CONTENTS

1. GENERAL PHYSICS

1.1. Quantity and Unit

Physical quantities

There are many physical quantities in Physics. These Physical quantities can be divided into two types as shown below;

Type of quantities	Base quantity	Derived quantity
Example	Mass Length Time Current Temperature	Speed Volume Area Force
Explanation	They have only one SI unit.	They can be expressed by combining suitable base quantities.

SI unit

The value of a physical quantity is written as a number by a suitable unit. The International System of Units is adopted in Physics. The following table shows some of SI units.

Physical quantity	SI unit	Symbol for unit	Example
Length	metre	m	100m
Mass	kilogram	kg	60kg
Time	second	s	30s
Current	Ampere	A	15A
Temperature	Kelvin	K	150K

(Basically, units of quantities are shown as SI units or derived SI units in this textbook.)

Prefixes

Sometime a physical quantity is too big or too small to be conveniently expressed in SI units. Then some symbols are used as the prefixes instead of Zeros or many places. Prefixes are multiples or decimals of ten. The following table shows some prefixes

Prefixes	Symbol	Exponent	Meaning	Example
Mega	M	10^6	1,000,000	3Mm = 3,000,000m
kilo	K	10^3	1,000	5km = 5,000m
centi	C	10^{-2}	1/100 (=0.01)	2cm = 0.02m
Milli	M	10^{-3}	1/1000 (=0.001)	6mm = 0.006m
Micro	M	10^{-6}	1/1000000 (=0.000001)	7μm = 0.000007m

Scalar and Vector

Definition A **scalar** is a quantity having magnitude only.

(e.g. mass, length, area, volume, density, time, distance, speed, energy, temperature, current, voltage...)

Definition A **vector** is a quantity having both magnitude and direction.

(e.g. weight, displacement, velocity, acceleration, force, moment...)

1.2. Length and Time

Length

Definition **Length** is defined as the measurement of something from one end to the other.

SI unit is metre. The symbol of unit is m.

Instruments for measuring length

Instrument	Uses for length	Accuracy	Example of measured objects
Measuring tape	Long length	1mm	Length of classroom, Height of building
Ruler	Medium length	1mm	Width of paper, Length of pen
Vernier calipers	Short length	0.1mm	Diameter of pen, Internal diameter of tube
Micrometer screw gauge	Very short length	0.01mm	Diameter of hair, Thickness of razor blade

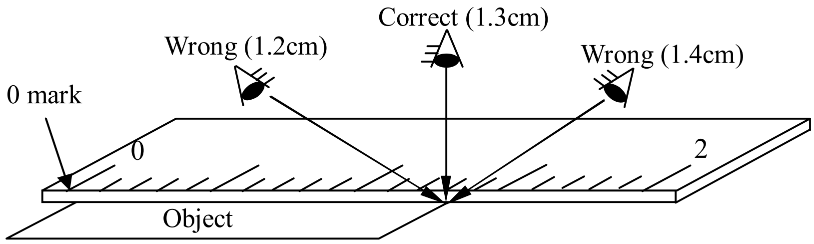
Ruler and Measuring tape

How to use the ruler or the measuring tape

(1) Put the 0 mark on the end of the object.

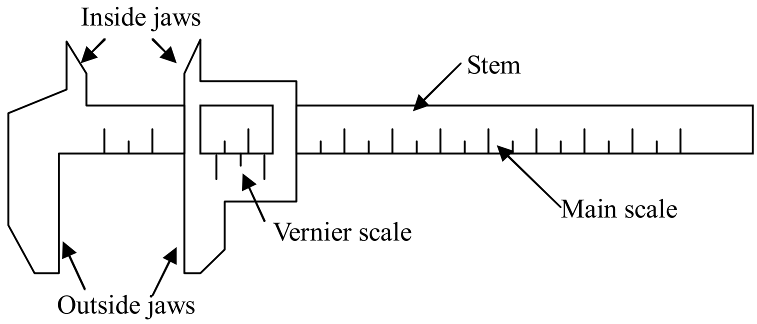
(2) Read the mark at the other end of the object.

Caution to use;
The eye must be placed vertically above the mark on the scale.



Vernier calipers

A pair of vernier calipers is shown in the diagram. The outside jaws are usually used to measure lengths of something such as external diameter. And inside jaws are used to measure internal diameter of a tube or cylinder.



How to use the vernier calipers

(1) Put an object to be measured between jaws.

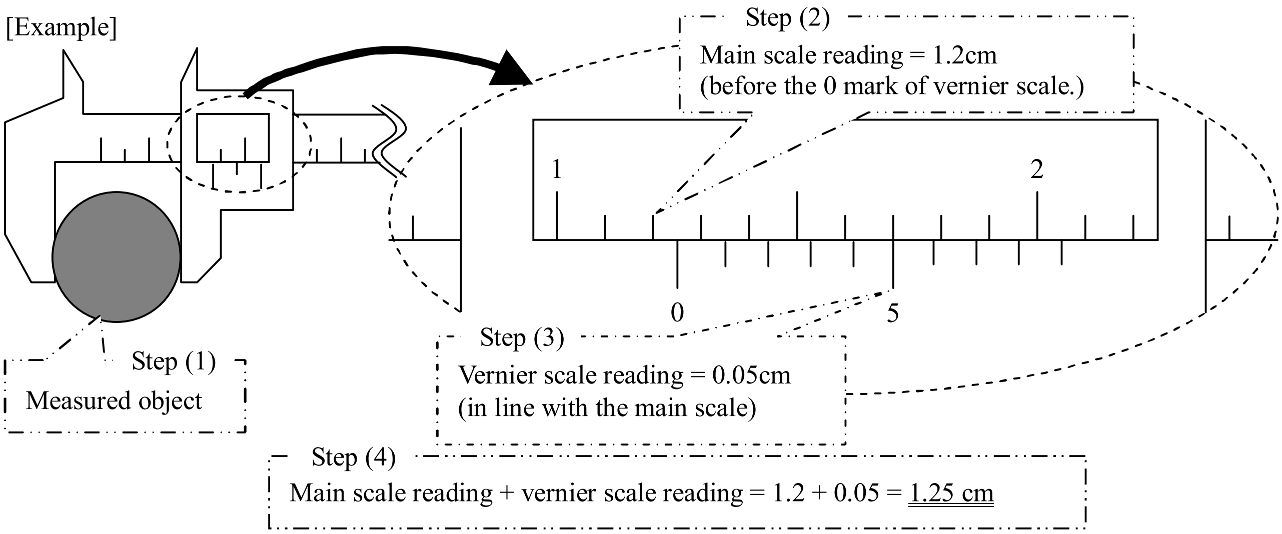
(2) Read the main scale before the 0 mark of vernier scale.

(3) Look at the vernier scale and find a marking on the vernier scale that is in line with the main scale.

(Commonly, the reading on the vernier scale is for the 2nd place of decimal in centimetre.)

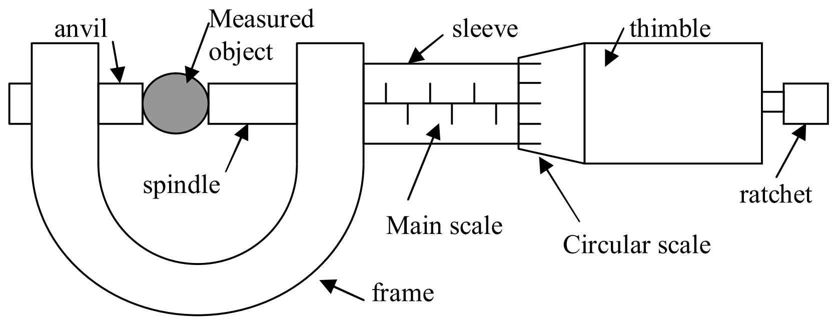
(4) Add the main scale reading and the vernier scale reading.

[Example]



Micrometer screw gauge

A micrometer screw gauge is shown as the diagram.



How to use the micrometer screw gauge

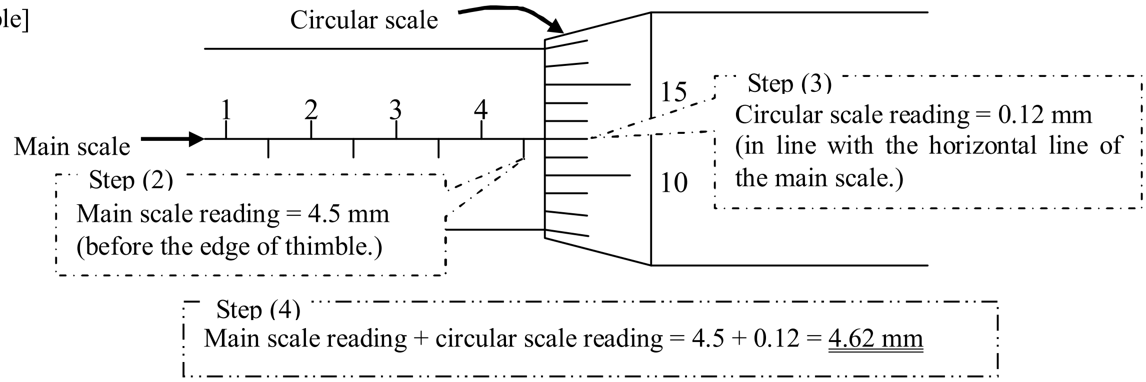
(1) Thimble is turned until the object is gripped between the anvil and the spindle very gently.

(2) Read the main scale on the sleeve before the edge of thimble.

(3) Look at the circular scale on the thimble. Find a marking on the circular scale that is in line with the horizontal line of the main scale. (Commonly, each division of circular scale represents a length of 0.01mm)

(4) Add the main scale reading and the circular scale reading.

[Example]



Time

SI unit: second (The symbol is s)
Other units: minute, hour, day, month, year, century

Conversion of the unit

1year =	365days =	8760hours =	525600minutes =	31536000s
	1 day =	24hours =	1440minutes =	86400s
		1hour =	60minutes =	3600s
			1minute =	60s

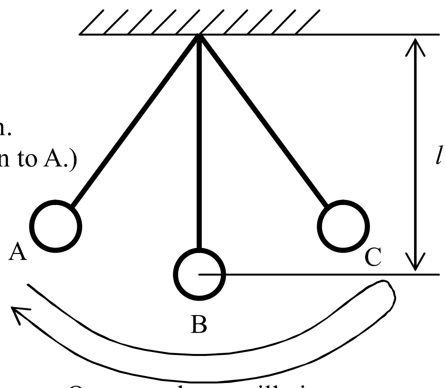
Instrument for measuring the time → Clock, Watch, Stopwatch, Pendulum

Simple pendulum

The diagram below shows a simple pendulum with length *l*.

The length *l* should be from the ceiling to the centre of the bob.

Definition **Period** (T) is defined as the time taken for one complete oscillation.
(time taken from A to C and back again to A.)



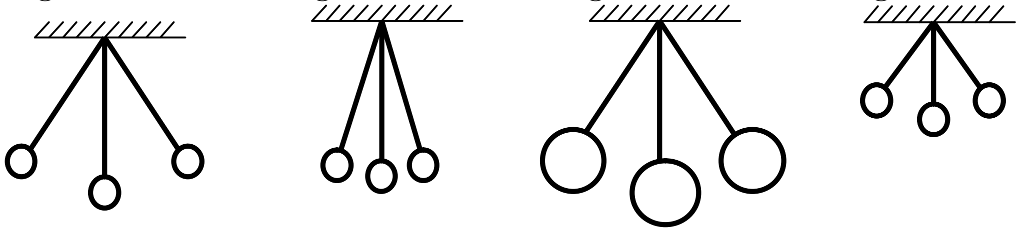
One complete oscillation

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

T: Period [s]
n: number of oscillation
t: time taken for n oscillation [s]

Experiment : What changes the period of pendulum?

①standard ②shorter arc ③heavier bob ④shorter string

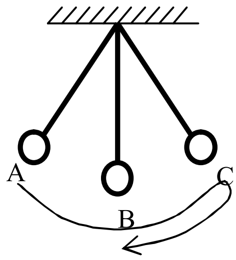


	n: number of oscillations	t: time taken [s]	T: period [s] (=t/n)
① standard			
② shorter arc			
③ heavier bob			
④ shorter string			

Conclusion: Period of pendulum depends on...

→ the length of the pendulum (l).

→ acceleration due to gravity (g).



[Example]

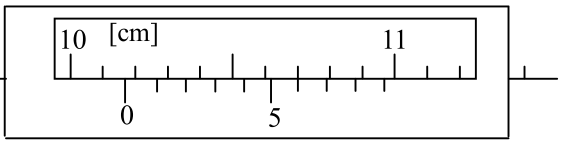
The diagram shows a pendulum oscillating between position A and C.
It takes 3s to go from A to C and back to B. What is its period?

DATA	Solution
t = 3s $\quad n = \frac{3}{4}$ (three quarter oscillations)	$T = \frac{t}{n} = t \div n = 3 \div \frac{3}{4} = 3 \times \frac{4}{3} = \underline{\underline{4s}}$

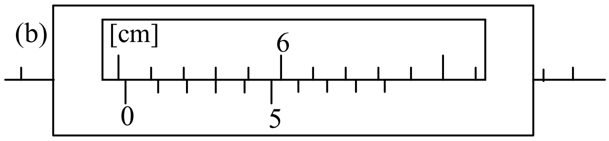
[EXERCISE]

(1) Vernier callipers are used to measure wooden cubes (a) and (b) as shown below. What is the width of the cubes?

(a)

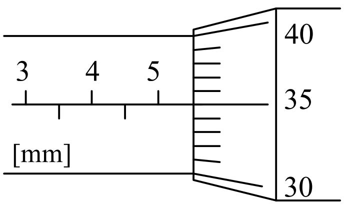


(b)

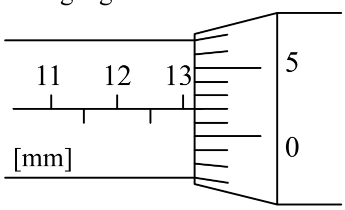


(2) Read the measurements of micrometer screw gauge below.

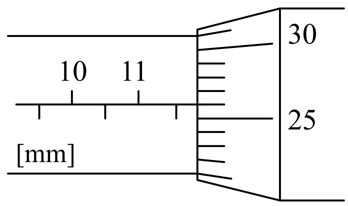
(a)



(b)

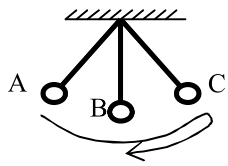


(c)



(3) Find the period of a pendulum if it oscillates 15 times completely for 45 seconds.

(4) The diagram shows a pendulum oscillating between positions A to C.
   (a) It takes 3s to go from A to C. What is its period?
   (b) How long does it take for 12 times complete oscillations?



1.3. Speed, Velocity and Acceleration

Distance and Displacement

Definition **Distance** is defined as the total length taken between two points.

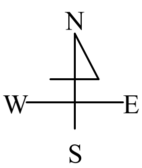
→ It is a scalar.

