.
(e) The energy at the height of 5m
(f) The work done by the force of 1000N.

2. A pupil of mass 50kg runs up a flight of 20 stairs each 5cm high in a time of 20 seconds. [Take g = 10N/kg]
   Calculate
   (a) The pupil's gain in potential energy
   (b) The useful power developed by the pupil in climbing the stairs.

Thermal physics

State of matter is the form in which a substance exists. Matter exists in three of Solids, liquids, gases

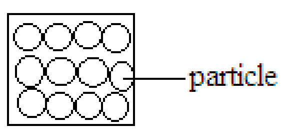
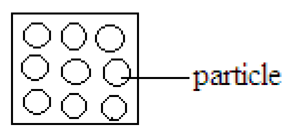
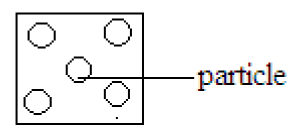
The physical differene between the three states of matter depends on the arrangement and behaviour of the molecules in each particular state. The differences can be explained in terms of the kinetic theory

The kinetic theory of matter

The theory states that:

- Matter is made up very tiny particles called molecules
- The molecules are not stationary but are in a contnous random motion
- The degree of movement of the molecules depends on their temperature

Characteristicproperties of the three states of matter

	Solids	Liquids	Gases
Shape	Have fixed shape Normally hard and rigid	Have no fixed shape. They take the shape of the container in which they are placed.	Have no fixed shape
Volume	Have fixed volume High density	Have fixed volume High density	Have no fixed volume. Particles spread to fill the space available. Low density
Compressibility	Can not be compressed	Can not be compressed	Can be compressed.
Arrangement of particles	Particles are closely packed and arranged in a regular pattern. The particles are held together by strong electrostatic forces of attraction called cohesive forces. 	Particles are slightly further apart than in solids. Paticles are held together by weak electrostatic forces of attraction. 	Particles are much further apart from each other. The forces which hold the particles together are negligible. 
Movement of particles	Particles move by vibrating at fixed positions	Particles move by vibrating rapidly over short distances. Particles move from one position to the other.	Particles move at random at a very high speed.

Solids and liquids can not be compressed because their particles are close together. However, gases can be compressed because the gas particles are far apart from each other and can be forced to move closer by exerting pressure.

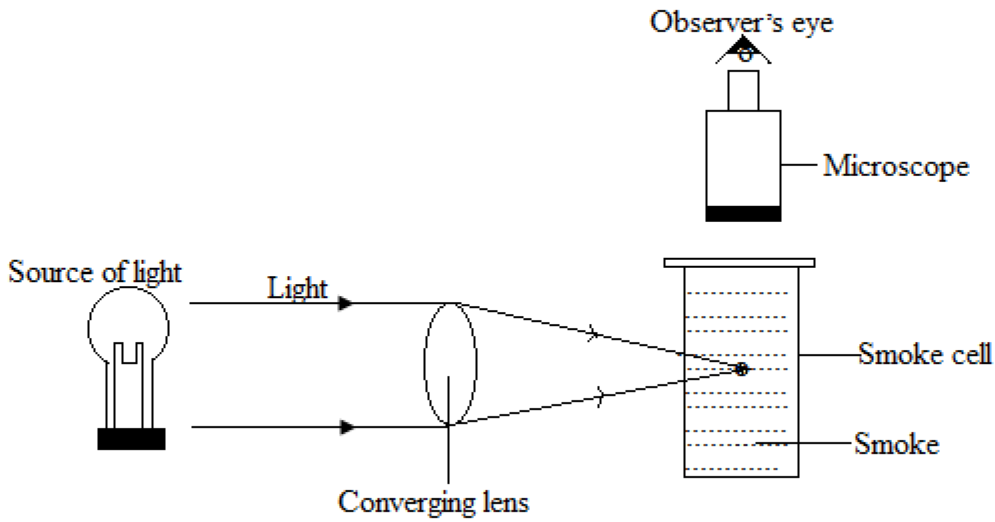
Brownian motion
Brownian motion provides the evidence of the continuous random motion of the molecules of air.
Experiment
Aim: To demonstrate Brownian motion in air

Apparatus

- Source of light
- Converging lens or glass rod
- Smoke cell
- Microscope
- Teat pipette

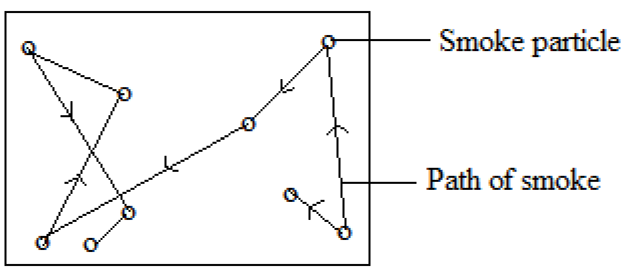
Method

Fix the converging lens parallel to the filament lamp to focus the light into the cell
View the smoke cell from above through the microscope.
Focus into the center of smoke cell and introduce smoke into the smoke cell using a teat pipette
Place the cover slip on top of the smoke cell.



Observation

When light strikes the smoke particles, they appear as bright points of light under the microscope moving randomly in a zig – zag path



Explanation

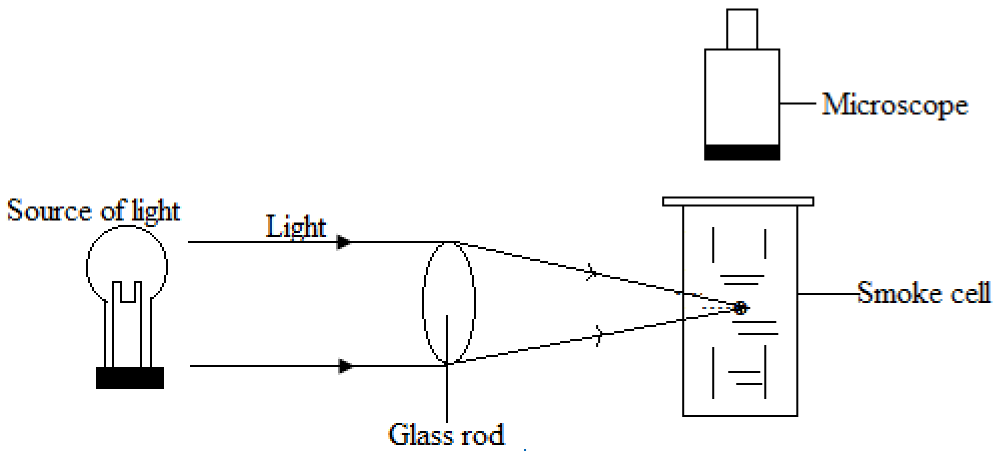
The zig – zag movement is due to the collision of the smoke particles with invisible air molecules that move about randomly in the smoke cell. This is called Brownian motion.

Conclusion

The air molecules are in a continuous random motion colliding with the smoke particles and the walls of the smoke cell

Exercise

1. The figure below shows one of the forms of an apparatus used to observe Brownian motion of smoke particles in air. Mr Naosa D. K looking through the microscope sees tiny bright specks which he describes as ‘dancing about’.

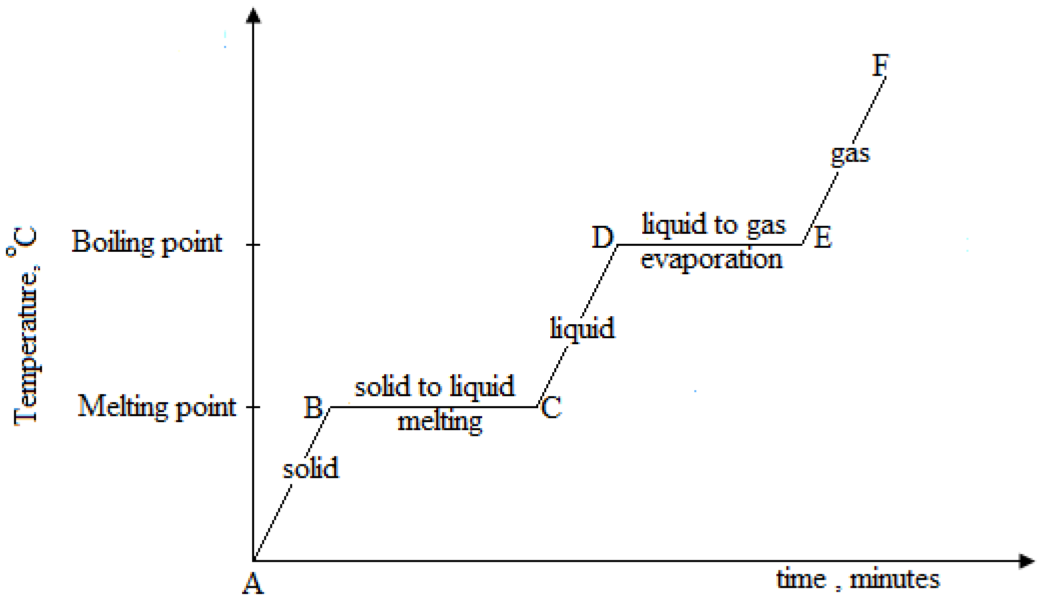


(a) What are bright specks?
(b) Why are the specks ‘dancing about’?
(c) State the conclusion that can be drawn from the Brownian motion?