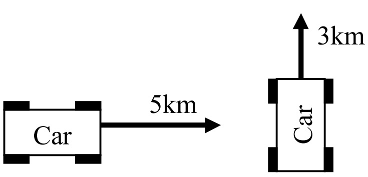
Definition **Displacement** is defined as the change of position of a point in a particular direction.

→ It is a vector.

SI units of both distance and displacement are metre [m].

[Example 1]





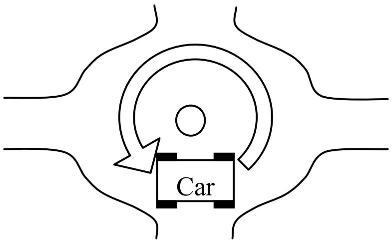
A car moves 5km to the East and 3km to the North.

What is the distance and the displacement of the car?

→ Distance of the car is 8km (= 5km +3km).

→ Displacement of the car is 5km East and 3km North.

[Example 2]



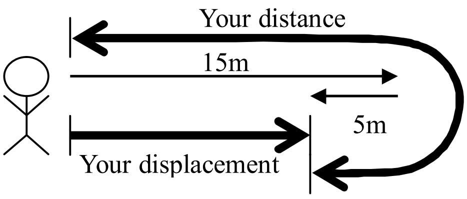
The circumference of a roundabout is 10m and the car turns it once.

What is the distance and the displacement of the car?

→ Distance of the car is 10m.

→ Displacement of the car is 0m because it came back to the starting position.

[Example 3]



You walk forward 15m and backward 5m.

What is your distance and your displacement?

→ Your distance is 20m (= 15m + 5m).

→ Your displacement is 10m (= 15m - 5m) forward.

Speed

Definition **Speed** is defined as the rate of change of distance traveled with time.

→ It is a scalar.

The unit of speed is metre per second [m/s].

Formula

$$\text{Speed} = \frac{\text{Distance traveled}}{\text{Time taken}} \ [\text{m/s}]$$

$$\text{Average Speed} = \frac{\text{Total distance traveled}}{\text{Total time taken}} \ [\text{m/s}]$$

Various speeds (m/s)

-man's walking: 1.5

-100m runner: 10

-Zoom bus: 30

-baseball thrown by a pitcher: 42

-sound in air (20℃): 340

-Light: 300000000

[Example]

A car travels a distance of 540km from Lusaka to Katete in 10 hours. Find the average speed in km/hr and m/s.

DATA	Solution
Total distance traveled = 540km = 540,000m Total time taken = 10Hrs = 36000s	Average speed in km/hr $= \frac{\text{Total distanve traveled}}{\text{Total time taken}} = \frac{540\text{km}}{10\text{hrs}} = \underline{\underline{54\text{km/hr}}}$ Average speed in m/s $= \frac{540000\text{m}}{36000\text{s}} = \underline{\underline{15\text{m/s}}}$

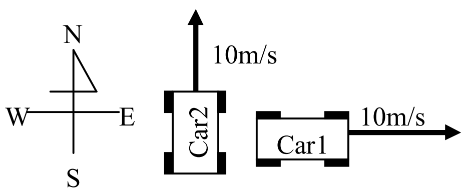
Velocity

Definition **Velocity** is defined as the rate of change of displacement with time.

→ It is a vector.

The unit of velocity is metre per second [m/s]. (It is the same unit as speed.)

[Example]



What are their speeds and their velocities?

→ They have the same speeds of 10m/s but they have different velocities.

→ Car1 has the velocity of 10m/s East.

→ Car2 has the velocity of 10m/s North.

Acceleration

Definition **Acceleration** is defined as the rate of change of velocity with time.

→ It is a vector.

The unit of acceleration is metre per second squared [m/s^2].

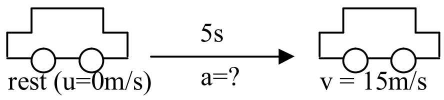
Formula

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

a: Acceleration [m/s^2]
v: final velocity [m/s]
u: initial velocity [m/s]
t: time taken [s]

[Example 1]

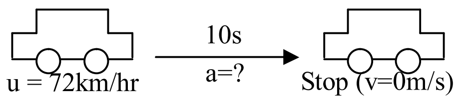
A car starting from rest increases its velocity uniformly to 15m/s in 5s. What is its acceleration?



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

[Example 2]

If a car slows down from 72km/hr and stops in 10s, calculate the acceleration.



DATA	Solution
u = 72km/hr = 20m/s v = 0m/s t = 10s a = ?	$a = \frac{v-u}{t} = \frac{0-20}{10} = -2\underline{\underline{m/s^2}}$

$$72km/hr = \frac{72km}{1hr} = \frac{72000m}{3600s} = \frac{20m}{1s} = 20m/s$$

When the velocity reduces, the acceleration becomes a negative number.
The acceleration is called the retardation or deceleration.

Uniformly accelerated liner motion

If a body moves with a uniform acceleration (the acceleration is constant), three important equations are given below.

Formula

$$v = u + at$$

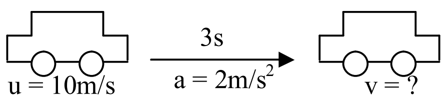
$$x = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2ax$$

a: Acceleration [m/s^2]
v: final velocity [m/s]
u: initial velocity [m/s]
t: time taken [s]
x: distance covered [m]

[Example 1]

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

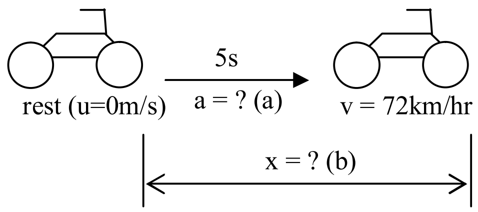


DATA		Solution
u = 10m/s t = 3s	a = $2m/s^2$ v = ?	$v = u + at = 10 + 2 \times 3$ $= \underline{16m/s}$

[Example 2]

A motorcycle starting from rest acquires a velocity of 72km/hr in 5s.

(a) What is its acceleration?
(b) How far does it travel during this time?



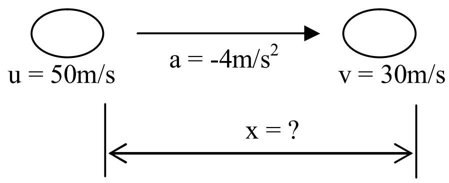
$\frac{7200m}{3600s}$

(a) <u>DATA</u> v = 72km/hr = 20m/s u = 0m/s t = 5s a = ?	<u>Solution</u> $a = \frac{v-u}{t} = \frac{20-0}{5} = \underline{\underline{4m/s^2}}$
(b) <u>DATA</u> u = 0m/s t = 5s $a = 4m/s^2$ x = ?	<u>Solution</u> $x = ut + \frac{1}{2}at^2 = 0\times5+\frac{1}{2}\times4\times5^2$ $= \underline{\underline{50m}}$

Don't use the formula: D=S×T.
Because there is acceleration.

[Example 3]

The velocity of an object is uniformly reduced from 50m/s to 30m/s. If the deceleration is $-4m/s^2$, how much is the distance of the body decelerating?



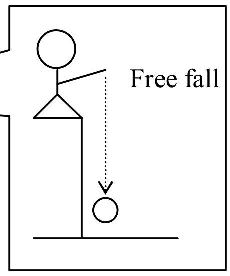
<u>DATA</u>	<u>Solution</u>
u = 50m/s v = 30m/s $a = -4m/s^2$ x = ?	$v^2 = u^2 + 2ax$ $x = \frac{v^2 - u^2}{2a} = \frac{30^2 - 50^2}{2\times(-4)} = \frac{-1600}{-8}$ $= \underline{\underline{200m}}$

<u>Acceleration due to gravity</u>

All objects accelerate uniformly towards the earth if air resistance is ignored. It is called acceleration due to gravity. It is represented by the symbol 'g'.

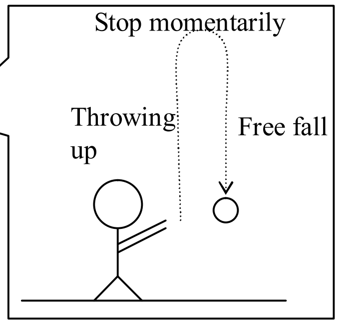
$$g = 9.8m/s^2 \approx 10m/s^2$$

If a stone is dropped from the top of a tall building, it accelerates uniformly downwards.
If you release a stone without applying force, it starts from rest. It is called free fall.



→ Free fall
u = 0m/s
$a = g = 10m/s^2$

If you throw up a stone, the stone decelerates to the top.
Then it stops momentarily at the top. And then it starts falling freely.

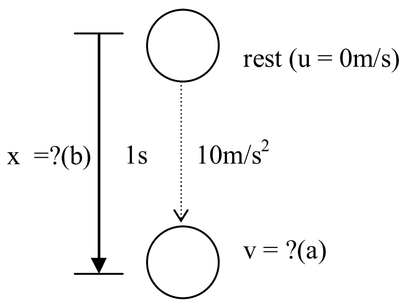


→ Throwing up
v = 0m/s
$a = -g = -10m/s^2$

[Example 1]

A body falls freely from rest. Air resistance is ignored. ($g = 10m/s^2$)

(a) What is its velocity after 1s?
(b) How far does it reach in 1s?



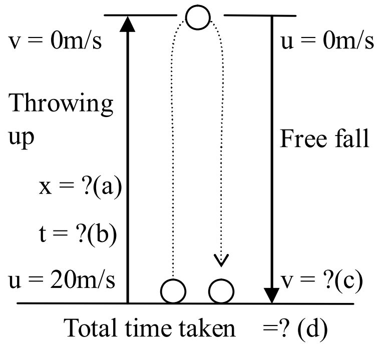
(a) <u>DATA</u> u = 0m/s $a = g = 10m/s^2$ } Free fall t = 1s v = ?	<u>Solution</u> v = u + at = 0 + 10×1 $= \underline{\underline{10m/s}}$
(b) <u>DATA</u> u = 0m/s $a = g = 10m/s^2$ } Free fall t = 1s x = ?	<u>Solution</u> $x = ut + \frac{1}{2}at^2 = 0\times1+\frac{1}{2}\times10\times1^2$ $= \underline{\underline{5m}}$

Try to solve for x using the formula :
$v^2 = u^2 + 2ax$

[Example 2]

A stone is thrown upward with an initial velocity of 20m/s. Air resistance is ignored. ($g = 10m/s^2$)

(a) How far does it take to reach the top?
(b) How long does it take to reach the top?
(c) What is its velocity just before reaching the ground?
(d) How long does it take to reach the ground?



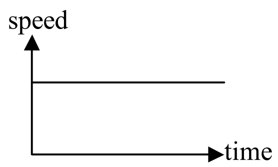
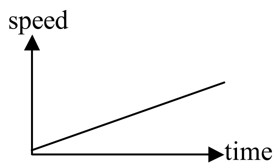
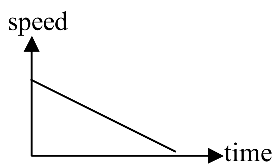
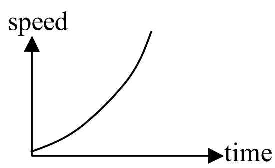
DATA	Solution
(a) DATA $u = 20m/s$ $v = 0m/s$ $a = -g = -10m/s^2$ } throwing up $x = ?$	$v^2 = u^2 + 2ax$ $x = \frac{v^2 - u^2}{2a} = \frac{0^2 - 20^2}{2 \times (-10)} = \frac{-400}{-20}$ $= \underline{\underline{20m}}$
(b) DATA $u = 20m/s$ $v = 0m/s$ $a = -g = -10m/s^2$ } throwing up $t = ?$	$v = u + at$ $t = \frac{v-u}{a} = \frac{0-20}{-10}$ $= \underline{\underline{2s}}$
(c) DATA $x = 20m$ $u = 0m/s$ $a = g = 10m/s^2$ } Free fall $v = ?$	$v^2 = u^2 + 2ax$ $= 0^2 + 2 \times 10 \times 20$ $= 400$ $v = \underline{\underline{20m/s}}$
(d) DATA $u = 0m/s$ $a = g = 10m/s^2$ } free fall $v = 20m/s$ $t_1 = 2s$, $t_2 = ?$, $t = ?$	$v = u + at_2$ $t_2 = \frac{v-u}{a} = \frac{20-0}{10} = 2s$ $t = t_1 + t_2 = 2+2 = \underline{\underline{4s}}$

Total time taken (t) $= t_1 + t_2$
t_1: time taken from the ground to the top
t_2: time taken from the top to the ground

Speed (velocity) – time graph

– Speed (velocity) – time graphs tell stories about the movement of an object.
– The gradient of the speed – time graph is equal to the acceleration of the object.
– The area under the speed – time graph represents the distance traveled by the object.

The diagrams below show the speed – time graphs for different kinds of motion.

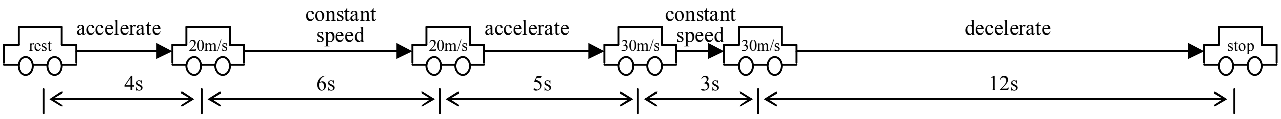
(a) Constant speed (no acceleration)  Horizontal straight line	(b) Uniform acceleration  Straight line sloping upward to the right
(c) Uniform deceleration  Straight line sloping downward to the right	(d) Non-uniform acceleration (or deceleration)  Curved line

[Example]

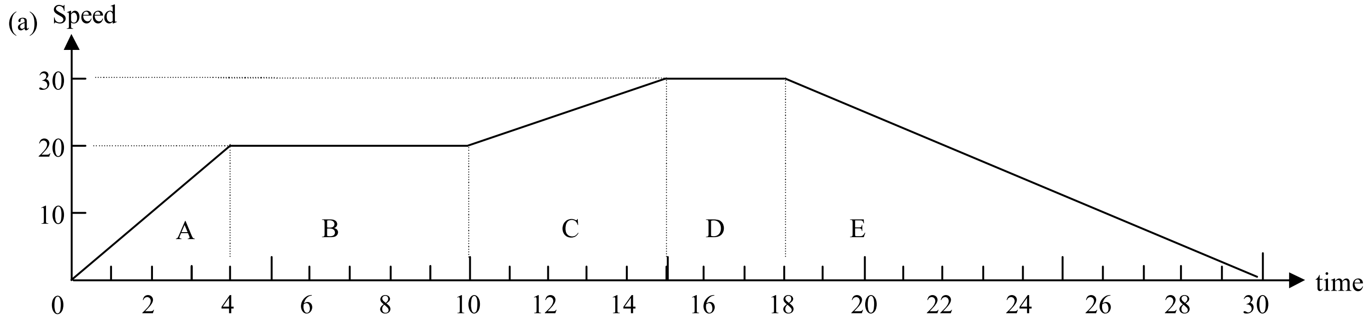
A car moving from rest acquires a velocity of 20m/s with uniform acceleration in 4s. It moves with this velocity for 6s and again accelerates uniformly to 30m/s in 5s. It travels for 3s at this velocity and then comes to rest with uniform deceleration in 12s.

(a) Draw a speed – time graph.
(b) Calculate the total distance covered.

(c) Calculate the average speed.



(a)



(b) To find the total distance covered, calculate the area under the speed – time graph.

Area A = triangle = $\frac{1}{2}$bh = $\frac{1}{2} \times 4 \times 20 = 40$

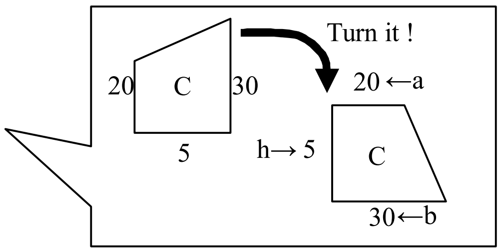
Area B = rectangle = lb = $6 \times 20 = 120$

Area C = trapezium = $\frac{1}{2}$(a+b)h = $\frac{1}{2}(20 + 30) \times 5 = 125$

Area D = rectangle = lb = $3 \times 30 = 90$

Area E = triangle = $\frac{1}{2}$bh = $\frac{1}{2} \times 12 \times 30 = 180$

Total distance covered = Total area = 40 + 120 + 125 + 90 + 180 = 555m



(c) DATA	Solution
Total distance covered = 555m Total time taken = 30s Average speed = ?	Average speed = $\frac{\text{Total distance covered}}{\text{Total time taken}} = \frac{555}{30} = 18.5$m/s

[EXERCISE]

(1) You walk from Chisale to St. Francis, a distance of 6km, in 50 minutes. Find the average speed in m/s.

(2) A man rides on a bicycle. He accelerates from rest to 8m/s in 5s. What is his acceleration?

(3) A man drives a car at 54km/hr. He brakes and it stops in 3s. Calculate the deceleration.

(4) A car starting from rest accelerates uniformly at 5m/s^2 in 3s.
  (a) Calculate the final velocity.
  (b) Calculate the distance covered.

(5) A car accelerated uniformly from 10m/s to 20m/s. It traveled a distance of 50m during this time.
  (a) What was the acceleration of the car?
  (b) How long did it take to travel this distance?

(6) A stone released from the top of a building takes 3s to reach the ground. The air resistance is ignored.
  (a) What is the final velocity?
  (b) How tall is the building?

(7) A car starting from rest accelerates uniformly to 20m/s in 5s. And it accelerates more to 40m/s in 2s. And then it decelerates until it stops 8s later.
  (a) Draw the speed–time graph.
  (b) Calculate the deceleration.
  (c) Calculate the total distance traveled.
  (d) Calculate the average speed.

[TRY]

Explain the reason why a piece of paper falls more slowly than a stone, although both of them are on the Earth and supposed to have the same acceleration: 10m /s^2.

1.4. Mass and Weight

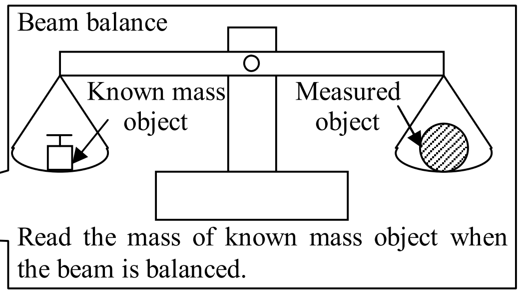
Mass

Definition **Mass** is defined as the quantity of matter in a substance.

→ The mass of an object is the same everywhere.

The unit of mass is kilogram [kg].

Instrument for measuring the mass → Beam balance



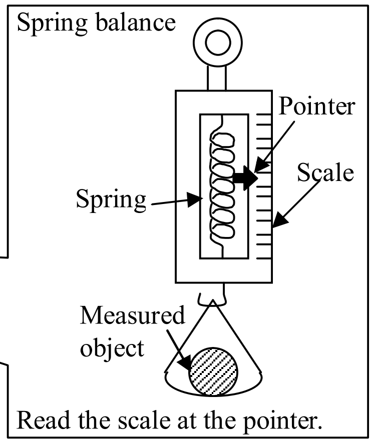
Weight

Definition **Weight** is defined as the attractive force exerted on an object by gravity.

→ The weight of an object varies from place to place.
(e.g. from the earth to the moon)

The unit of weight is Newton [N].

Instrument for measuring the weight → Spring balance, Bathroom scale



Relationship between mass and weight

The weight of an object is directly proportional to its mass.

Formula $w = mg$

w: weight [N]
m: mass [kg]
g: acceleration due to gravity[m/s^2]

→ Gravity of the moon is only about 1/6 that of the earth.

$g = 10 \times \frac{1}{6}$ m/s^2 (≈ 1.67 m/s^2) on the moon

→ No gravity in outer space.

$g = 0$ m/s^2 in the outer space

The following table shows the changes to the mass and weight of an astronaut when he travels from the earth to the moon in a spacecraft.

	Earth	Moon	Outer space
Mass	60kg	60kg	60kg
Weight	600N	100N	0N

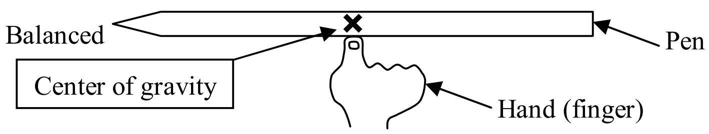
[Example]

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

DATA	Solution
$m = 70kg$, $g = 10m/s^2$, $w = ?$	$w = mg = 70 \times 10 = \underline{\underline{700N}}$

Centre of gravity

Definition **The center of gravity** of a body is defined as the point through which its whole weight appears to act.



Experiment To find the centre of gravity.

Apparatus: Paper, Pen, String

Procedure:

(1) Fold the paper tightly and make the shape which you want to find the centre of gravity. (It must be flat.)

(2) Make three holes near the edge. Three holes are as far as possible.

(3) Cut the string into two, short one(5cm) and long one(15cm).

(4) Make the plumb by the long string and a pen.

(5) Thread a hole with the short string.

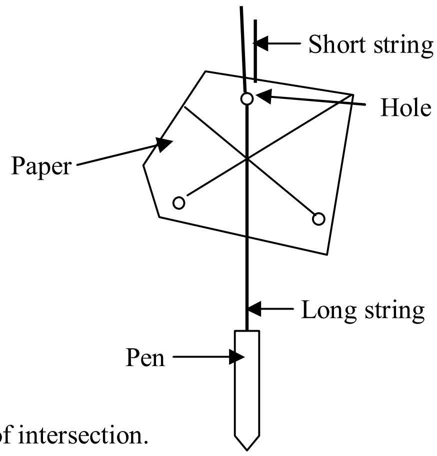
(6) Hang the plumb on the short string.

(7) Draw the line of the plumb on the paper after it is steady.
(The paper must be free to move at the hanging point.)

(8) Repeat (5) to (7) for other holes.

(9) Find the intersection of three lines.

(10) Make sure that the paper balances by putting a finger at the point of intersection.



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

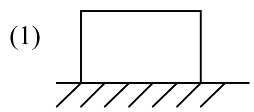
Stability

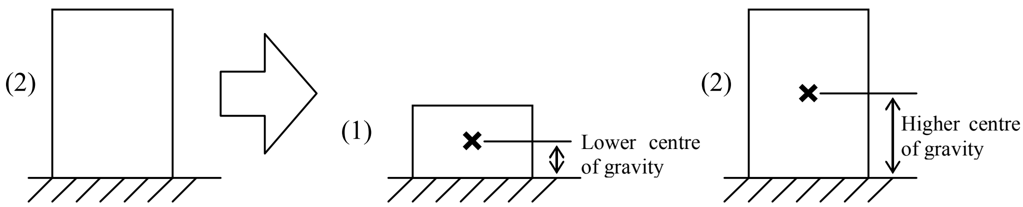
Definition **The stability** of an object is defined as the ability of an object to regain its original position after it has been displaced slightly.

The position of centre of gravity affects the stability of a body.

[Example 1]

Which is more stable?

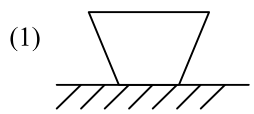


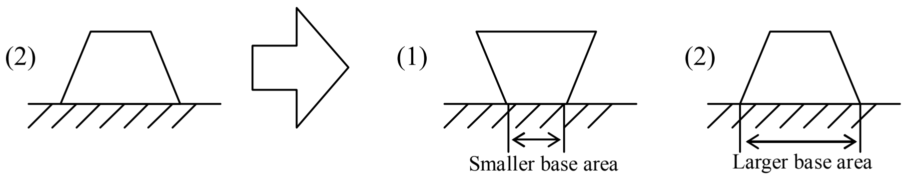


→ (1) is more stable than (2) because it has a lower centre of gravity.

[Example 2]

Which is more stable?





→ (2) is more stable than (1) because it has a larger base area.

To increase the stability of an object,
— the centre of gravity should be as low as possible.
— the base area should be as large as possible.

[EXERCISE]

(1) The mass of a man is 1200g. What is his weight on the earth and on the moon? The gravity on the moon is 1/6 that on the earth (g_{earth}=10m/s^2).

(2) The weight of an object is 300N on the earth.
 (a) What is its mass on the earth?
 (b) What is its weight and mass on the moon? The gravity on the moon is 1/6 that on the earth (g_{earth} =10m/s^2).
 (c) What is its weight and mass in the outer space?

[TRY]

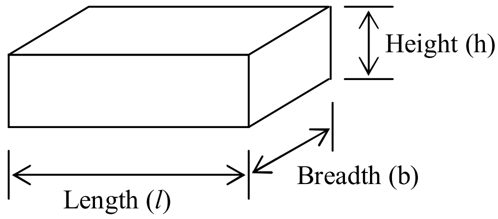
Why is it not advisable to put heavy luggage on the roof of a minibus?

1.5. Volume and Density

Volume

Definition **Volume** is defined as the amount of space an object occupies.

The unit of volume is Cubic metre [m^3].



Formula

$$\text{Volume of cuboid} = l \times b \times h$$

l: length
b: breadth
h: height

Instrument for measuring volume of liquid → Measuring cylinder

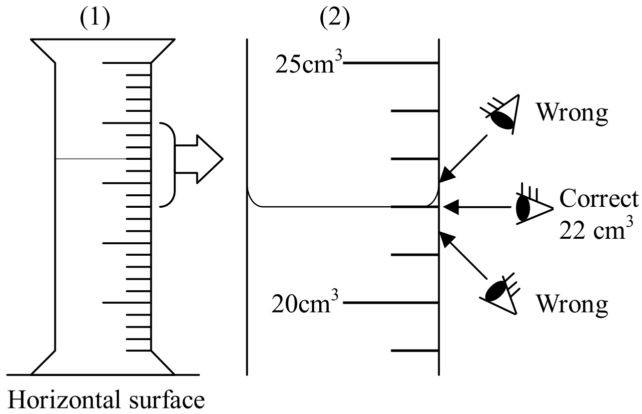
How to use the measuring cylinder

(1) Pour the measured liquid into the measuring cylinder.

(2) Read the scale at the flat surface of liquid.

Caution to use;

- Put the measuring cylinder on the horizontal surface.
- Place the eye level with the flat surface of liquid. (The surface of liquid is curved where it meets the glass. This surface is called the meniscus.)



Density

Definition **Density** is defined as mass per unit volume.

The unit of density is kilogram per cubic metre [kg/m^3]. (Also gram per cubic centimetre [g/cm^3] is frequently used.)

Formula

$$D = \frac{m}{V}$$

D: Density [kg/m^3] or [g/cm^3]
m: mass [kg] or [g]
V: volume [m^3] or [cm^3]

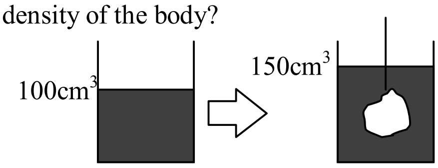
[Example 1]

A material has a mass of 450g and a volume of 50cm^3. What is its density?

DATA	Solution
$m = 450g$ $V = 50cm^3$ $D = ?$	$D = \frac{m}{V} = \frac{450}{50} = \underline{9\ g/cm^3}$

[Example 2]

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



DATA	Solution
$m = 500g$, $V = 50cm^3$, $D = ?$	$D = \frac{m}{V} = \frac{500}{50} = \underline{10\ g/cm^3}$

Volume of the body = Total volume – volume of water = 150 – 100 = 50 cm^3

[EXERCISE]

(1) A metal has a mass of 255g and a volume of 30cm^3. What is its density?

(2) A cube with side 2m long has a mass of 8kg. What is its density?

(3) A container of mass 200g contains 160cm^3 of liquid. The total mass of the container and liquid is 520g. What is the density of the liquid?

[TRY]

(1) How many g/c m^3 is equal to $1kg/m^3$?

(2) Try to find out if an egg will sink or float in (a) pure water and (b)salt water. Suggest the reason for it.

1.6. Force

Force

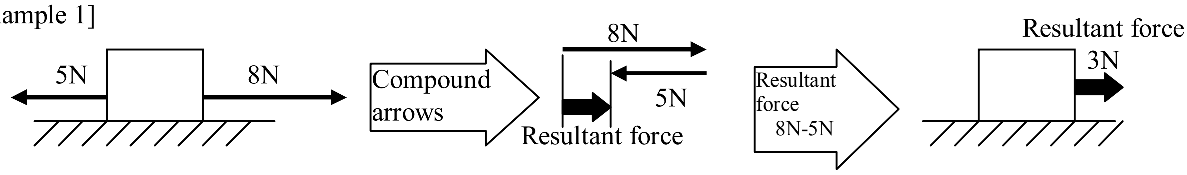
→ Force is a pull or a push.
→ The unit of force is Newton [N].
→ It is a vector.
→Weight is a kind of force.
  → Force can be measured by a spring balance, as weight is measured.

Ability of force
→ Force can change the size or shape of a body.
→ Force can change the motion of a body.

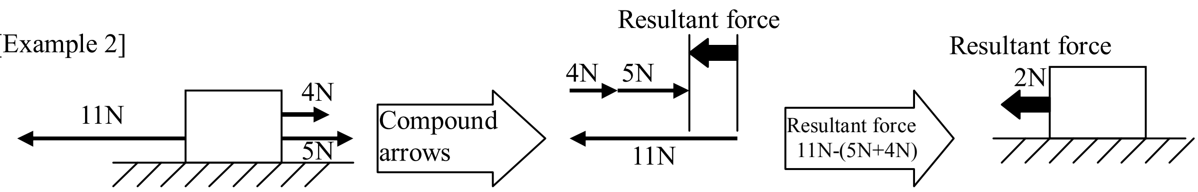
Resultant force

If two forces or more act on an object, they can be simplified. It is called a **resultant force**.