Differences between evaporation and boiling

Evaporation	Boiling
Occurs at any temperature below boiling	Occurs at boiling point
Occurs only at the surface of the liquid	Occurs throughout the liquid
No bubbles are observed	Bubbles are observed
Occurs slowly	Occurs rapidly

The heating curve
The heating curve is a graph showing changes in temperature with time for a substance being heated

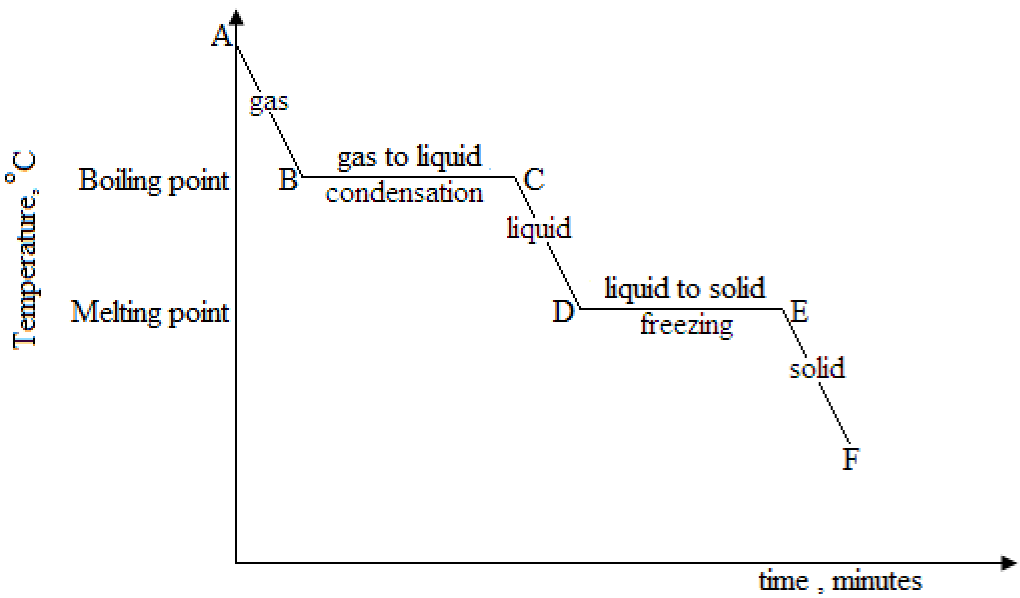


Slope sections of the heating curve
As a substance is heated, it absorbs heat energy and its temperature rises, then it changes from solid to liquid and finally to gas.
Flat sections of the heating curve
The flat section shows the melting point and boiling point. Here the temperature remains constant over a period of time as energy being absorbed is used to change the state of a substance

Note
A pure substance has a fixed temperature. It has an exact boiling point and melting point. Impurities raise the boiling point and lower the melting point.

The cooling curve

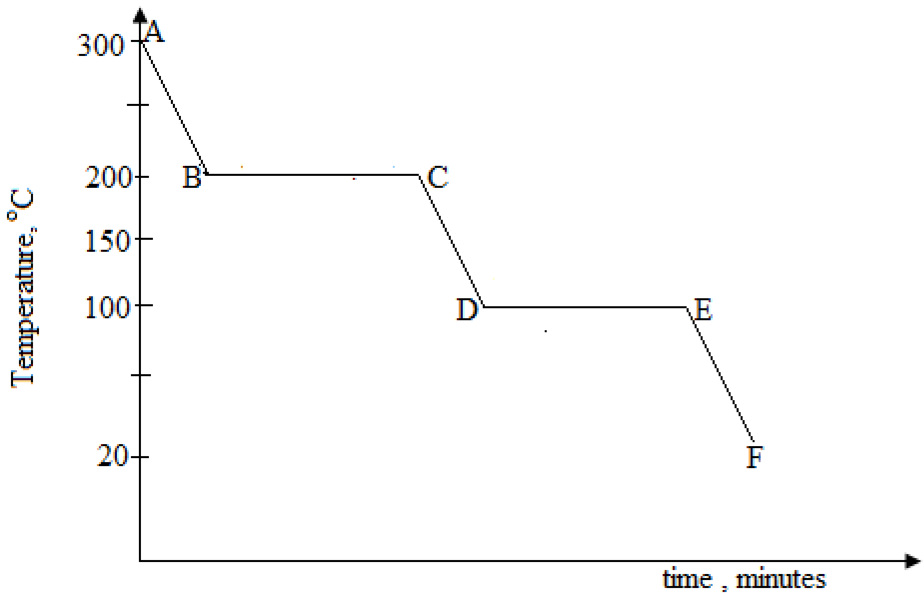
The cooling curve is a graph showing changes in temperature with time for a substance being cooled.



Slope sections of the cooling curve
As a substance is cooled, it loses heat energy and its temperature falls, then it changes from gas to liquid and finally to solid.
Flat sections of the cooling curve
The flat section shows the melting point and boiling point. Here the temperature remains constant over a period of time as energy being lost is used to change the state of a substance.

Exercise

1. The graph below shows a cooling curve of a substance as its temperature falls from $300^{o}C$ to $20^{o}C$.



(a) At $250^{o}C$, is the substance a solid, liquid or gas?
(b) What was the boiling point of the substance?
(c) What was the melting point of the substance?
(d) Why does the temperature stay constant over the section BC and DE despite the fact that the substance is losing energy to the surrounding?

Pressure
Symbol: P
Units: Newton per metre squared, N/m^2
Pascal, Pa
Note: 1 Pascal = $1N/m^2$
Definition: Pressure is force per unit area
Formula: Pressure = $\frac{\text{Force}}{\text{Area}}$

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

Gas pressure is as a result of the collisions of the gas molecules with the walls of the container vessel

Pressure of a gas depends on:

1. Frequency of collisions
2. Speed of molecules

Frequency	Pressure
High	High
Low	Low

Speed	Pressure
High	High
Low	Low

Examples

1. If a 70N is applied over an area of $0.8m^2$, how much pressure is exerted?

Data	Solution
P =? F = 70N $A = 87.5m^2$	$P = \frac{F}{A}$ $P = \frac{70N}{0.8m^2}$ $P = 87.5\ N/m^2$

2. When a force acted over an area of $16cm^2$, a pressure of 20 Kpa was established. Determine the magnitude of the force.

Data	Solution
F =? P = 20Kpa = 20,000Pa $A = 16cm^2 = 0.00016m^2$	$P = \frac{F}{A}$ F = PA $F = 20 \times 10^3 Pa \times 16 \times 10^{-4} m$ F = 32N

3. Explain why
   (a) A sharp knife cuts well
   (b) Low heeled shoes are more comfortable than high heeled shoes

Solution

   (a) A sharp knife cuts well because it exerts less pressure
   (b) Low heeled shoes exerts pressure on the feet compared to high heeled shoes

4. A block measuring 0.1m x 0.2m x 0.8m has a mass of 20Kg.
   What is the maximum and minimum pressure it can exert on the ground?

Data	Solution
P =?	$P = \frac{F}{A}$

m = 20Kg g = 10N/Kg L = 0.1m B = 0.2m	$P = \frac{mg}{L \times B}$ $P = \frac{20Kg \times 10N/Kg}{0.1m \times 0.2m}$ $P = \frac{200N}{0.02m^2}$ $P = 10000N/m^2$

Exercise

1. A person weighing 1200N is supported on an inflated air pillow. The total area of soles of his shoes is $0.1m^2$. Calculate the minimum pressure of the air inside the pillow.

Pressure due to a liquid column

Formula: $P = \rho hg$

Note

P = pressure
ρ = density
h = height or depth
g = acceleration due to gravity
Pressure due to a liquid column increases with depth
Pressure due to a liquid column increases with density of the liquid

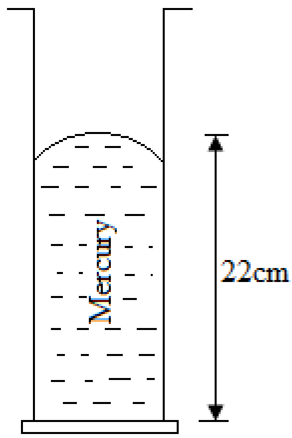
Example

1. Density of water is $1000Kg/m^3$. Determine the pressure due to a liquid at the bed of a 6m deep river.

Solution

$P = \rho hg$
$P = 1000Kg/m^3 \times 6m \times 10N/Kg$
$P = 60000N/m^2$

2. Refer to the diagram below



Density of mercury is $13.6g/cm^3$. Calculate the pressure exerted by the mercury at the base area of the measuring cylinder.

Solution

$P = \rho hg$

$P = 13.6g/cm^3 \text{ x } 22 \text{ x }^{-2}m \text{ x } 10N/Kg$

$P = 13600Kg/m^3 \text{ x } 0.22m \text{ x } 10N/Kg$

P = 29920 Pa

Measurement of pressure using a manometer

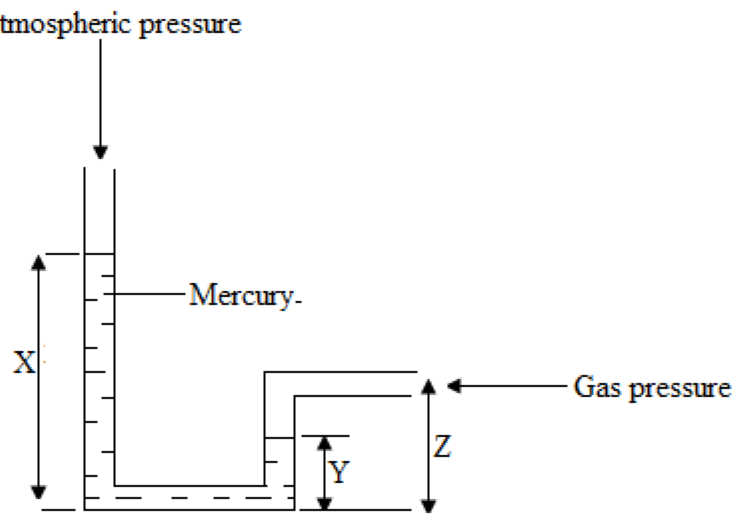
A manometer can be used to measure pressure. It applies the following relationship