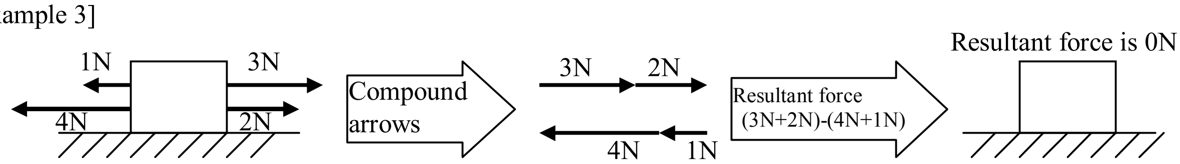
[Example 1]



[Example 2]



[Example 3]



If a resultant force is 0N on an object, then the forces are balanced on the object.

Newton's first law of motion

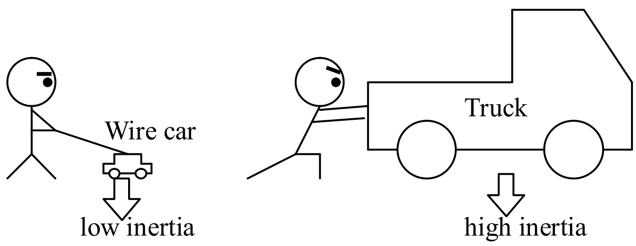
$\boxed{\text{Law}}$ If all the forces are balanced on a body,

— if it is at rest, it will continue to stay at rest
— if it is moving, it will keep moving at a constant speed in a straight line.

The property of a body that resists a change to its motion is called **Inertia**.
Inertia depends on the mass of an object. If something has a high resistance to change of motion (a high mass), it is said to have high inertia.

[Example]

Which is easier to move, a wire car or a truck?
→ The wire car is easier to move than the truck because the wire car has lower inertia. (The truck has higher inertia.)



Newton's second law of motion

$\boxed{\text{Law}}$ Unbalanced forces acting on a body produce acceleration in the direction of the force.

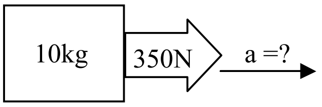
This acceleration is directly proportional to the force and inversely proportional to the mass of the body.

Formula $F = ma$

F: Force (Resultant force) [N]
m: mass [kg]
a: acceleration [m/s^2]

[Example 1]

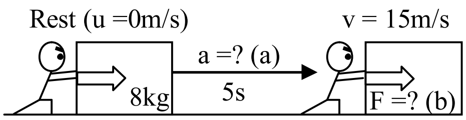
A force of 350N acts on an object of mass 10kg. Find the acceleration.



DATA	Solution
F = 350N, m = 10kg, a =?	$a = \frac{F}{m} = \frac{350}{10} = \underline{\underline{35\ m/s^2}}$

[Example 2]

A man pushes an 8kg luggage on the smooth floor. It starts from rest and reaches 15m/s in 5s.
(a) What is its acceleration?
(b) What is the acting force on the luggage?

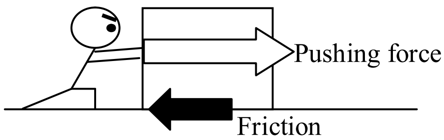


(a) DATA	Solution
u = 0m/s, v = 15m/s t = 5s, a = ?	$a = \frac{v-u}{t} = \frac{15 - 0}{5} = \underline{\underline{3m/s^2}}$
(b) DATA	Solution
m = 8kg, a = $3m/s^2$, F =?	$F = ma = 8 \times 3 = \underline{\underline{24N}}$

Friction

Definition **Friction** is a force which acts to stop the motion of two touching surfaces.
→ Friction acts in the opposite direction of the motion or tendency of motion.
→ The larger friction exists between rougher surfaces.

For example, if you push a luggage, friction is caused between the luggage and the floor. Its direction is opposite to pushing force and it resists moving. If you push it on a smooth floor like ice, friction reduces and it is easy to push.

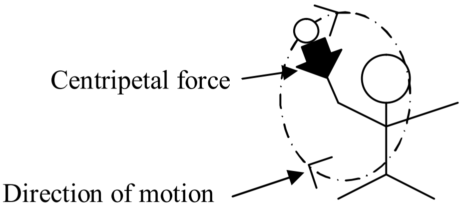


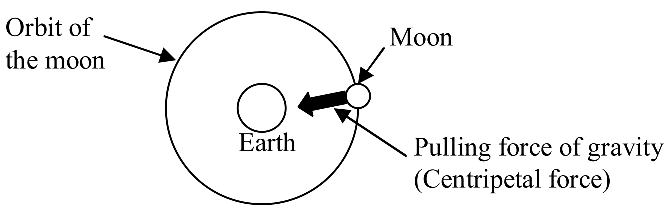
Application of friction	Consequence of friction
– We can walk without slipping. – Vehicle (car) can move and stop. – We can grip (hold) something (e.g. pen) in our hands. – Nails hold something tight.	– Friction causes energy lost and reduces the efficiency of machines. – It causes rapid wear and tear.

↓
To reduce friction, lubricants (oil, grease) are added to machines.

Centripetal force

The force of circular motion is always at right angle to the motion. The direction of the force is always towards the centre of circular motion. This force is called the **centripetal force**.





The moon is in a circular orbit round the earth because the earth pulls the moon by the force of gravity.

Load and Extension

Experiment To find the relationship between loads and extensions on a spring.

Apparatus: spring, loads

Procedure:

(1) Hold an end of a spring (the other end must be free) and measure the length of the spring. It is called the original length.

(2) Hang a load on the free end.

(3) Measure the length of the spring.

(4) Calculate the extension by [Extension = length of spring – original length]

(5) Repeat (2) to (4) adding loads.

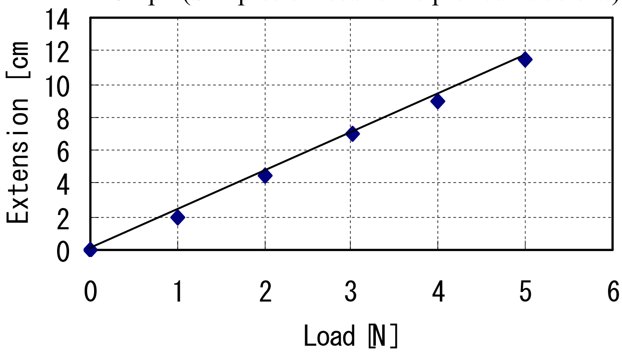
(6) Calculate $\frac{\text{Extension}}{\text{load}}$

(7) Plot a graph of Extension against load. (Use a scale of 2cm to 1N and 2cm to 2cm.)

Result: (Samples of results are shown in the brackets.)

Load	Length of spring	Extension	$\frac{\text{Extension}}{\text{load}}$
0N	(10.5cm)	(0cm)	(–)
1N	(12.5cm)	(2.0cm)	(2.0)
2N	(15.0cm)	(4.5cm)	(2.25)
3N	(17.5cm)	(7.0cm)	(2.33)
4N	(19.5cm)	(9.0cm)	(2.25)
5N	(21.5cm)	(11.5cm)	(2.30)

Graph (Samples of results are plotted as below.)



Conclusion: The extension of a loaded spring is directly proportional to the load (force) applied.

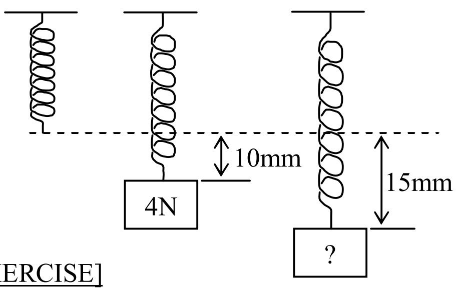
It is called **Hooke's Law**.

Formula $\frac{\text{Extension}}{\text{load}} = \text{Constant}$

But springs have not been permanently stretched. They have the limitations.
The limitation is called **Elastic limit**.

[Example]

A load of 4N extends a spring by 10mm. What load would extend it by 15mm?



DATA	Solution
Extension 1 = 10mm Load 1= 4N Extension 2 = 15mm Load 2=?	$\frac{\text{Extension 1}}{\text{Load 1}} = \frac{\text{Extension 2}}{\text{Load 2}}$ $\text{Load 2} = \frac{\text{Load 1} \times \text{Extension 2}}{\text{Extension 1}} = \frac{4 \times 15}{10} = \frac{60}{10}$ = <u>6N</u>

[EXERCISE]

(1) An 8kg object accelerates at $2m/s^2$. What is the acting force on it?

(2) A force of 20N acts on a mass of 5kg. What is the acceleration?

(3) If an object accelerates at $6m/s^2$ by a force of 24N, What is the mass?

(4) A pupil pushes a wheelbarrow carrying 30kg sand. It accelerates from rest to 2m/s in the distance of 1m.

(b) What is the acceleration?

(c) What is the acting force on the wheelbarrow?

(5) A load of 1N extends a spring by 5mm. What load would extend it by 1cm?

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

1.7. Moment

Moment

Definition **Moment** of a force about a pivot is defined as the product of the force and the perpendicular distance of its line of action from pivot.

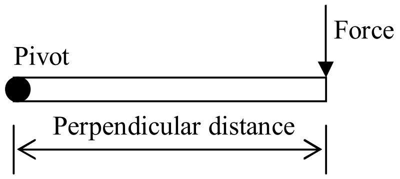
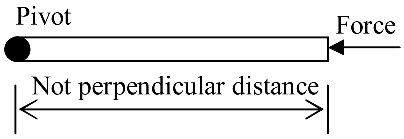
→ Moment is a turning effect of a force about a certain point.

Formula $M = Fd$

M: Moment [Nm]
F: Force [N]
d: perpendicular distance [m]

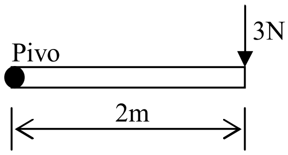
→ Perpendicular distance must be a distance from the pivot to the force.

→ Perpendicular distance must be at right angle to the force.

	In this case, there is a moment because 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. M=0

[Example]

Calculate the moment of the force at the pivot.



DATA	Solution
F=3N, d=2m, M=?	$M = Fd = 3\times2 = \underline{\underline{6Nm}}$

Principle of moment

Law For a body to be in equilibrium (balanced), the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point.

↓ In other words

If a body is balanced, then

Formula Total clockwise moment = Total anticlockwise moment

Experiment To verify the principle of moment.

Apparatus: long ruler (30cm or more), 3 strings, Loads

Procedure:

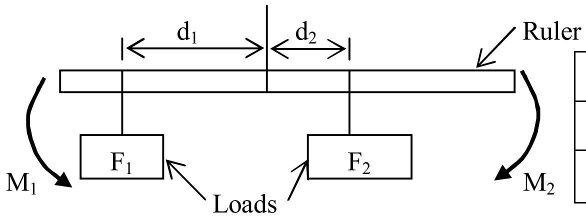
(1) Hang a ruler by a string at the cntre of mass and make it balanced.

(2) Hang some loads (e.g. 2N) at a certain point (e.g. 10cm from pivot).

(3) Find the position where other loads (e.g. 4N) are hung to balance the ruler and find the distance from the pivot to the position.

(4) Calculate the clockwise moment and the anticlockwise moment.

(5) Repeat (2) to (4) with different pairs of loads and distances.



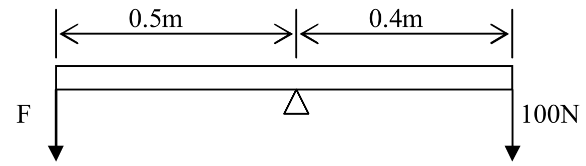
Result: (Samples of results are shown in the brackets.)

Anticlockwise			Clockwise		
F_1	d_1	$M_1(=F_1d_1)$	F_2	d_2	$M_2(=F_2d_2)$
(2N)	(10cm)	(0.2Nm)	(4N)	(5cm)	(0.2Nm)

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

[Example 1]

Calculate the force F if it is balanced.



Data & Solution

Anticlockwise			Clockwise		
F	D	M	F	d	M
F	0.5m	0.5F	100N	0.4m	40Nm

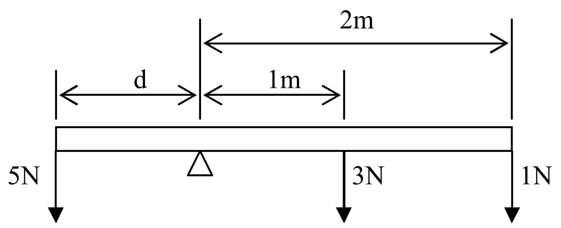
Total anticlockwise moment = Total clockwise moment

0.5F = 40

F = 80N

[Example 2]

Calculate the distance d if it is balanced.



Data & Solution

Anticlockwise			Clockwise		
F	d	M	F	d	M
5N	d	5d	3N	1m	3Nm
			1N	2m	2Nm

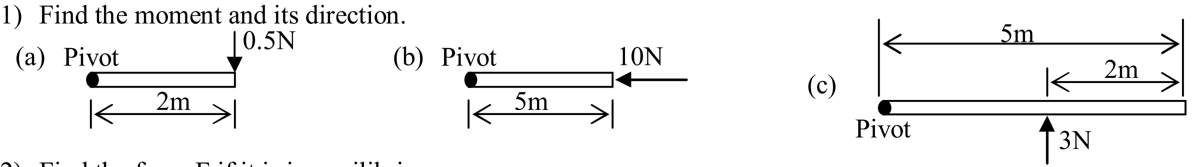
Total anticlockwise moment = Total clockwise moment

5d = 3 + 2

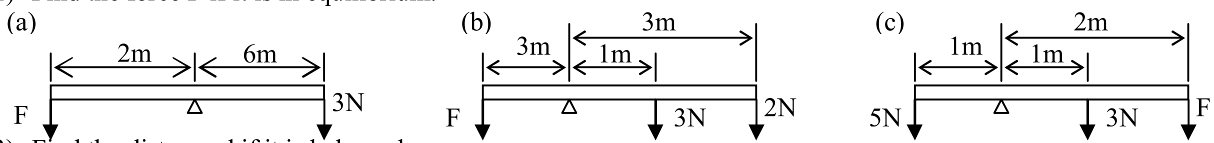
d = 1m

[EXERCISE]

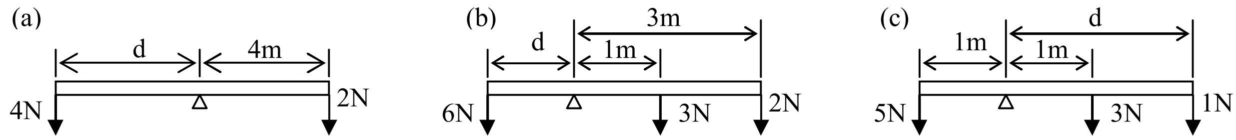
(1) Find the moment and its direction.



(2) Find the force F if it is in equilibrium.



(3) Find the distance d if it is balanced.



(4) A metre ruler hangs by a string at the 80cm mark and a mass of 140g hangs at the 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.