$P_1 + P_2 = P_3$

P_1 = atmospheric pressure

P_2 = pressure due to a liquid column

P_3 = pressure due to a gas supply



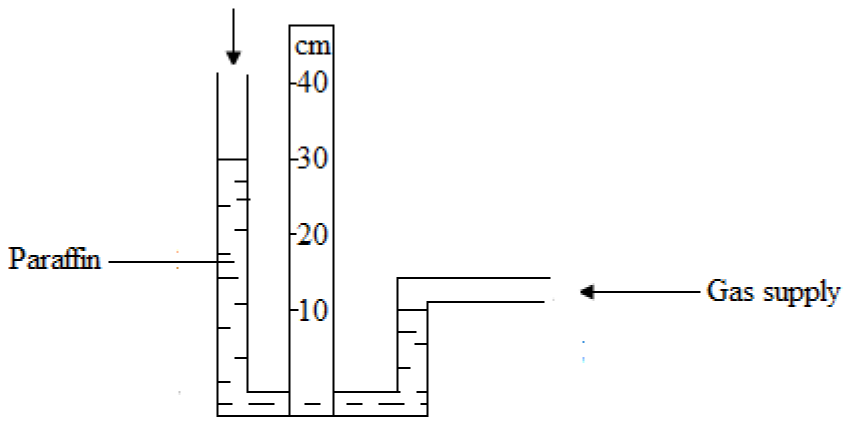
Note

h = X – Y

Atmospheric pressure = 76cmHg $= 760\text{mmHg} = 1 \times 10^5$ Pa

Example

1. Refer to the diagram below



The density of paraffin is 790Kg/m^3 and atmospheric pressure is 1×10^5 Pa, determine

(a) Pressure due the liquid head of the paraffin column

(b) The pressure of the gas supply

Solution

(a) P = ρhg

P = $790\text{Kg/m}^3 \times (0.3\text{m} - 0.1\text{m}) \times 10\text{N/Kg}$

P = $790\text{Kg/m}^3 \times 0.2\text{m} \times 10\text{N/Kg}$

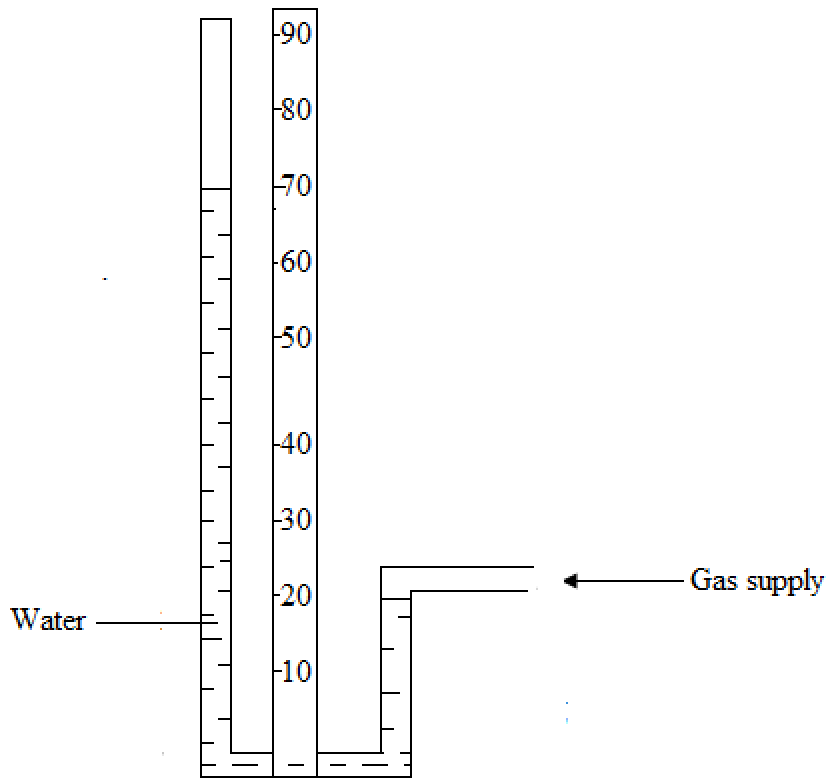
P = 1580 Pa

(b) $P_3 = P_1 + P_2$

P_3 = 1×10^5 Pa + 1580 Pa

P_3 = 101580 Pa

2. Refer to the diagram below



The density of water is $1000Kg/m^3$ and atmospheric pressure is 1×10^5 N/Kg

(a) Calculate pressure due to the head of the water column
(b) Calculate pressure of the gas supply
(c) If ethanol (density $8 \times 10^2 Kg/m^3$) was used in place of water, what would have been the difference in the liquid columns in the two arms of the manometer? Assume the pressure of the gas supply is unchanged.

Solution

(a) $P = \rho hg$

$P = 1000Kg/m^3 \times (0.7m - 0.2m) \times 10N/Kg$

$P = 1000Kg/m^3 \times 0.5 \times 10N/Kg$

P = 5000 pa

(b) $P_3 = P_1 + P_2$

$P_3 = 1 \times 10^5 \text{ Pa} + 5 \times 10^3 \text{ Pa}$

$P_3 = 105000$ Pa

(c) $P = \rho hg$

$h = \frac{P}{\rho g}$

$h = \frac{5000 \text{ Pa}}{800Kg/m^3 \times 10N/Kg}$

h = 0.625m

Transmission of pressure in a fluid

Pascal's law

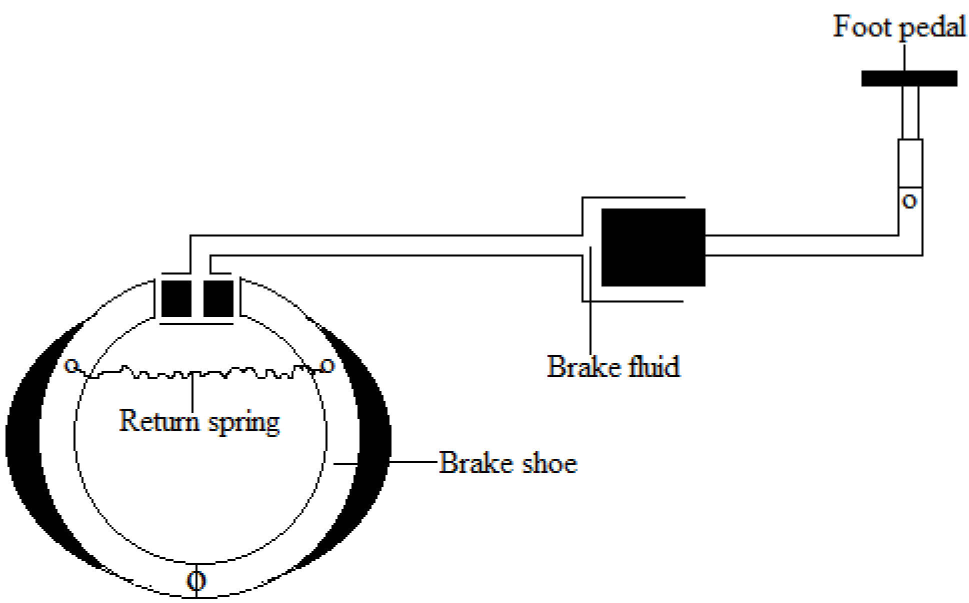
The law state that: Pressure of a fluid is transmitted undiminished to every part of a fluid and every part of the container

Application

1. Hydraulic press

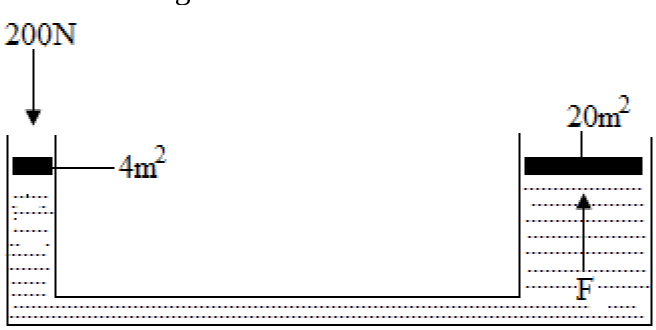
$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

2. Hydraulic brakes



Example

1. Refer to the diagram below



Calculate the force, F

Solution

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

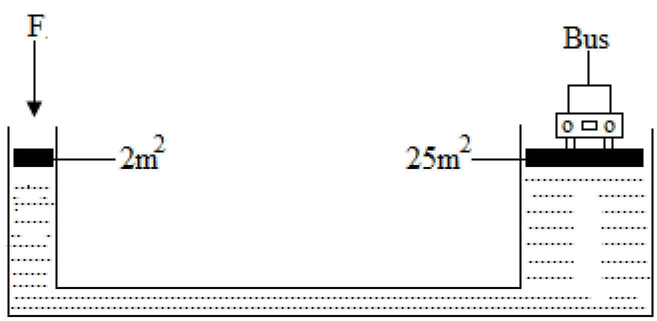
$$F_2 = \frac{F_1 A_2}{A}$$

$$F_2 = \frac{200\text{N x } 20\text{m}^2}{4\text{m}^2}$$

$$F_2 = 1000\text{N}$$

Exercise

1. State Pascal's law
2. Refer to the figure below



The mass of the bus is 4 tonnes

Calculate

(a) The weight of the bus

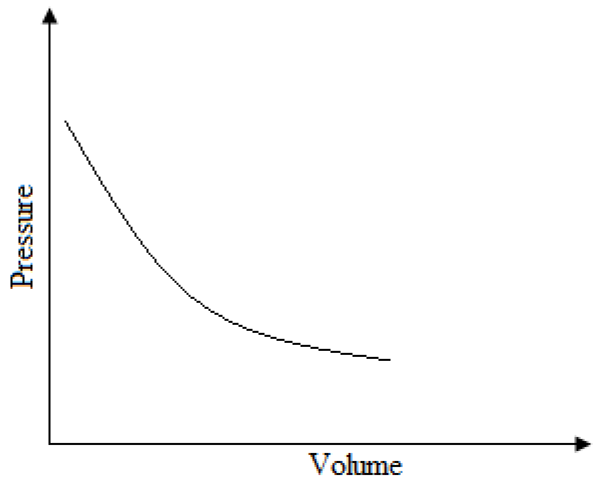
(b) The minimum force, F, required to lift the bus

Boyle's law

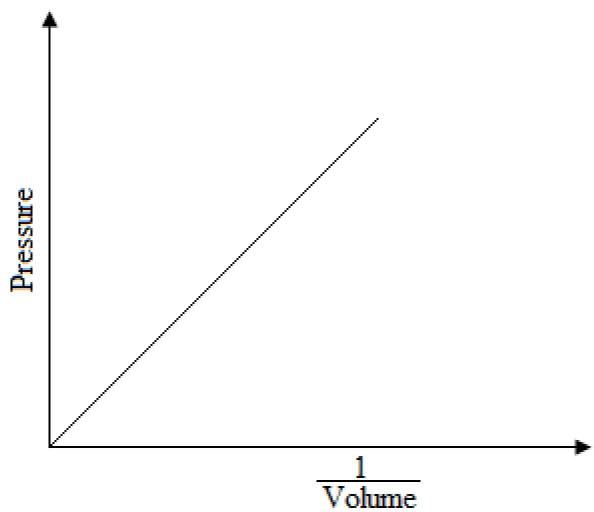
The law state that: The pressure of a fixed mass of gas at constant temperature is inversely proportional to its volume.

Formula: $P_1V_1 = P_2V_2$

Graph of pressure against volume



Graph of pressure against $\frac{1}{\text{Volume}}$



Example

1. A sample of gas has volume $1000cm^3$ and pressure 8×10^3Pa. Assuming temperature remains constant,
   Calculate
   (a) The pressure of the gas when its volume is doubled
   (b) The volume of the gas when its pressure is $1 \times 10^5 Pa$

	Data	Solution
a	P_2= ? $P_1 = 8\ X\ 10^3\ Pa$ $V_1 = 1000cm^3$ $V_2 = 2000cm^3$	$P_1V_1 = P_2V_2$ $P_2 = \frac{P_1V_1}{V_2}$ $P_2 = \frac{8 \text{ x } 10^3 \text{ x } 1000cm^3}{2000cm^3}$ $P_2 = 4 \text{ x } 10^3 Pa$
b	V_2= ? $P_1 = 8 \text{ x } 10^3\ Pa$ $V_1 = 1000cm^3$ $P_2 = 1 \text{ x } 10^5 Pa$	$P_1V_1 = P_2V_2$ $V_2 = \frac{P_1V_1}{P_2}$ $V_2 = \frac{8 \text{ x } 10^3 Pa \text{ x } 1000cm^3}{1 \text{ x } 10^5 Pa}$ $V_2 = 80cm^3$

2. The table below shows the relationship between pressure and volume.

V (cm^3)	120	110	100	90	80
P (Kpa)	11	16	19	23	28

(a) Calculate the value of $\frac{1}{V}$ for each pair of the readings

(b) Plot the graph of :

(I) P against V

(II) P against $\frac{1}{V}$

(c) Estimate the volume when pressure is 109Kpa

(d) Estimate the pressure when volume is 20cm^3.

Exercise

1. A gas occupies a volume of 10cm^3 at 100Kpa. If the pressure is increased to 200Kpa, what is the new volume if the temperature remains the same at 27^{o}C?
2. In an experiment to verify Boyle's law, a gas syringe containing some air was connected to a bourdon pressure gauge. The pressure, P, was measured for different volumes, V. the results are tabulated below

V (cm^3)	10	12	14	16	18
P (Kpa)	198	167	142	125	112

(a) Plot a graph of volume against pressure

(b) State the relationship between pressure and volume of a gas at a constant temperature.

(c) Using your graph, find the pressure when the volume is 15cm^3.

(d) Find the volume of air at a pressure of 102Kpa.

Thermal properties

Internal energy

Definition: Internal energy is the total energy due to the random motion of molecules in a sample of a substance

Note

- When a substance is heated, its internal energy increases
- An increase in internal energy cause temperature rise

Heat capacity

Symbol: C

SI unit: Joule per kelvin, J / K

Definition: Heat capacity is the quantity of thermal energy required to raise the temperature of a body through 1^{o}C or 1K

Formula: C = $\frac{\Theta}{\Delta T}$

Specific heat capacity

Symbol: c

SI unit: Joule per kilogram kelvin, J / KgK

Definition: Specific heat capacity is the quantity of thermal energy required to raise a 1kg substance through 1^{o}C or 1K. Specific heat capacity can also be defined as the heat capacity per unit mass

Formula: c = $\frac{\Theta}{m\Delta T}$

Substance	**Specific heat capacity ($JKg^{-1}K^{-1}$)**
Water	4200
Ice	2100
Alcohol	2500
Glycerine	2400
Brine	3900
Paraffin	2200
Glass	670
Aluminium	880
Copper	390
Lead	130
Silver	230
Mercury	140
Iron	460
Air	720

Relationship between heat capacity and specific heat capacity

c = $\frac{C}{m}$

Examples

1. Calculate the quantity of energy required to raise the temperature of 500g of water from 20^oC to 30^oC.

Solution

$Q = mc\Delta T$

$Q = 0.5Kg \text{ x } 4200JKg^oC^{-1} \text{ x } 10^oC$

$Q = 21000J$

2. Determine the heat capacity of a 2Kg aluminium block

Solution

$c = \frac{C}{m}$

$C = mc$

$C = 2Kg \text{ x } 880JKg^{-1}K^{-1}$

$C = 1760JK^{-1}$

3. To 5Kg of water at 22^oC was added 500g of water at 77^oC, calculate the final temperature of water.

Solution

Heat lost = Heat gained

$C \text{ x } 0.5Kg \text{ x } (77^oC – T_f) = C \text{ x } 5Kg \text{ x } (T_f – 22^oC)$

$38.5Kg^oC – 0.5TKg = 5TKg – 110Kg^oC$

$38.5Kg^oC + 110Kg^oC = 5TKg + 0.5TKg$

$148.5Kg^oC = 5.5TKg$

$T = \frac{148.5Kg^oC}{5.5Kg}$

$T = 27^oC$

4. Calculate the heat energy required to raise the temperature of 5Kg of water from 20K to 100K.

Solution

$Q = mc\Delta T$

$Q = 5Kg \text{ x } 4200JK^{-1}Kg^{-1} \text{ x } (100 – 20)K$

$Q = 1.68 \text{ x } 10^6 J$

5. In an experiment,920000J of energy is transferred to 2kg of iron ($c = 460JKg^{-1}K^{-1}$). The initial temperature of iron is 25K. What is the final temperature of iron?

Solution

$Q = mc\Delta T$

$\Delta T = \frac{Q}{cm}$

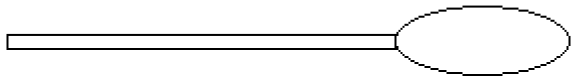
$\Delta T = \frac{920000J}{460J(KKg)^{-1} \text{ x } 2Kg}$

$(T – 25K) = 1000K$

$T = 1000K + 25K$

$T = 1025K$

6. The figure below shows a silver spoon



The mass of the spoon is 75.0g.
The spoon is heated using an electric circuit

(a) Determine the quantity of thermal energy needed to raise the temperature of the spoon from 15°C to 105°C
(b) It took 40s for the temperature of the spoon to rise from 15°C to 105°C. neglecting the heat loss to the surrounding, determine the power of the electric heating system

Solution

(a) Q = mcΔT
Q = 0.075Kg x 230J/(Kg°C) x (106 – 15)°C
Q = 1552.5J

(b) $P = \frac{Q}{t}$

$P = \frac{1552.5J}{40s}$

P = 38.8125W

Latent heat

Definition: Latent heat is thermal energy that is transferred to cause phase change of a pure substance without temperature change

Specific latent heat

Symbol: L
SI unit: Joule per Kilogram, J/Kg
Definition: Specific latent heat is the quantity of thermal energy that is transferred to cause phase change of 1Kg of a pure substance without temperature change

Formula: $L = \frac{Q}{m}$

Specific latent heat of fusion

Symbol: L_f
SI unit: Joule per Kilogram, J/Kg
Definition: Specific latent heat of fusion is thermal energy required to change 1Kg of a substance from solid to liquid state without a change in temperature

Values of specific latent heat of fusion

Substance	J/Kg	Melting point, °C
Ice	335000	0
Copper	212000	1083
Lead	26200	327
Naphthalene	148000	80

Specific latent heat of vaporization

Symbol: L_V
SI unit: Joule per Kilogram, J/Kg
Definition: Specific latent heat of vaporization is thermal energy required to change 1Kg of a substance from liquid to gaseous state without a change in temperature.
Values of specific latent heat of vaporization

Substance	J/Kg	Melting point, ºC
Water	2250000	100
Chloroform	240000	61
Alcohol	850000	78
Ether	350000	34

Example
1. Calculate thermal energy required to convert 5Kg of ice at 0ºC to steam at 100oC [specific heat capacity of ice = $2100JKg^{-1o}C^{-1}$, water = $4200JKg^{-1o}C^{-1}$,]
   [$L_V = 2.3 \times 10^6 J/Kg$, $L_f = 3.3 \times 10^5 J/Kg$]