1.8. Work, Energy and Power

Work

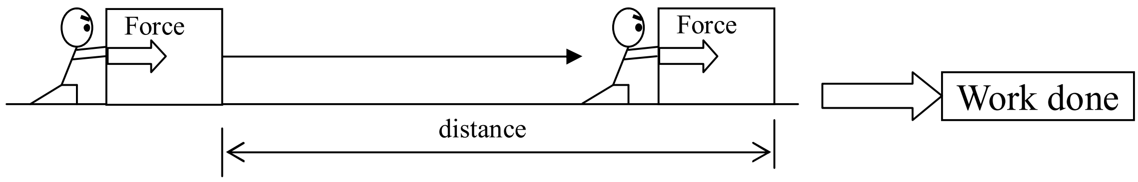
Definition **Work** is defined as the product of the force and the distance moved in the direction of the force.

The unit of work is Joule [J].

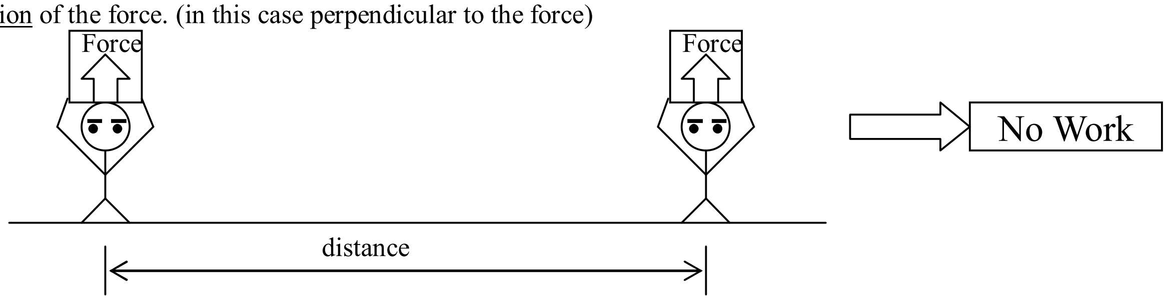
Formula $W = Fd$

W: Work [J]
F: Force [N]
d: distance moved in the direction of the force [m]

If a man pushes an object on the floor, he does the work on the object because the distance is in the same direction of the force.

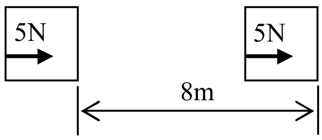


But if a woman carries a container on her head, she does no work on the container because the distance is in the different direction of the force. (in this case perpendicular to the force)



[Example]

A force of 5N acts on a 3kg brick, moving it 8m horizontally from rest. Find the work done by the force.



DATA	Solution
F = 5N d = 8m W =?	$W = Fd = 5 \times 8 = \underline{\underline{40J}}$

[EXERCISE]

(1) A man pushes the big stone through 10m and exerts the force of 25N. Find the work done by the man.

(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. ($g = 10m/s^2$)

(4) A car of mass 1000kg is accelerated at $2m/s^2$ from rest in 20s. Find
   (a) the force acting on the car.
   (b) the distance travelled by the car in this period.
   (c) the work done by the car in this period.

Energy

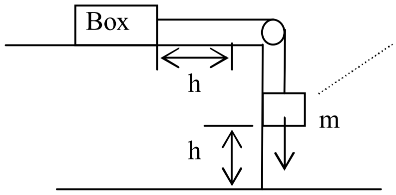
Definition **Energy** is defined as the ability to do work.
The unit of energy is Joule [J].

Potential energy

Definition **Potential energy** is defined as the energy by the position or state of an object. The potential energy due to height is called gravitational potential energy.

Formula $PE = mgh$

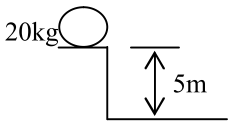
PE: Potential energy [J]
m: mass [kg]
g: acceleration due to gravity [m/s^2]
h: height [m]



This object has the ability to do work of:
$F \times d = mg \times h = mgh$

[Example]

A 20kg object is raised to a height of 5m. What is its potential energy?



DATA	Solution
m =20kg h = 5m g = 10m/s^2 PE=?	$PE = mgh = 20 \times 10 \times 5$ $= \underline{\underline{1000J}} = 1kJ$

Kinetic energy

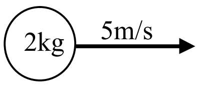
Definition **Kinetic energy** is defined as the energy due to the motion of an object.

Formula $KE = \frac{1}{2}mv^2$

KE: Kinetic energy [J]
m: mass [kg]
v: velocity [m/s]

[Example]

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



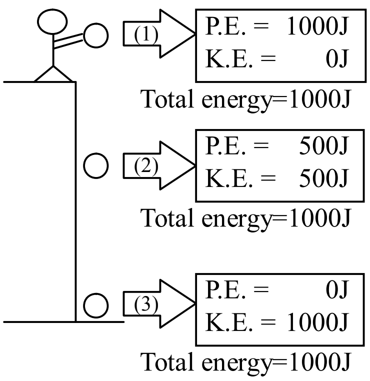
DATA	Solution
m =2kg v = 5m/s KE=?	$PE = \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times 5^2$ $= \underline{\underline{25J}}$

Conservation of energy

Law Energy can be changed from one form to another, but cannot be created or destroyed.

[Example 1]

If a ball falls freely from a certain point, how does the energy change?



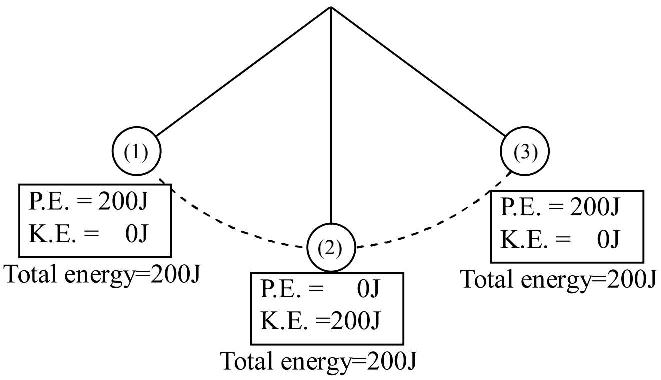
(1) Before a ball is released, its potential energy is 1000J and the kinetic energy is 0J because it doesn't move.

(2) At the midpoint of its journey, the potential energy drops to 500J but the kinetic energy increses to 500J. Total energy is still 1000J.

(3) Just before hitting the ground, the potential energy becomes 0 J but the kinetic energy increases to 1000J. There is no change in the total energy throughout its falling.

[Example 2]

How does the energy change on the pendulum?



(1) The pendulum bob is pulled to position (1). Before it is released, its potential energy is 200J and kinetic energy is 0J because it is at rest.

(2) As the bob moves from (1) to (2), it loses potential energy and gains kinetic energy to 200J because of reducing the height and increasing the velocity. It has maximum velocity at the bottom (2).

(3) Moving from (2) to (3), the bob slows down, losing kinetic energy but gaining poteintial energy. If air resistance is ignored, the height of (1) is the same as the height of (3) because these potential energies must be the same.

Conservation of energy → Each energy can be changed but total energy is constant.
→When there are only PE and KE, **P.E. + K.E. = constant**

<u>Use of energy (Source, Transducer, Use)</u>

When energy is used for our life,first energy comes from energy sources, and the energy forms are changed by a transducer. Then useful energy is provided. The diagrams below show some examples of sources of energy, transducers and useful energy provieded.

Source of energy	Transducer	Useful energy
Food [Chemical energy] →	You	→ Movement of your body [Kinetic energy]
Sun light [Solar(light) energy] →	Solar system	→ Electricity [Electrical energy]
Wind [Kinetic energy] →	Generator	→ Electricity [Electrical energy]
Electricity [Electrical energy] →	Electrical motor	→ Movement of motor [Kinetic energy]

<u>Environmental effect</u>

If sources of energy are used in our life, it may affect on the environment. The followings show some cases of effect to enviroment. We must prevent such kind of bad influence.

[Case 1] Effect of a car

Fuel [Chemical energy] → Car → Movement [Kinetic energy]

Car → Sound (Noise), Heat, Exhaust gas ⇒

- Sound causes the noise pollution.
- Heat causes global warming.
- Exhaust gas causes the air pollution.

[Case 2] Effect of a hydraulic Plant

Stocked water [Potential energy] → Lake Kariba → Movement of water [Kinetic energy] → Hydro-generator → Electricity [Electrical energy]

Hydrauric plants are clearn. It doesn't cause any pollution. However it may changes natural ecosystem. When the dam is built, very large space is needed. Many trees are cut. It is a deforestration. And also many living things (animals and insects) lose their living places.

[Case 3] Effect (risk) of an atomic Plant

Radioactive substance [Nuclear energy] → Atomic power station → Electricity [Electrical energy]

If an atomic power station is damaged, the radiation leaks. It brakes cells or gene of living things. As a result, it causes some diseases such as cancer.

Power

Definition **Power** is defined as the rate of doing work.
The unit of power is Watt [W].

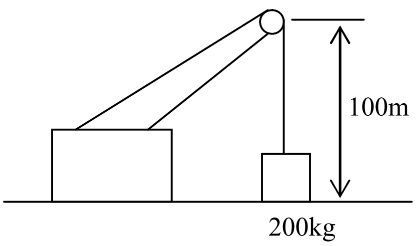
Formula
$$P = \frac{W}{t} = \frac{E}{t}$$

P: Power [W]
W: work done [J]
t: time taken [s]
E: Energy changed [J]

[Example]

A crane can lift 200kg to a height of 100m in 20s. What is the useful power of the crane?

Step (1) Find the weight.
Step (2) Find the work done.
Step (3) Find the power.



	DATA	Solution
(1)	$m = 200kg$ $g = 10m/s^2$ $W = ?$	$W = mg = 200 \times 10 = 2{,}000N$
(2)	F = Weight = 2000N d = 100m Work =?	Work = Fd = $2000 \times 100 = 200{,}000J$
(3)	Work done = 200,000J t = 20s P =?	$P = \frac{\text{Work done}}{t} = \frac{200000}{20}$ $= \underline{\underline{10{,}000W}} = 10kW$

[EXERCISE]

(1) A 10kg rock is on the hill of 50m. What is its potential energy?

(2) A book which has a mass of 1.2kg is put on the desk. the height of desk is 0.8m. Calculate the potential energy.

(3) A car of mass 500kg moves with a velocity of 20m/s. What is its kinetic energy?

(4) A 3kg brick is released from the top of building. Calculate;
 (a) the velocity after one second.
 (b) the kinetic energy after one second.

(5) A rock of mass 200kg is dropped from a height of 200m. What is the potential energy and the kinetic energy at;
 (a) 0 second (b) 2seconds (c) 4seconds (d) just before it hits the ground.

(6) 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 an 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.
 (g) the power developed if the force is exerted for 20s.

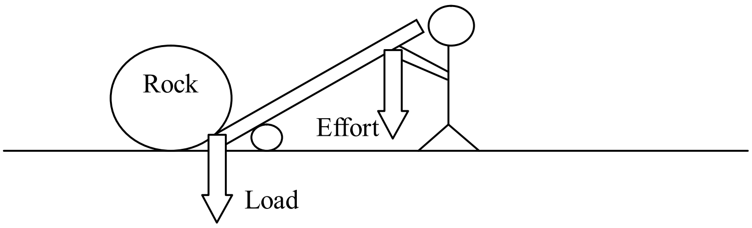
(7) A 60kg pupil runs for 600m in 1minute uniformly.
 (a) Calculate his velocity.
 (b) Calculate his kinetic energy.
 (c) If eating one banana enables a pupil to perform about 3kJ of work, how may banana should he eat?

1.9. Simple Machine

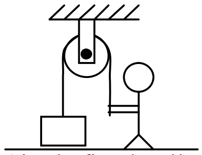
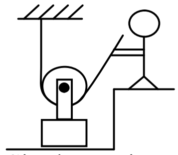
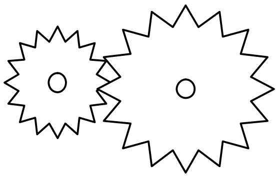
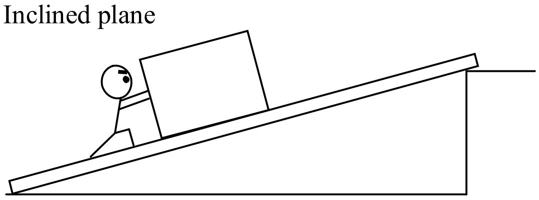
Machine

Definition **Machine** is any device by means of which a force applied at one point can be used to overcome a force at a different point.

→ The applied force is called **Effort**
→ The force which effort overcomes is called **Load** (The force which an object pulls or pushes on a machine is called Load.)



Types of simple machine

(1) Lever (Examples) – Wheelbarrow – Borehole – Scissors – Opener – Slasher – Hoe – Shovel – Cooking stick	(2) Pulley  Single fixed pulley  Single moving pulley
(3) Gear 	(4) Inclined plane 

Mechanical Advantage (M.A.)

Definition **The mechanical advantage** of a machine is defined as the ratio of the load to the effort.

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

Velocity Ratio (V.R.)

Definition **The velocity ratio** of a machine is defined as the ratio of the distance moved by effort to the distance moved by the load in the same time.

Formula
$$\text{V.R.} = \frac{\text{distance moved by effort}(d_E)}{\text{distance moved by load in the same time}(d_L)}$$

Efficiency

Definition **The efficiency** of a machine is defined as the ratio of the useful work done by the machine to the total work put into the machine.

$$\text{Efficiency} = \frac{\text{Useful work done}}{\text{Total work put into}} = \frac{\text{Work done by load}}{\text{Work done by effort}}$$

Since, W=Fd, Load and Effort are forces

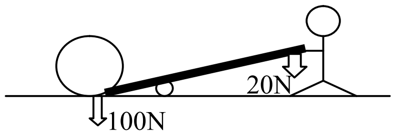
$$\text{Efficiency} = \frac{\text{Load} \times d_L}{\text{Effort} \times d_E} \times 100 = \frac{\text{Load}}{\text{Effort}} \times \frac{d_L}{d_E} \times 100 = \frac{\text{Load}}{\text{Effort}} \div \frac{d_E}{d_L} \times 100 = \text{M.A.} \div \text{V.R.} \times 100$$

Formula
$$\text{Efficiency} = \frac{\text{M.A.}}{\text{V.R.}} \times 100\ [\%]$$
(Efficiency $\leq 100\%$)

[Example 1]

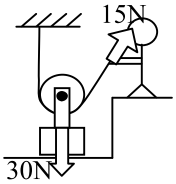
Calculate the mechanical advantage of the diagrams below.