Solution
$Q_1 = mL_f$
$Q_1 = 5Kg \times 3.3 \times 10^5 J/Kg$
$Q_1 = 1.65 \times 10^6 J$

$Q_2 = mc\Delta T$
$Q_2 = 5Kg \times 4200JKg^{-1o}C^{-} \times 100^oC$
$Q_2 = 2.1 \times 10^6 J$

$Q_3 = mL_V$
$Q_3 = 5Kg \times 2.3 \times 10^6 J/Kg$
$Q_3 = 1.2 \times 10^7 J$

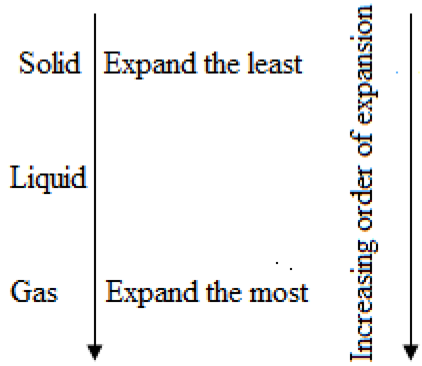
$Q = Q_1 + Q_2 + Q_3$
$Q = 1.65 \times 10^6 J + 2.1 \times 10^6 J + 1.2 \times 10^7 J$
$Q = 1.6 \times 10^7 J$

Exercise
1. Define specific latent heat of fusion
2. Calculate the quantity of heat:
(a) Which has to be supplied to melt 5g of ice at 0ºC
(b) Which has to be removed to turn 10g of water into ice at 0ºC
3. Determine the quantity of heat needed to convert 2Kg of ice at 0ºC to water at 50ºC.

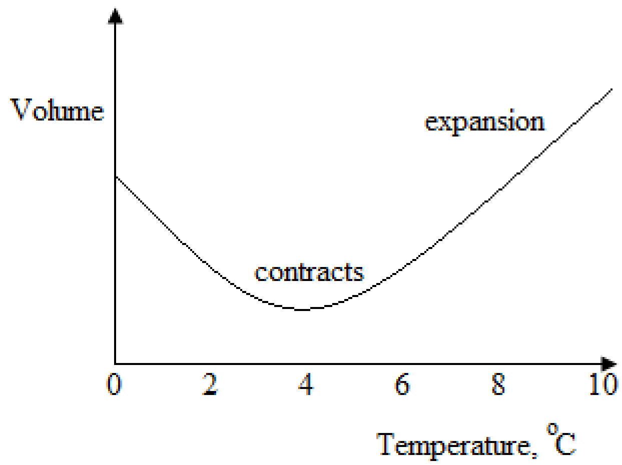
Thermal expansion

Definition: Thermal expansion is the increase in volume of a material resulting from the application of heat

Relative order of expansion in solids, liquids and gases



Anomalous expansion of water



When temperature of water is rising from a value lower than 4ºC, water contracts
When temperature rises from 4ºC to higher value, the water expands.
The anomalous behavior of water explains why its density is highest at 4ºC.

Absolute temperature

Definition: Absolute temperature is the temperature expressed in kelvins

Conversions

$$\mathrm{T_K} = (\mathrm{T_C^o} + 273)\mathrm{K}$$

$\mathrm{T_C^o} = (\mathrm{T_K} - 273)\mathrm{K}$

$\mathrm{T_K}$ = Temperature in kelvins

$\mathrm{T_C^o}$ = Temperature in degrees Celsius

Examples

1. Convert
   (a) 20^oC to K
   (b) 300K $to\ ^oC$
   (c) 0^oC to K

Exercise

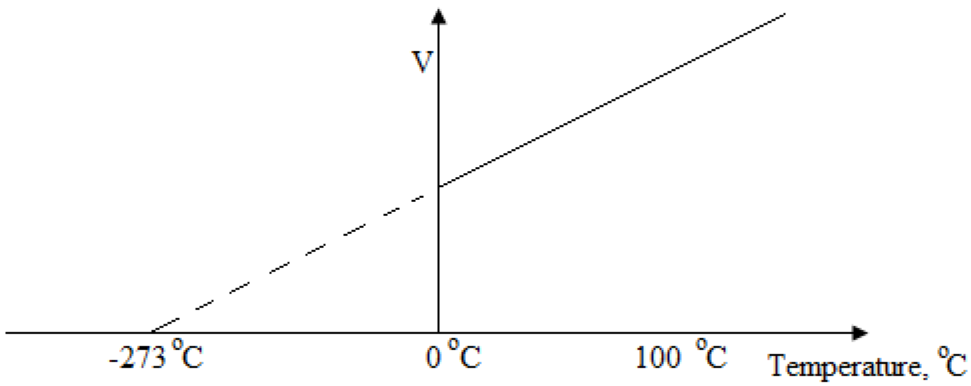
1. Convert
   (a) 30^oC to K
   (b) -50K to ^{o}C
   (c) 450K to ^{o}C

Charles law

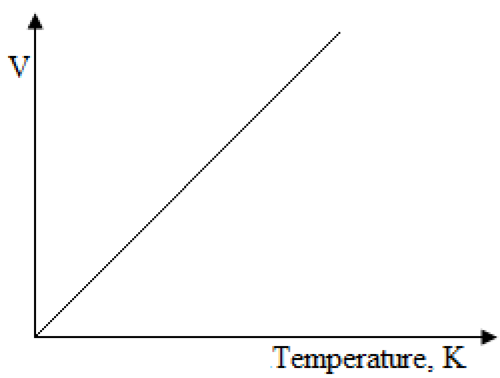
The law states that: The volume of a fixed mass of a gas at constant pressure is directly proportional to the absolute temperature

Formula: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Graph of volume against temperature,^{o} C



Graph of volume against temperature, K



Note

The temperature value of -273^oC or 0K is called absolute zero.

Examples

1. At 20^oC, a sample of gas occupies a volume of 250cm^3. Assuming pressure remains unchanged, determine the volume which the gas sample would occupy at 30^oC.

Data	Solution

V_2= ? $V_1 = 250cm^3$ $T_1 = 20^oC = 293K$ $T_2 = 30^oC = 303K$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $V_2 = \frac{V_1 T_2}{T_1}$ $V_2 = \frac{250cm^3 \text{ x } 303K}{293K}$ $V_2 = 258.5cm^3$

2. A gas at 27°C extends from a volume of 5cm³ to 7.5cm³ at constant pressure. Find its final temperature.

Data	Solution
T_2= ? $V_1 = 5cm^3$ $T_1 = 27^oC = 300K$ $V_2 = 7.5cm^3$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $T_2 = \frac{V_2 T_1}{V_1}$ $T_2 = \frac{7.5cm^3 \text{ x } 300K}{5cm^3}$ $T_2 = 450K$

Exercise

1. At what temperature will a mass of gas occupying 200cm³ at 0°C have a volume of 300cm³ if pressure remains constant?

Combination of Boyle's law and Charles law – General gas law

Formula: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Examples

1. 15cm³ of a gas at pressure 70N/m² and temperature of 27°C. Find the volume at a temperature of 127°C and pressure of 35N/m².

Data	Solution
V_2=? $V_1 = 15cm^3$ $P_1 = 70N/m^2$ $P_2 = 35N/m^2$ $T_1 = 27^oC = 300K$ $T_2 = 127^oC = 400K$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $V_2 = \frac{P_1V_1T_2}{T_1P_2}$ $V_2 = \frac{70N/m^2 \text{ x } 15m^2 \text{ x } 400K}{300K \text{ x } 35N/m^2}$ $V_2 = 40m^3$

Exercise

1. A mass of gas occupies a volume of 200cm³ at a temperature of 27°C and a pressure of 1atm. Calculate the new volume when the pressure is 2atm and the temperature is 37°C.
2. A gas at 7°C and 100Kpa occupies 20L. The gas is heated to 27°C at a pressure of 120Kpa. Find the new volume.

Summary

Constant	Law applied
Temperature	Boyle's law
Pressure	Charles law
None	General gas law

Temperature

Definition: Temperature is the measure of how hot or cold an object is as compared to a particular scale.

Measuring instrument: Thermometer

Principles of thermometry

Temperature is measured using some physical properties which vary with temperature

Physical properties which vary with temperature

- Length of liquid column
- Electromotive force (e.m.f)

Physical property	Thermometer
Length of liquid column	Liquid in glass thermometer
Electromotive force (e.m.f)	Thermocouple thermometer

Thermometric liquid

- Mercury
- Alcohol

Reasons why mercury is suitable for use in thermometers

1. It is easy to see through the glass
2. It does not wet the glass
3. It expands uniformly
4. It is a liquid over a wide range of temperature
5. It conducts heat rapidly and therefore more sensitive to temperature variations

Advantages of mercury over alcohol

1. It is coloured (so it is easily seen through the glass)
2. It is a good thermal conductor (so it expands evenly)
3. It is highly cohesive (so it does not wet the glass)
4. It has a high boiling point and a low freezing point (so it is used over a wide temperature range)

Advantages of alcohol over mercury

1. It is cheaper
2. It is safe
3. It expands more than mercury
4. It has a low freezing point

Thermometer

The thermometer is an instrument used to measure temperature.