(1) Lever



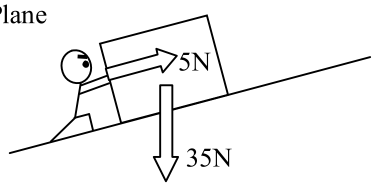
DATA	Solution
Effort = 20N Load = 100N M.A. =?	M.A. = $\frac{\text{Load}}{\text{Effort}} = \frac{100}{20} = \underline{\underline{5}}$

(2) Single moving Pulley



DATA	Solution
Effort = 15N Load = 30N M.A. =?	M.A. = $\frac{\text{Load}}{\text{Effort}} = \frac{30}{15} = \underline{\underline{2}}$

(3) Inclined Plane

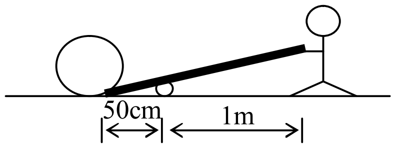


DATA	Solution
Effort = 5N Load = weight = 35N M.A. =?	M.A. = $\frac{\text{Load}}{\text{Effort}} = \frac{35}{5} = \underline{\underline{7}}$

[Example 2]

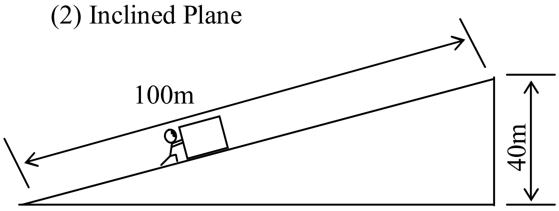
Calculate the velocity ratio of the diagrams below.

(1) Lever



DATA	Solution
distance from pivot to effort = 1m distance from pivot to load = 50cm = 0.5m V.R. =?	V.R. = $\frac{d_E}{d_L}$ $= \frac{\text{distance from pivot to effort}}{\text{distance from pivot to load}}$ $= \frac{1}{0.5} = \underline{\underline{2}}$

(2) Inclined Plane

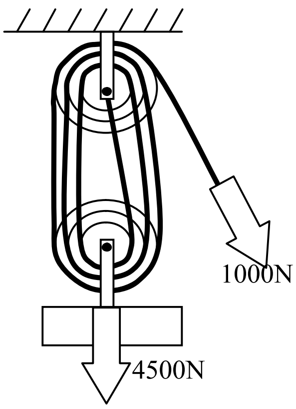


DATA	Solution
Height = 40m Length of slope= 100m V.R. =?	V.R. = $\frac{d_E}{d_L} = \frac{\text{Length of slope}}{\text{height}}$ $= \frac{100}{40} = \underline{\underline{2.5}}$

[Example 3]

The diagram below shows a pulley system. An effort of 1000N is required to raise a load of 4500N.

(a) Find the mechanical advantage.
(b) Find the velocity ratio.
(c) Find the efficiency.

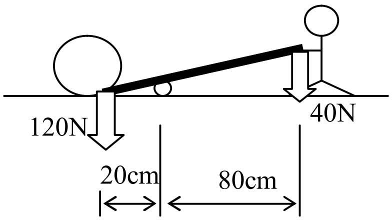


(a) DATA Effort = 1000N Load = 4500N M.A. =?	Solution M.A. = $\frac{\text{Load}}{\text{Effort}} = \frac{4500}{1000} = \underline{\underline{4.5}}$
(b) To find the velocity ratio of the pulley system, <u>count the number of lines connected to moving pulley.</u>	Solution 6 lines connected to moving pulleys. V.R. = $\underline{\underline{6}}$
(c) DATA M.A. = 4.5, V.R. = 6 Efficiency =?	Solution Efficiency = $\frac{\text{M.A.}}{\text{V.R.}} \times 100 = \frac{4.5}{6} \times 100 = \underline{\underline{75\%}}$

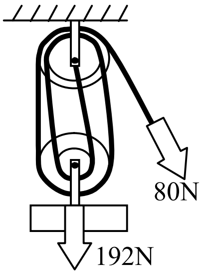
[EXERCISE]

(1) Calculate the mechanical advantage, the velocity ratio and the efficiency of the diagrams below.

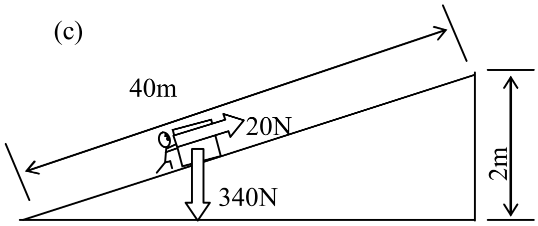
(a)



(b)



(c)



(2) The system of levers with a velocity ratio of 25 overcomes a resistance of 3300N when an effort of 165N is applied to it.

(b) Calculate the mechanical advantage of the system.

(c) Calculate its efficiency.

[TRY]

Prove that M.A. $\geq$ V.R.

2. THERMAL PHYSICS

2.1. Kinetic theory

State of matter

Matter exists in the three states of Solid, Liquid and Gas. The physical difference between the three states of matter depends on the arrangement and behaviour of the molecules in each particular state. This difference can be explained in trems of the Kinetic Theory, model which states that;

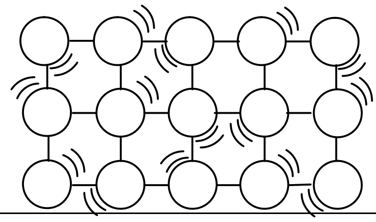
— Matter is made up of very small particles called molecules.
— These molecules are not stationary but are constantly moving.
— The degree of movement of the molecules depends on their temperature.

Solid

(1) Properties
- Fixed shape and volume
- Normally hard and rigid
- Incompressible
- Large force needed to change shape
- High density

(2) Arrangement and movement of particles
- The particles are close together.
- They are arranged in a regular pattern.
- The attractive forces between them are strong. (The attractive force is called Cohesive force.)
- They vibrate to and fro at the fixed positions. (They cannot change positions.)

(3) Molecular model (Solid model)

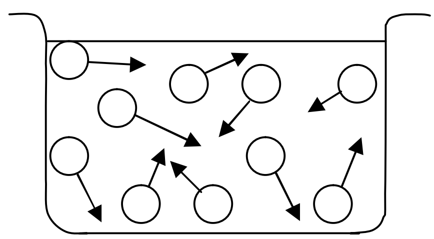


Liquid

(1) Properties
- Fixed volume but does not have a fixed shape
- Not compressible
- High density

(2) Arrangement and movement of particles
- The particles are close together but they have wider space than those in solid.
- The attractive forces between them are weaker than those in solid.
- They move vigorously.
- They can move from one position to another.

(2) Molecular model (Liquid model)

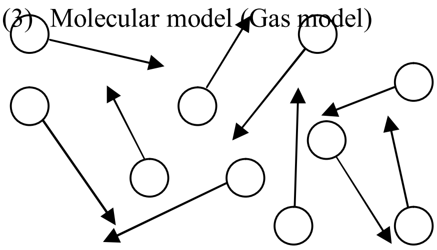


Gas

(1) Properties
- No fixed shape or volume
- Compressible
- Low density

(2) Arrangement and movement of particles
- The particles are very far apart.
- They can hardly attract each other.
- They move randomly with a high speed.

(3) Molecular model (Gas model)

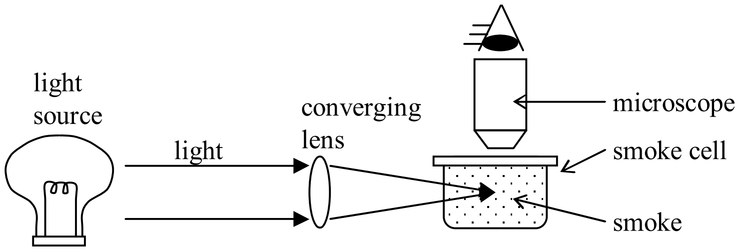


Brownian motion

Brownian motion provides an evidence of the continuous random motion of the molecules in the air.

→ Experimental Set up

A microscope is used to look into a smoke cell that contains some smoke particles (as well as air molecules) as shown below.

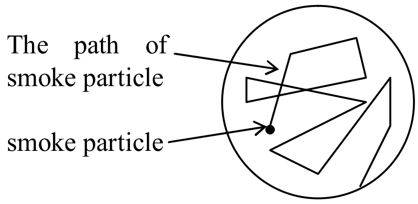


→ Observation

When the light strikes the smoke particles, they are observed as bright specks of light. They move in a random zig-zag path as the diagram in the circle.

→ Explanation

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



View of microscope

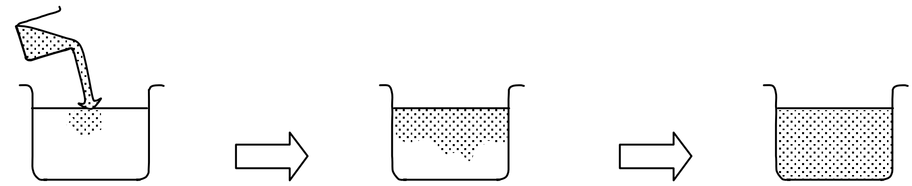
<u>Diffusion</u>

Definition **Diffusion** is defined as the process by which different substances mix as a result of the randum motions of their molecules.

→ The substances move freely from a region of high concentration to a region of low concentration at their own pace.
→ The rate of diffusion depends on the temperature and the density of the substances involved.
→ It supports the kinetic theory, since the particles must be moving to mix, and gases can be seen to diffuse faster than liquids.

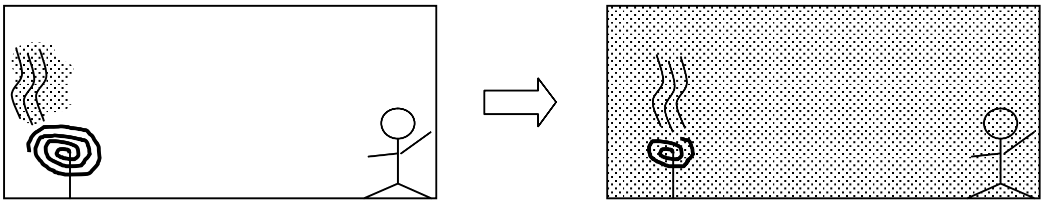
[Case 1] Diffusion of ink in water

The colour of water is changed by the diffusion of ink paticles. (without mixing)



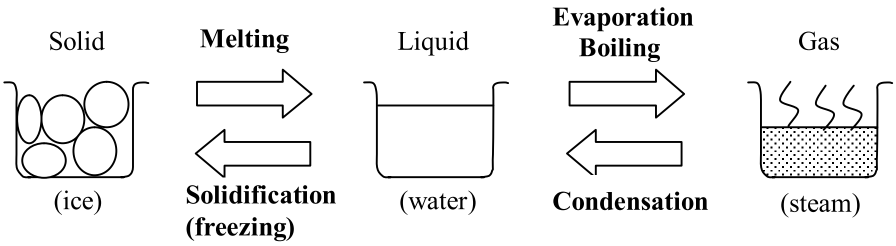
[Case 2] Diffusion of mosquito coil

The smell of mosquito coil reaches to your place by the diffusion of its smoke paticles.



<u>Change of state</u>

The names of changes of states are indicated in the diagram below.

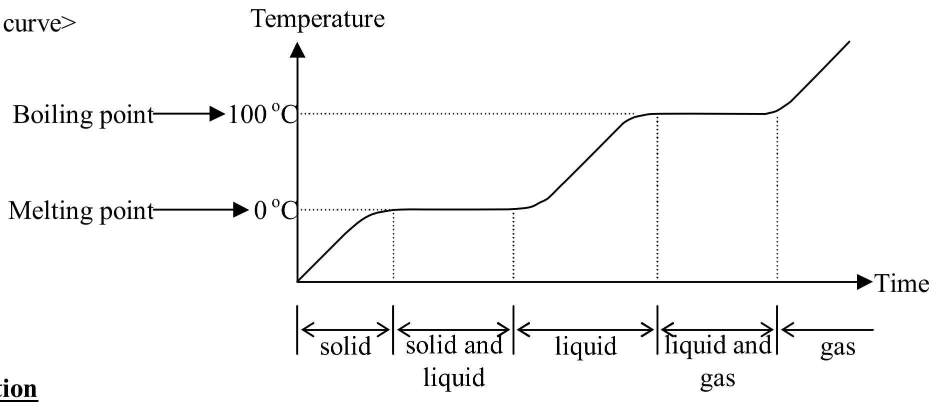


The temperature is unchanged during the change of state of a substance. All the energy supplied to the substance is used for breaking the strong forces between molecules.

— The melting point is the temperature at which a solid melts.

— The boiling point is the temperature at which a liquid boils.

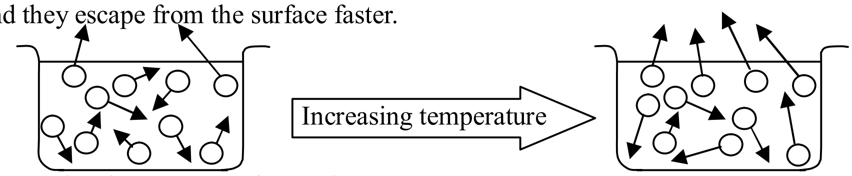
<Heating curve>



Evaporation

Definition **Evaporation** is defined as the change of a liquid into a gas at the surface.

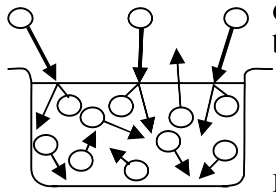
→ It occurs at any temperature but occurs more rapidly at higher temperature because heat gives more kinetic energy to the molecules and they escape from the surface faster.



Some molecules escape from the surface of liquid at any temperature.

If temperature increases, molecules move faster and they have larger kinetic energy. Then they escape from the surface faster.

→ Increased gas pressure on the surface of the liquid reduces the rate of evaporation because more collisions occur between the evaporating liquid molecules and the gas molecules, and some of the evaporated liquid molecules bounce back into the liquid. (See the right diagram.)



Gas (air) molecules have higher speed because of increasing of pressure.

More gas (air) molecules collide with liquid molecules.

Liquid molecules bounce on the surface.

→ The molecules that have the largest kinetic energy escape from the liquid. Then, the average kinetic energy of molecules in the liquid is reduced, and also the temperature of liquid reduces. This is called the **cooling effect of evaporation**.

[The difference between evaporation and boiling]

Evaporation	**Boiling**
Occurs at any temperature	Occurs at the boiling point
Occurs on the surface of liquid	Occurs within liquid
No bubbles	Bubbles appear

[TRY]

How do you feel when spirits are applied on your hand? Why?

2.2. Thermal properties

Thermal expansion

When a body of something is heated, the body increases in size. It is called **Thermal expansion**.

→ When molecules get heat energy, they have more kinetic energy. They move or vibrate more. Then they need larger spaces between them.

Applications of thermal expansion

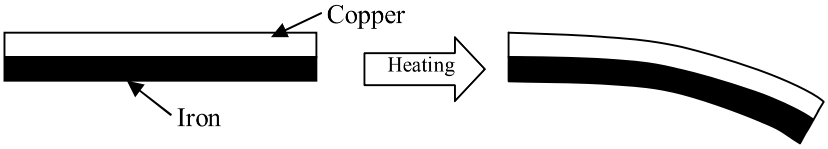
— Thermometer

→ See after next section.