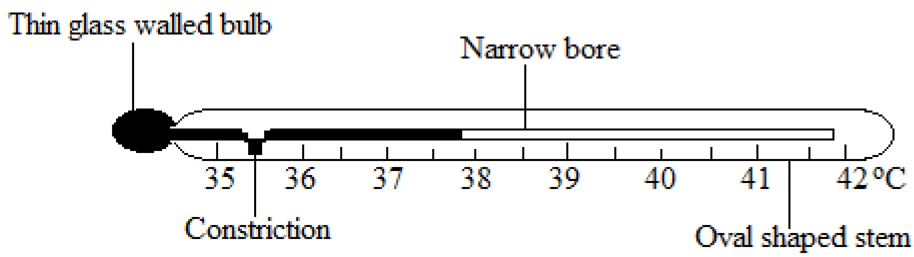
Types of thermometers

- Clinical thermometer
- Laboratory thermometer
- Thermocouple thermometer

Clinical thermometer

The clinical thermometer is used to measure the temperature of the human body.

Structure of the clinical thermometer



Features of the clinical thermometer

1. **Constriction**

The constriction is a sharp bend in bore at the bottom of the scale
The constriction helps to prevent the mercury thread from flowing back before the reading is taken.

2. **Short range**

It has a short range of temperature calibration because it measures body temperature which fluctuates within a narrow range. The range is from 35°C to 42°C
The short range also gives accuracy

3. **Narrow bore**

The narrow bore makes the thermometer have a greater precision and sensitivity

4. **Thin glass walled bulb**

The thin walled bulb makes the thermometer sensitive to temperature changes and for quick responsiveness

5. **Oval shaped glass stem**

Convenience for replacement in the armpit

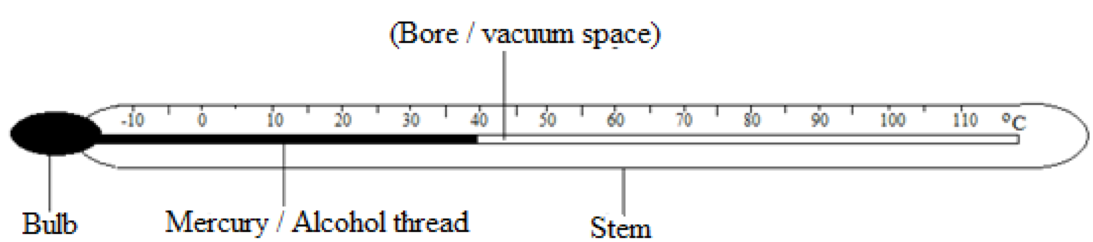
Exercise

1. The figure below shows a diagram of a clinical thermometer some features labeled.
   Explain why it has each of the following features

(a) A thin glass walled bulb
(b) A constriction
(c) A short range of temperature calibration
(d) A narrow bore
(e) An oval shaped stem

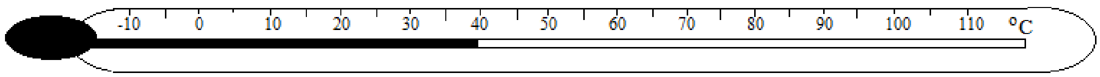
Laboratory thermometer

Structure of the laboratory thermometer



Example

1. The student uses the mercury-in-glass thermometer shown in the diagram below. He does not detect any temperature rise in the water in the beaker.



(a) Describe how you would check the 0 °C and 100 °C points on the thermometer.
(b) Explain why the thermometer is not sensitive enough to detect the temperature rise.
(c) State and explain one change that will make a mercury-in-glass thermometer more Sensitive.

Solution

(a) Pure melting ice for 0° C
Pureboiling water/steam above boiling water (at 1 atmosphere)for 100° C
(b) Each division on thermometer is too small described in some way e.g. does not expand far up tube (not bore too thin, notenough mercury)
(c) Change : Use more mercury or use smaller bore
Reason: More expansion or further distance uptube (for same expansion)

Graduating a thermometer – temperature scale

When a mercury – in – glass thermometer is produced, the temperature scale must be marked on the stem. Then, two known temperatures are needed for marking the scale. These temperatures are called fixed points

Fixed point

Definition: Fixed point is a reference temperature chosen because it is readily reproducible

Fixed points are important for calibration of thermometers

Ice point

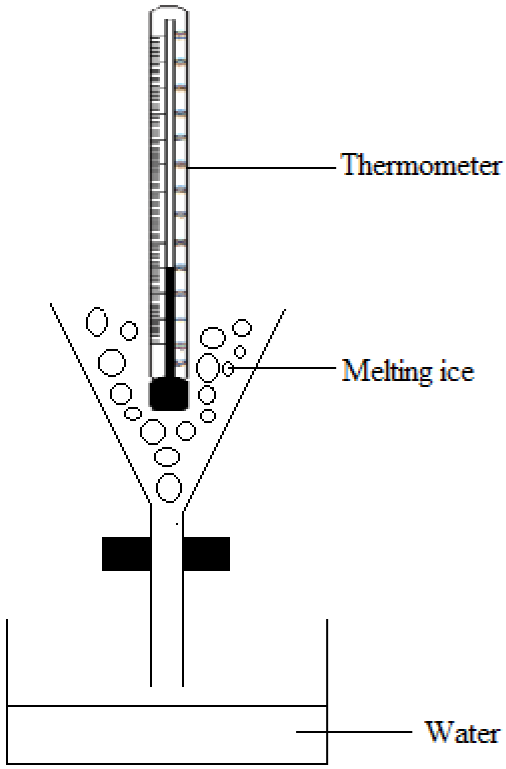
Alternative term: Lower fixed point

Value: 0°C

Definition: Ice point is the temperature of melting pure ice.

Determining ice point

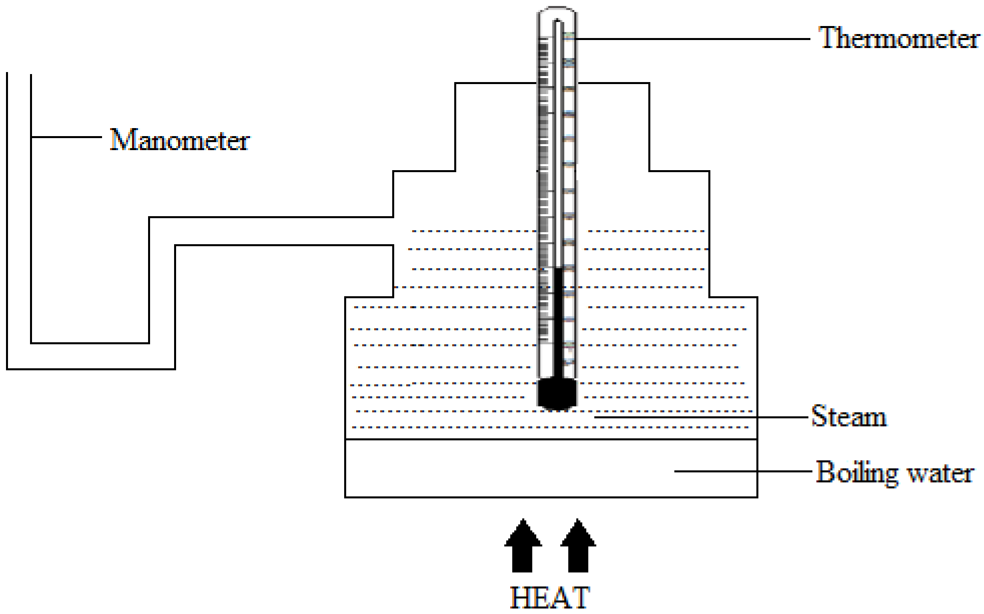
Place the bulb in the melting ice



Measure the length of the mercury thread when it has stabilized. Mark it. It is the ice point.

Steam point
Alternative term: Upper fixed point
Value: $100^{o}C$
Definition: Steam point is the temperature of steam from boiling water at a pressure of 1 atmosphere.

Determining steam point
Place the bulb in the steam from boiling water



Measure the length of the mercury thread when it has stabilized. Mark it. It is the steam point.

Measurement of temperature using uncalibrated thermometer

Formula: $\Theta = \left(\frac{L_{\Theta} - L_0}{L_{100} - L_0}\right) \text{x } 100\%$

Note

L_{Θ} = length of mercury at Θ

L_{100} = length mercury at 100^{o}C

L_0 = length of mercury at 0^{o}C

Example

1. At 0^{o}C, the length of mercury thread in a thermometer is 2cm. at 100^{o}C, the length of mercury is 22cm. At a temperature, Θ, the length of mercury thread is 18cm. Determine the temperature, Θ.

Solution

$$\Theta = \left(\frac{L_{\Theta} - L_0}{L_{100} - L_0}\right) \text{x} 100^{o}\text{C}$$

$$\Theta = \left(\frac{18\text{cm} - 2\text{cm}}{22\text{cm} - 2\text{cm}}\right) \text{x} 100^{o}\text{C}$$

$$\Theta = \left(\frac{16\text{cm}}{20\text{cm}}\right) \text{x} 100^{o}\text{C}$$

$$\Theta = 80^{o}\text{C}$$

2. The table below shows information about a mercury – in – glass thermometer

Length of mercury thread / cm	Temperature / ^{o}C
1	−10
25	110

At a temperature, ϴ, the length of the mercury thread is 13cm. determine the temperature, ϴ.