— Bimetallic strip

This is a compound bar made from two metals riveted together. When it is heated, it bends because the metals expand differently.

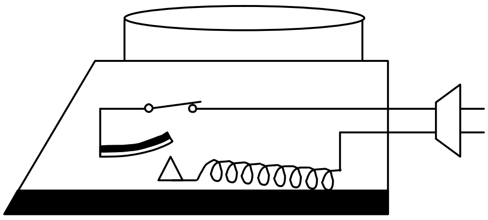
[Bimetallic strip of copper and iron]



Copper expands more than iron when they are headed. It causes the bimetallic strip to bend.

This is used as a thermostat which is a switch to keep the temperature in electrical circuits e.g. a pressing iron, refrigerator and fire alarm.

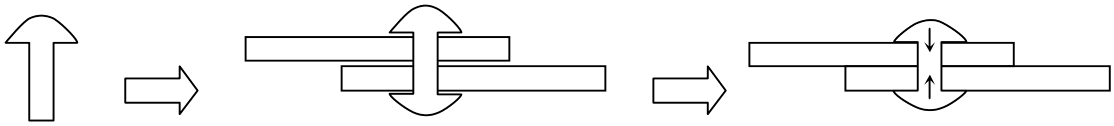
[Electric pressing iron]



When a bimetallic strip is bent by heat, the circuit is disconnected. This system controls the heat on the iron. It is called a thermostat.

— Rivets

Rivets are a form of nail used to hold two metal plates tightly together. If hot rivet is used, the rivet contracts after cooling. It can fix plates tightly.



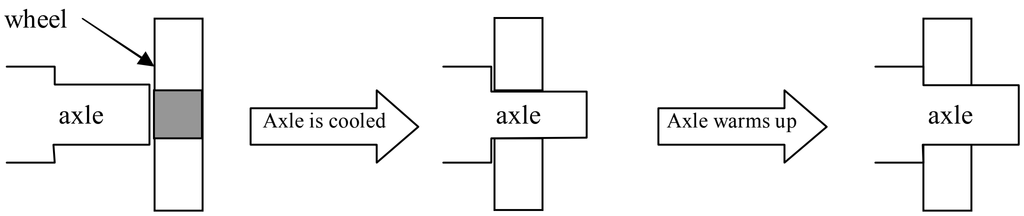
hot rivet

The rivet is still hot. It holds two metal plates.

The rivet contracts after cooling. Then it can fix them tightly.

— Wheel fitting

A slightly larger axles does not fit into the wheel. However it can fit into the wheel by cooling because it is contracted. As it warms up again, it will expand back to its natural size. It causes a tight fit between axle and wheel.

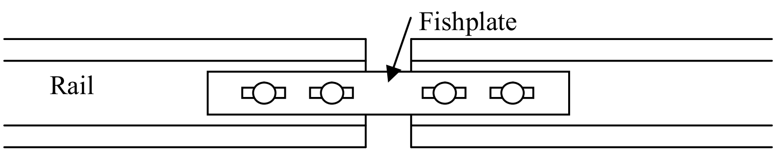


Consequences of thermal expansion

The expansion of materials may cause bad influences. If a solid or a liquid is prevented from expanding, very large forces are exerted. The forces may destroy something. The effects of expansion must be remembered when you design any thing.

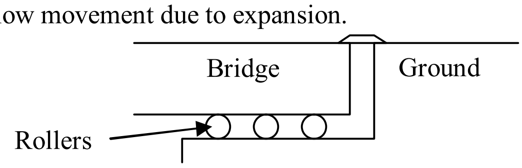
— Railway

The rails of railway lines expand when the temperature rises. The expansion can cause bending of the rails. One way to prevent the rails from bending due to expansion is to leave gaps between the ends of the rails and to join them by “fishplate”.



— Bridge

Metal bridges must be made to allow for expansion on one end of the bridge. One end is usually fixed while the other end rests on rollers to allow movement due to expansion.

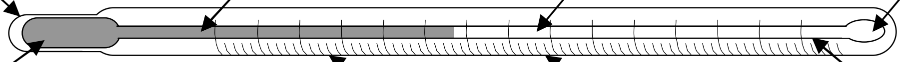


Thermometer

The thermometer is an instrument used to measure temperature. There are different types of thermometers. They make use of a physical property which changes continuously with temperature to show the temperature. The table in the next page shows some thermometers and those physical properties that change with temperature.

Thermometer	Physical property
Liquid-in-glass Thermometer	Volume of a fixed mass of liquid
Thermocouple	Electromotive force (e.m.f.)
Resistance thermometer	Resistance of piece of metal
Constant volume gas thermometer	Pressure of a fixed mass of gas at constant volume

Liquid-in-glass thermometer



The thermometer which utilises the expansion of a liquid to measure temperature is called Liquid-in-glass thermometer. The liquids commonly used in it are mercury and alcohol. The temperature is read at the top of the mercury thread. The most widely used temperature scale is the Celsius scale (^{o}C).

Properties of Mercury and Alcohol

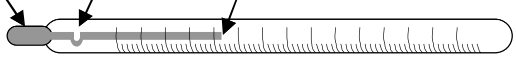
Mercury	Alcohol
It has a high freezing point (-39^{o}C).	It has a low freezing point (-112^{o}C).
It has a high boiling point (357^{o}C)	It has a low boiling point (78^{o}C)
It is silvery coloured and dosen't allow light through. (It is easy to see.)	It is colourless but is made visible by adding colouring.
It expands uniformly. But its expansion is not very large.	It doesn't expand uniformly. However, it expands about six times more than mercury.
It does not wet glass. (It doesn't stick to glass.)	It stick to the wall of the capillary tube when the thread is falling.
It doesn't vaporise at room temperature onto the upper parts of the tube.	It easily vaporises.
It is a good conductor of heat and therefore responds to change in temperature.	It is not a good conductor of heat.
It is poisonous.	It is safe.
It is expensive.	It is cheap.

Clinical thermometer

This thermometeer is used to measure the temperature of the human body. The features of the clinical thermometer are shown below;

— Very sensitive (High sensitivity)
  → Because it has a large bulb
  → Because it has a narrow bore

— Short range
  → The range is from 35 ^{o}C to 42 ^{o}C.
  → It gives greater accuracy.



— Constriction
  → The constriction is a sharp bend in the bore at the bottom of the scale.
  → The constriction prevents the contracting mercury from flowing back into the bulb. It can record the maximum temperature.

— Quick responsiveness
  → Because it has a thin glass wall of the bulb.

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.

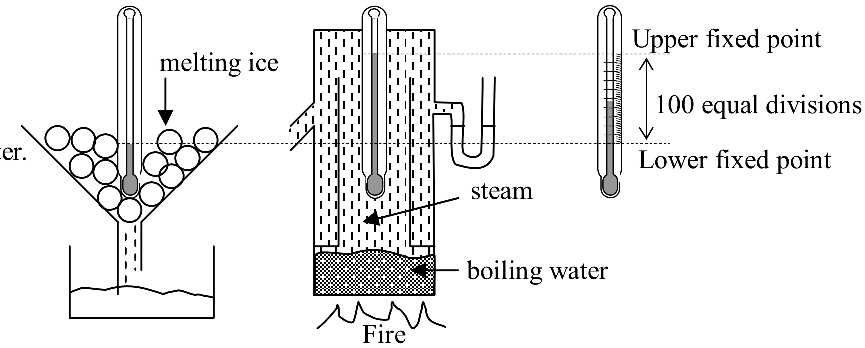
— The lower fixed point
  This is the temperature of pure melting ice. It is 0 ^{o}C. Ice and water are present together at the lower fixed point.

— The upper fixed point
This is the temperature of steam from water boiling under standerd atomospheric pressure. It is 100^{o}C. Water and steam are present together at the upper fixed point.

When pure ice at a temperature below 0^{o}C is heated slowly, the states changes as below;

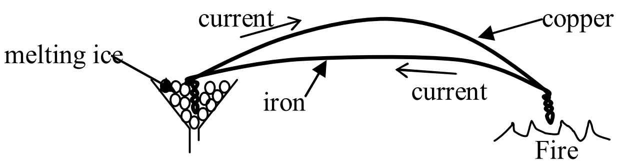
How to mark the temperature scale

(1) Place the bulb in melting ice.
(2) Measure the length of mercury thread. (Mark the lower fixed point.)
(3) Place the bulb in the steam from boiling water.
(4) Measure the length of mercury thread. (Mark the upper fixed point.)
(5) Divide the interval between two fixed points into 100 equal parts.



Thermocouple

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 the two junctions are placed in different temperatures, an electric current flows around the circuit. The amount of the current depends on the difference 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 temperarure by reading the current. Thermocouple is very sensitive and it can measure high temperatures because of high melting point of metals.



2.3. Gas laws

Gas pressure

Definition **Pressure** is defined as the force per unit area acting on the surface.
The unit of pressure is Newton per metre squared [N/m^2]. (or Pascal[[Pa]: 1Pa=1 N/m^2)

→ The gas molecules are in random and continuous motion. They exert a force on the wall of container when they collide to it. Since the force is exerted over an area, pressure is produced.

→ The pressure of a gas of constant volume increases when
- there are more molecules in the gas
- the molecules move faster
- the molecules have a greater mass.

Boyle's law

Law For a fixed mass of a dry gas at constant temperature, The product of its volume and pressure is constant.

Formula $PV = \text{constant}$
P: Pressure [N/m^2]
V: Volume [m^3]

If the initial pressure and volume are P_1 and V_1, and the final ones are P_2 and V_2,

$$P_1V_1 = P_2V_2$$

[Example]
A gas occupies a volume of 2m^3 at 25^{o}C and pressure of 200N/m^2. What would be the volume of the gas if the pressure is reduced to 100N/m^2 at the same temperature?

DATA	Solution
$P_1 = 200\text{N/m}^2$ $V_1 = 2\text{m}^3$ $P_2 = 100\text{N/m}^2$ $V_2 = ?$	$P_1V_1 = P_2V_2$ $V_2 = \frac{P_1V_1}{P_2} = \frac{200\times 2}{100} = \underline{\underline{4\ \text{m}^3}}$

Kelvin temperature scale

SI unit of temperature is Kelvin [K].

- → The size of the degree in Kelvin is the same as in Celsius.
- → According to the calculations (Charle's law), a gas would contract as it cools until at -273 °C. Then, the gas has no volume at -273 °C.
- → -273 °C is called absolute zero (0K).
- → 273 must be added to convert Celsius into Kelvin.

Formula $T_K = T_C + 273$

T_K: Temperature in Kelvin scale [K]
T_C: Temperature in Celsius scale [°C]

[Example]

Convert (a) 0 °C and (b)100 °C into K.

(a) $T_K = 0\,°C + 273 = 273K$
(b) $T_K = 100\,°C + 273 = 373K$

Charles' law

Law The volume of a fixed mass of a gas at constant pressure is directly proportional to its Kelvin temperature.

Formula $\frac{V}{T} = \text{constant}$

V: Volume [m^3]
T: temperature [K]

If the initial volume and temperature are V_1 and T_1, and the final ones are V_2 and T_2,

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

[Example]

The sun heats $15m^3$ of dry air at 27 °C until its volume increases to 16 m^3 under the atmospheric pressure. Calculate the temperature of the air.

DATA	Solution
$V_1 = 15m^3$ $T_1 = 27\,°C = 300K\ (= 27 + 273)$ $V_2 = 16m^3$ $T_2 = ?$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $T_2 = \frac{V_2\,T_1}{V_1} = \frac{16\times300}{15} = \underline{\underline{320K}}$ $T_C = T_K - 273 = 320 - 273 = \underline{\underline{47\,°C}}$

Combination of Boyle's and Charles' laws

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

This equation is called the general gas equation.

[Example]

$15m^3$ of gas is at a pressure of $70N/m^2$ and a temperature of 27 °C. Find its volume when it is at a temperature of 127°C and a pressure of $35N/m^2$.

DATA	Solution
$P_1 = 70N/m^2$ $V_1 = 15m^3$ $T_1 = 27\,°C = 300K\ (= 27 + 273)$ $P_1 = 35N/m^2$ $V_2 = ?$ $T_2 = 127\,°C = 400K\ (= 127 + 273)$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $V_2 = \frac{P_1V_1\,T_2}{P_2T_1} = \frac{70\times15\times400}{35\times300} = \underline{\underline{40m^3}}$

[EXERCISE]

(1) 1.5 m^3 of gas is collected at a pressure of 80N/ m^2. What would be its pressure if it expands to 2.4 m^3 at the same temperature?

(2) Convert the following temperatures;

(a) 47 °C	(b) 32 °C	(c)-13 °C	(from Celsius to Kelvin)
(d) 323K	(e) 300K	(f)272K	(from Kelvin to Celsius)

(3) 4m^3 of a certain gas is at 27°C. Calculate its volume when the temperature is raised to 127°C under atmospheric pressure.

(4) 5m^3 of gas at 27°C is under a pressure of 120kN/m^2. What would be its volume at 0°C and pressure of 91kN/m^2.

1.1. Transfer of thermal energy

Heat transfer

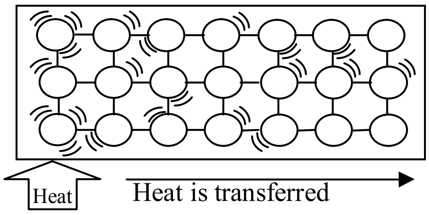
Heat energy is transferred from a higher temperature region to a lower temperature region until the temperatures are balanced. There are three methods by which heat is transmitted from one place to another.

— Conduction
— Convection
— Radiation

Conduction

Definition **Conduction** is defined as the process by which heat is transmitted through a medium from its hotter part to its colder part.

→ At the hotter part, the molecules vibrate actively. They collide with neighbors. Then, the vibration is transferred from the hotter part to the colder part.



Conductivity

Thermal conductivity depends on the materials. For example;

→ Air, wool, cotton, wood, water, glass and plastic are bad conductors.

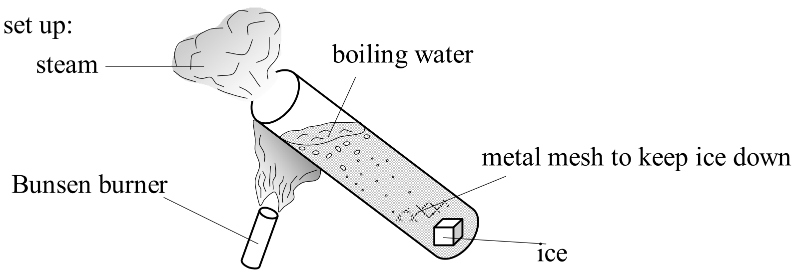
→ Metals (e.g. steel, iron, copper, silver) are generally good conductors.

The relative order is as follows;

(higher conductivity) Metal > Non metal solid > Liquid > Gas (lower conductivity)

Experiment To show that water is a bad conductor of heat.