Solution

$$\Theta = \left(\frac{L_{\theta} - L_{-10}}{L_{110} - L_{-10}}\right) x120^{o}C$$

$$\Theta = \left(\frac{13cm - 1cm}{25cm - 1cm}\right) x120^{o}C$$

$$\Theta = \left(\frac{12cm}{24cm}\right) x120^{o}C$$

$$\Theta = 60^{o}C$$

Thermocouple thermometer

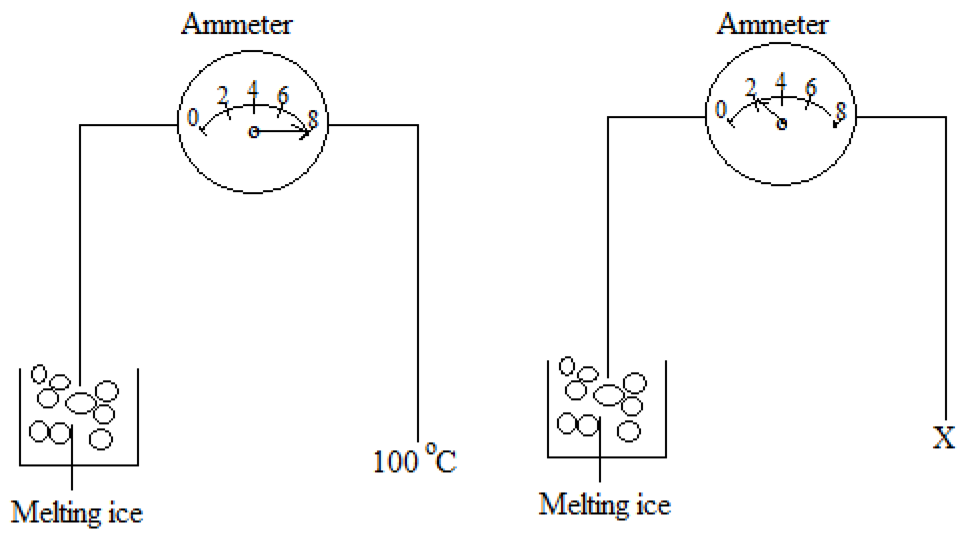
A thermocouple is made from wires of two different materials e.g. copper and iron. The wires are soldered or just twisted tightly together at the ends. When two junctions are placed in different temperatures, anelectric current flows around the circuit. The amount of current depends on the differences in temperatures. If one of the junctions is placed into the known temperature, e.g. melting ice ($0^{o}C$), and the other junction is placed into the measured object, e.g. fire, it is possible to measure the temperature by reading the current. The thermocouple is very sensitive and it can measure high temperatures because of melting points of metals.

Advantages of the thermocouple thermometer

1. It can measure temperature at a point
2. It can measure very high temperatures
3. It can measure rapidly changing temperatures

Examples

1. Refer to the diagram below

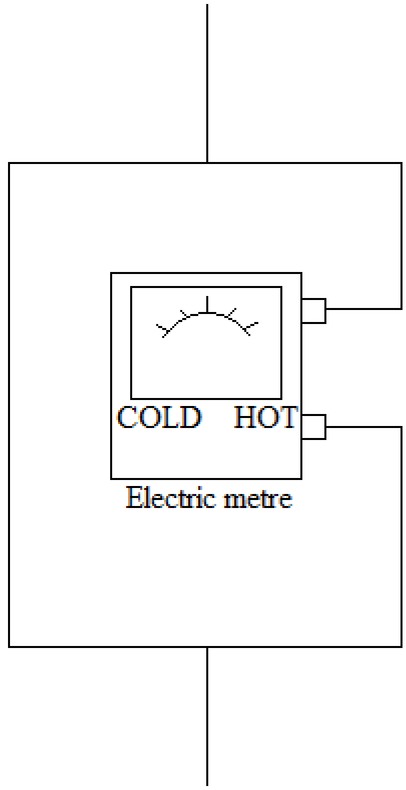


Determine temperature x

Solution

$$x = \frac{2A}{8A} \times 100^oC$$

$$x = 25^oC$$



HEAT TRANSFER
Heat travels from a place with a high temperature to the place with a low temperature. Heat transfer is through the three methods namely conduction, convection and radiation.

Conduction
This is the transfer of heat through solids. It is characterized by vibrations of particles which are bonded to each other. When heat is supplied to one part of a solid, the particles vibrate faster. This vibration is passed on to the neighbouring particles through the bonds there by spreading the heat throughout the object.

Demonstration of heat transfer in solids

Good and bad conductors of heat

Conductors are classified as good or bad depending on how fast they transfer heat from a region of high temperature to a region of lower temperature.

Good conductors are used where heat is required while the bad conductors are used as insulators where heat is not needed. Metals are good conductors used to manufacture cooking utensils such as pots, pans; used in the manufacture of electrical cables while on the other hand wood and plastics are examples of bad conductors used in making pot handles, insulation of electrical cables among many other uses.

Waves

Definition: A wave is a disturbance in a medium which transmits energy

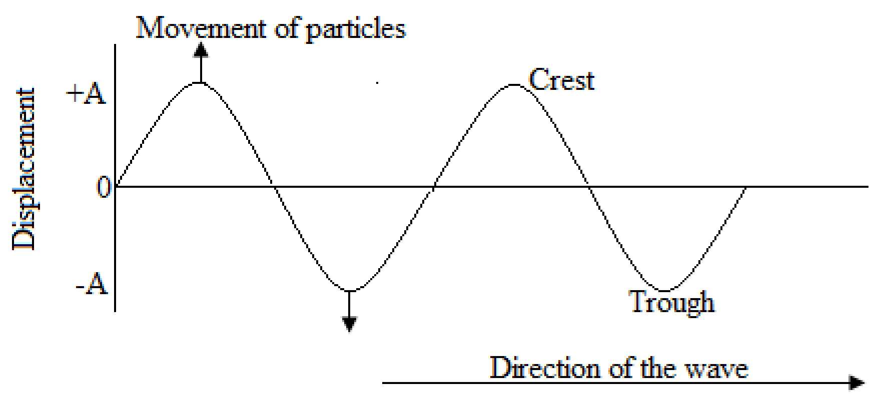
A wave front is a line joining points on a wave which are in phase

Types of waves

- Transverse waves
- Longitudinal waves

Transverse wave

Transverse wave is a wave in which the movement of particles is perpendicular to the direction of travel of the wave



Examples of transverse waves

- Water waves
- Light
- A wave on a rope

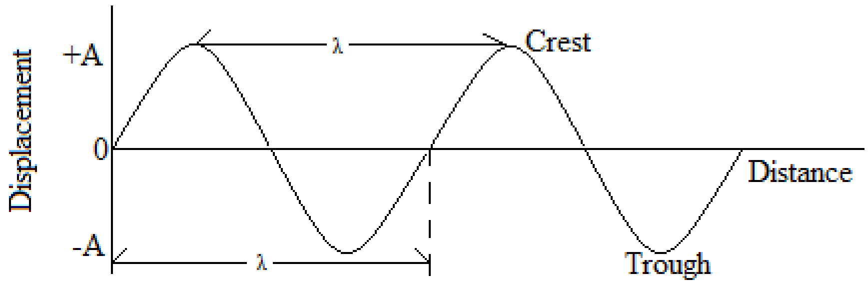
Longitudinal wave

Longitudinal wave is a wave in which the movement of the particles is parallel to the direction of travel of the wave

Examples of longitudinal waves

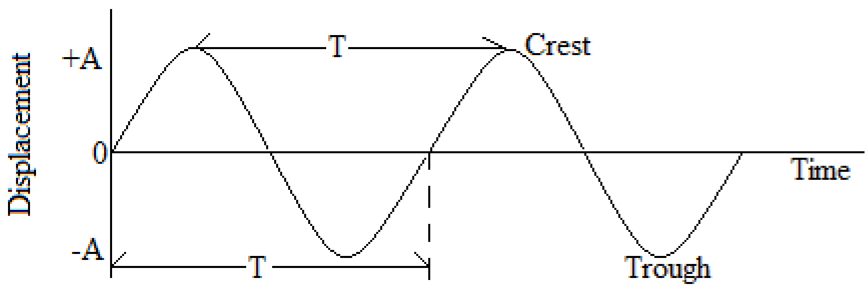
- Sound waves
- Waves on the spring
- Seismic wave

Graphs of waves
Graph of displacement against distance



Amplitude
Symbol: A
SI unit: Meter, m
Definition: Amplitude is the maximum displacement of a wave from its rest position(height of crest or depth of trough)

Wave length
Symbol: λ
SI unit: Meter, m
Definition: Wave length is distance between two successive similar points on a wave
Graph of displacement against time



Period
Symbol: T
SI unit: Second, s
Definition: Period is the time taken for one complete wave to be generated
Formula: $T = \frac{1}{f}$

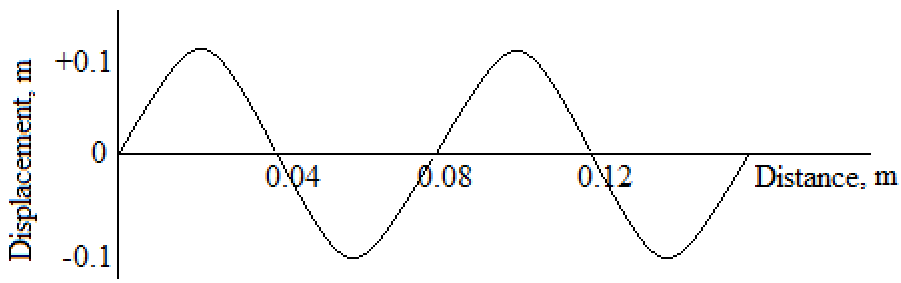
Frequency
Symbol: f
SI unit: Hertz, Hz
Definition: Frequency is the number of waves generated per second

Formula: f = $\frac{1}{T}$
f = $\frac{\text{Number of waves}}{\text{Time}}$

Speed
Symbol: V
SI unit: Meter per second, m/s
Definition: Speed of a wave is the distance travelled by the wave in one second
Formula: V = λ x f

Example

1. Refer to the graph below



(a) What is the amplitude of the wave?
(b) What is the wavelength of the wave?
(c) Given that the speed of the wave is 4m/s, calculate its frequency

Solution

(a) A = 0.1m
(b) λ = 0.08m
(c) f = $\frac{V}{\lambda}$
f = $\frac{4m/s}{0.08m}$
f = 50Hz

2. If 100 waves were produced in 5 seconds, what is the frequency?
f = $\frac{\text{Number of waves}}{\text{Time}}$
f = $\frac{100}{5}$
f = 20Hz

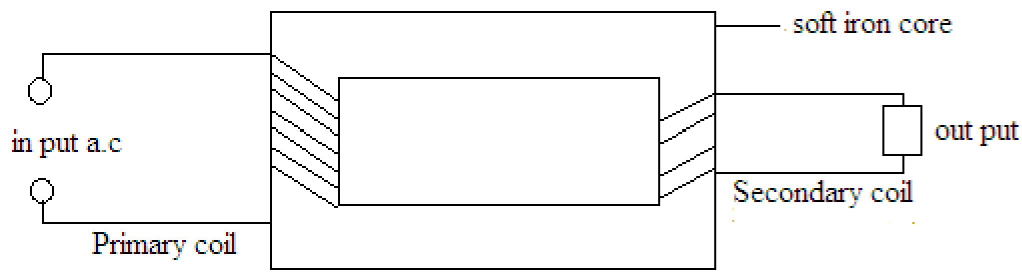
Transformers

Definition: A transformer is a device which is used to change the voltage of an appliance (load) by mutual induction

Structure of a transformer

A transformer consists of two coils (primary coil and secondary coil) wound on a soft iron core.

The coil that is connected to the alternating current input is called primary coil and the coil that provides the alternating current output is called the secondary coil.



Types of transformers

There are two types of transformers

1. **Step - up transformer**

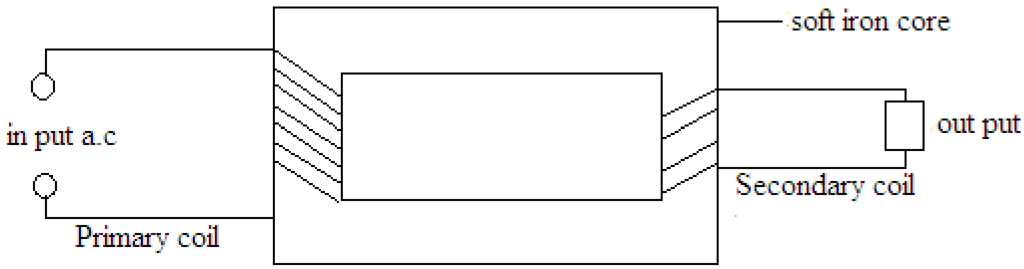
This is a transformer which increases the voltage of an appliance

The voltage in the primary coil (input) is lower than the voltage in the secondary coil (output)

The number of turns in the primary coil is less than the number of turns in the secondary Coil

2. **<u>Step - down transformer</u>**

This is a transformer which reduces the voltage of an appliance
The voltage in the primary coil (input) is higher than the voltage in the secondary coil (output)
The number of turns in the primary coil is greater than the number of turns in the secondary coil

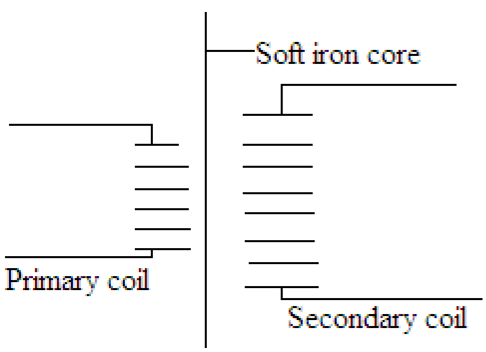


<u>Principle of operation of a basic iron - cored transformer</u>

A transformer functions by mutual induction. That is;
An alternating voltage applied to the primary coil causes an alternating current to flow in the coil. The alternating current induces a changing magnetic field.
The changing magnetic field induces an alternating voltage in the secondary coil. This causes flow of alternating current in the secondary coil

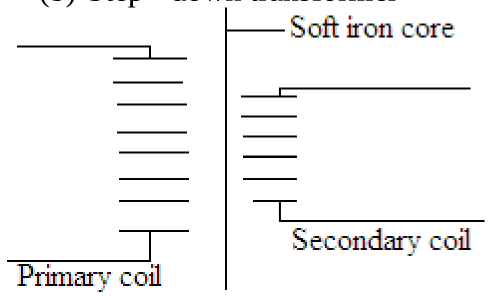
Circuit symbols

(a) Step - up transformer



$N_p < N_s$
$V_p < V_s$
$I_p > I_s$

(b) Step - down transformer



$N_p > N_s$
$V_p > V_s$
$I_p < I_s$

Note

- N_p = Number of turns in primary coil
- N_s = Number of turns in secondary coil
- V_p = Voltage of primary coil
- V_s = Voltage of secondary coil
- I_p = Current in primary coil
- I_s = Current in secondary coil
- A transformer will not operate using a direct current input because direct current produces a steady magnetic field which cannot induce a voltage in the secondary coil.
- Transformers are used to transmit electricity because they can easily convert the type of voltage needed. For domestic purposes, a step down transformer can be used to drop a very high voltage to a suitable voltage in our homes. A step up transformer can be used to amplify the voltage so that industrial areas can utilize such high voltages

Factors that cause energy loses in a transformer and how this can be minimized

If a transformer has efficiency 100%, it is called ideal transformer.
However, no transformer is ideal. This means that a transformer cannot be 100% perfect. It has energy loses. The following are factors that can cause energy loses in a transformer and how they can be minimized

1. **The resistance of the coils**. As the coils have resistance, they give off heat when current flows through. Coil resistance and energy loses can be minimized by making the coils from thick copper because thick copper does not heat up easily.
2. **Magnetization and demagnetization of the core**. Work has to be done to alter sizes and direction of domains and heat is released in the process. These energy loses are reduced by making the core from soft iron because soft iron is easy to magnetize and easy to demagnetize
3. **Eddy currents in the core**. Eddy currents are small currents produced within the iron. These occur because the core itself is a conductor in a changing magnetic field. The energy loses are reduced by laminating the iron core.

Advantage of transmitting electrical energy using high voltage

This can reduce energy loses due to long distances since the energy is transmitted from long distances, the wires offer resistance. Some energy will be lost in the cables due to heating effect.

Advantage of transmitting electrical energy using alternating current

Alternating current can be transformed to higher voltage; which is efficient to transmit

Transformer equations

1. $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

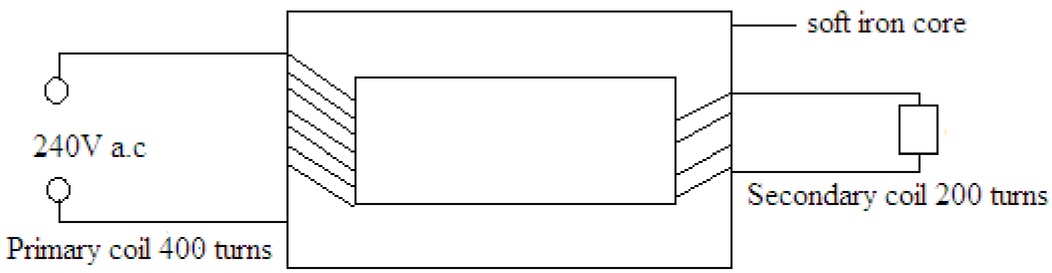
2. $I_p V_p = I_s V_s$

Note

N_p = Number of turns in primary coil
N_s = Number of turns in secondary coil
V_p = Voltage of primary coil
V_s = Voltage of secondary coil
I_p = Current in the primary coil
I_s = Current in secondary coil

Transformercalculations
Examples

1. The figure below represents a transformer with a primary coil of 400 turns and a secondary coil of 200 turns



(a) If the primary coil is connected to a 240V a.c mains supply, calculate the secondary voltage
(b) Distinguish between the step-down and step-up transformers
(c) Explain carefully how a transformer works
(d) Why is the core made of iron?

Solution

(a) $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

$V_s = \frac{V_p \text{ x } N_s}{N_p}$

$V_s = \frac{240V \text{ x } 200}{400}$

$V_s = 120V$

(b) A step down transformer reduces the voltage of an appliance while a step up transformer increases the voltage of an appliance
In the step down transformer, the voltage in the primary coil is higher than the voltage in the secondary coil while in the step up transformer the voltage in the primary coil is lower than the voltage in the secondary coil
In the step down transformer, the number of turns in the primary coil is greater than the number of turns in the secondary coil while in the step up transformer; the number of turns in the primary coil is less than the number of turns in the secondary coil.
(c) An alternating voltage applied to the primary coil causes an alternating current to flow in the coil. The alternating current induces a changing magnetic field.
The changing magnetic field induces an alternating voltage in the secondary coil. This causes flow of alternating current in the secondary coil
(d) Because soft iron can magnetize and demagnetize easily.

2. The primary coil of a transformer is connected to a 240V a.c mains and a current of 5A passes through. If the voltage at the secondary coil is 12V, calculate the secondary current.

Data	**Solution**
I_s =? I_p = 5A V_s = 20V V_p = 240V	$I_sV_s = I_pV_p$ $I_s = \frac{I_p \text{ x } V_p}{V_s}$ $I_s = \frac{5A \text{ x } 240V}{12V}$ I_s = 100A

Exercise

1. The primary coil of a transformer has 800 turns; its secondary coil has 2400 turns. Voltage in the primary coil is 50V;
   (a) Calculate voltage in the secondary coil;
   (b) Given that the current in the secondary coil is 12A, determine the current in the primary coil.
2. A step down transformer is required to transform 240V a.c to 12V a.c for a model railway. If the primary coil has 1000 turns. How many turns should the secondary coil have?