Experimental set up:



Cautions for the setting:

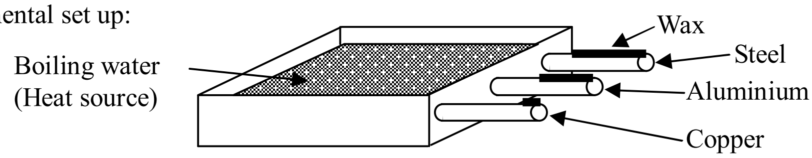
(1) Ice block must be at the bottom of the test tube. (The wire gauze prevents the ice from floating.)
(2) The flame from the Bunsen burner must be placed on the top of water. (It prevents the convection of water.)

Result: When the water on the top begins to boil, the ice block at the bottom does not melt immediately.

Conclusion: Water is a bad conductor.

Experiment To compare the thermal conductivities of metals.

Experimental set up:



Cautions for the setting:

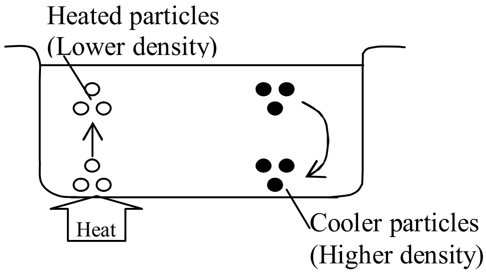
(1) These bars must be the same size (length and diameter).
(2) They begin to heat at the same time.

Result: Melting speeds of the waxes on the bars are in the following order.

Copper → Aluminium → Steel

Conclusion: The copper is the best conductor of the three.

Convection

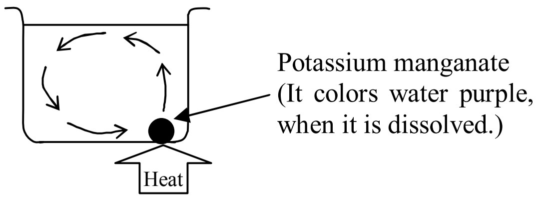


Definition **Convection** is defined as the process by which heat is transmitted from one place to another by the movement of heated particles of a gas or liquid.

- → When we heat a fluid (a gas or a liquid), it expands and its volume increases. Its density is therefore reduced. Hotter fluid surrounded by cooler fluid (higher density) will tend to float. The warmed fluid will move upwards, and it carries heat energy with it.
- → The movement of fluid is called convection current.
- → Convection only occurs in a fluid.
- → Convection current rises vertically from the source of heat where the fluid is hottest.

Experiment To observe convection current in water.

Experimental set up:



Cautions for the setting:

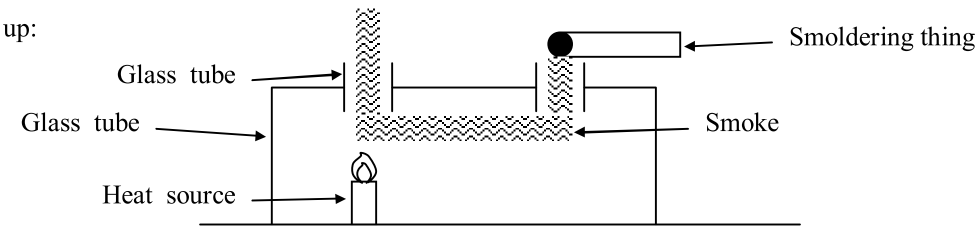
It must be heated at the bottom of the potassium manganate.

Result: The colour changes as shown by arrows.

Conclusion: The coloured path shows the convection current in water.

Experiment To observe convection current in air.

Experimental set up:



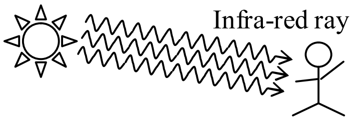
Cautions for the setting:

(1) Smoldering thing must be placed just above the glass tube.
(2) The heat source must be placed under another glass tube.

Result: The smoke produced by the smoldering thing goes down through the tube, flows through the top of the box and comes out the other tube.

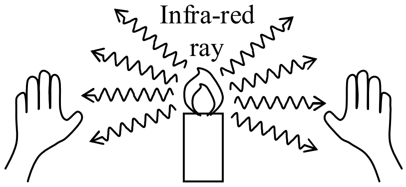
Conclusion: The smoke shows the convection currents in air.

Radiation



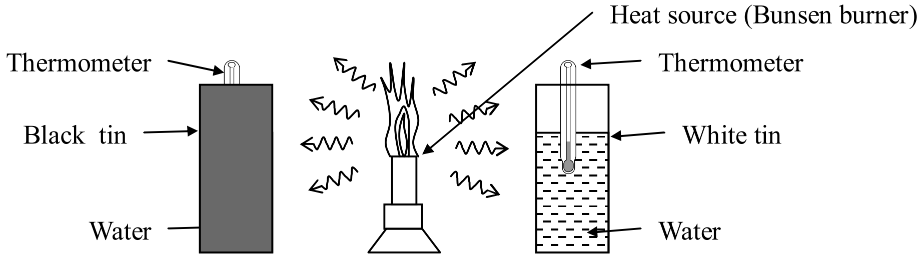
Definition **Radiation** is defined as the flow of heat energy in the form of electromagnetic waves.

→ This process does not require any medium.
→ It can occur in a vacuum space.
→ These electromagnetic waves are called infra-red ray.
→ Infra-red rays are invisible.
→ An object which receives infra-red rays is called an Absorber.
→ An object which releases infra-red rays is called an Emitter.



Experiment To show which surface absorbs heat better (black and white).

Experimental set up:



Cautions for the setting:

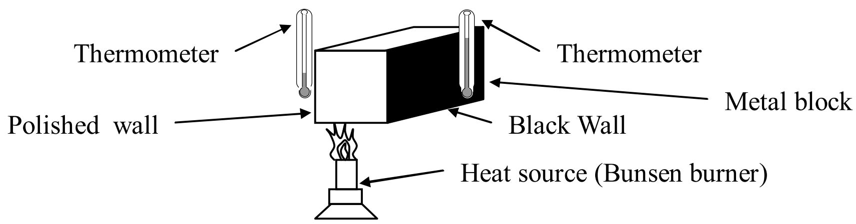
(1) These tins must be the same size.
(2) They must be at the same distance from the heat source.
(3) They must have the same amount of water.

Result: The thermometer in the black tin shows a higher temperature reading than the one in the white tin.

Conclusion: The black (dark) surface is a good absorber of heat.

Experiment To show which surface emits heat better (black and white).

Experimental set up:



Cautions for the setting:

(1) The thermometers must be at the same distance from each wall (don't touch the walls).
(2) The thermometers must be far from the heat source.
(It prevents the thermometers from heating by the heat source directly.)

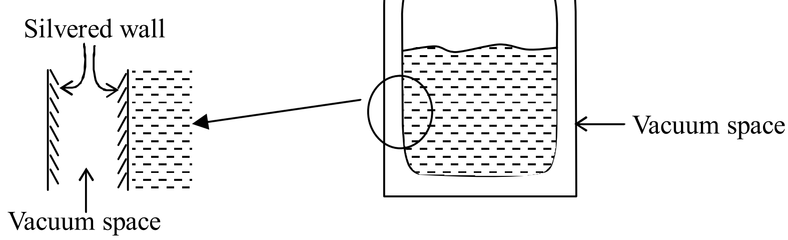
Result: The thermometer near the black wall shows a higher temperature reading than the other.

Conclusion: The black (dark) surface is a good emitter of heat.

→ The dark colour emits and absorbs the heat well, otherwise the bright shiny colour can prevent the heat loss by radiation.

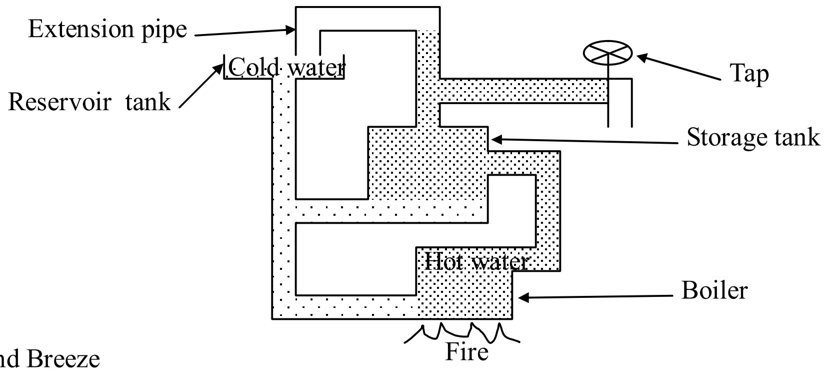
Applications of heat transfer

— Vacuum flask (Thermos flask)
It can keep liquid hot or cold.
→ Vacuum space prevents conduction and convection.
(If there is no particles, conduction and convection don't occur)
→ Silvered wall prevents radiation.



— Hot water system

Water is heated in the boiler. It rises by convecion to the hot water tank, while colder water flows from the tank to the boiler. The convection current keeps the water in the tank hot. When you open a tap, hot water flows out.



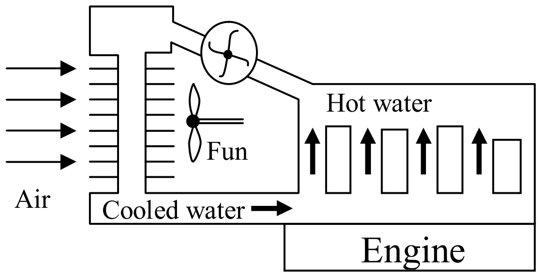
— Sea and Land Breeze

The sun can cause very large convection currents of air. This flow of air is wind. In daytime, The land has higher temperature than the sea. The warm air rises over the land and it is replaced by colder air from the sea. This is called Sea breeze.

At night, the reverse occurs, because the land cools down faster than the sea. This is called Land breeze.

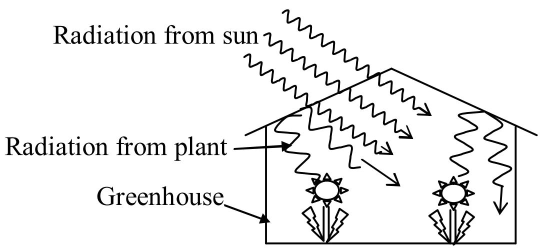
— Radiator

Car engines are cooled by convection current in the water pipe. The radiator is a heat exchanger where water gives up its heat to the air.



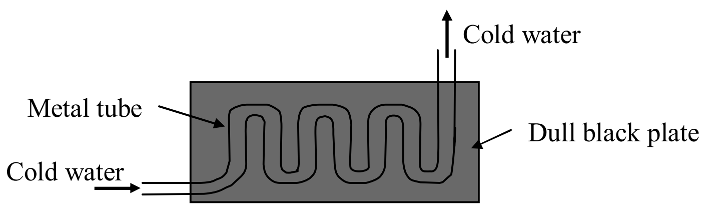
— Greenhouse

A greenhouse is a building made of glass or transparent plastic for growing plants. Radiation from the sun enters through the glass but radiation from the plants can't get out of the glass. It keeps the temperature inside warm.



— Solar panels

In sunny countries, warm water can be produced using solar panels. In one type of panel, a metal tube is welded to the metal plate which is painted dull black. The plate absorbs the sun's radiation, and shares this energy with the water by conduction.



[TRY]

Why are the nails colder than cotton when we touch them?

2. PROPERTIES OF WAVES

2.1. General wave

Wave

Definition A **wave** is defined as the form that some types of energy take as they move.

→ e.g. Water wave, Sound wave, Light wave Electromagnetic wave...

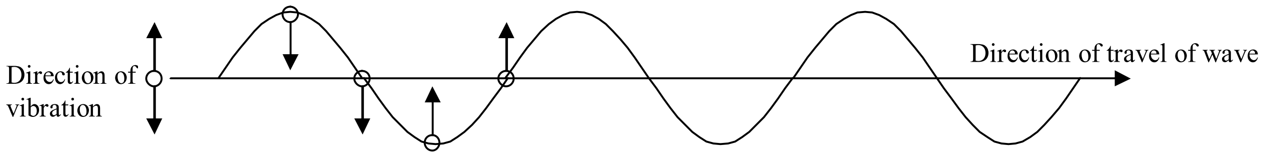
→ There are two types of waveforms;

— Transverse wave

— Longitudinal wave

Transverse wave

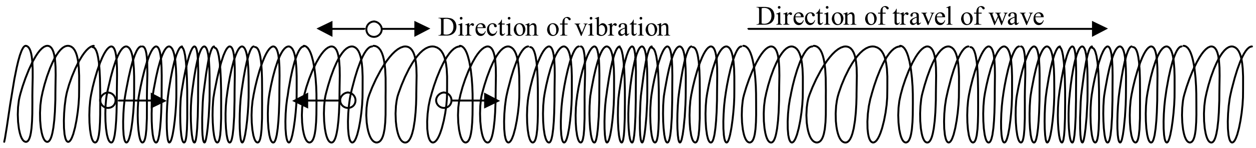
Definition A **transverse wave** is defined as a wave in which the vibrations of the particles are *at right angle* to the direction of the travel of the wave.



Examples of transverse waves are waves on the rope, light waves, electromagnetic waves...

Longitudinal wave

Definition A **longitudinal wave** is defined as a wave in which the vibrations of the particles are *parallel* to the direction of the travel of the wave.



Examples of longitudinal waves are waves on the spring, sound waves...

Wave terms

— Amplitude

Definition **Amplitude** of a wave is the maximum displacement of a particle from its resting position.

→ Unit of amplitude is metre [m].

→ The symbol is A.

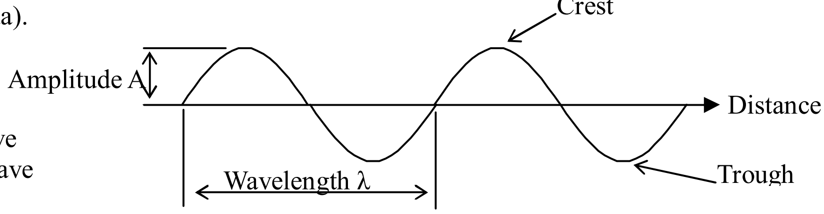
— Wavelength

Definition **Wavelength** of a wave is the minimum distance at which the wave repeats itself.

→ Unit of wavelength is metre [m].

→ The symbol is λ (lambda).

Crest: Highest point of a wave
Trough: Lowest point of a wave



— Period

Definition **Period** of a wave is the time taken for one complete vibration of a particle.

→ In other words, period means the time it takes to make one wave.

→ Unit of period is second [s].

→ The symbol is T.

— Frequency

Definition **Frequency** of a wave is the number of complete waves produced per second.

→ In other words, frequency means the number of waves made in one second.

→ Unit of period is Hertz [Hz]. ($1Hz = 1s^{-1}$)
→ The symbol is f.
→ Relationship between frequency and period is;

Formula $f = \dfrac{1}{T}$

f: Frequency [Hz]
T: Period [s]

— Speed

Definition **Speed** of a wave is distance traveled by the wave in one second.
→ Unit of speed is metre per second [m/s].
→ The symbol is v.

Formula $v = f\lambda$

v: Speed of wave [m/s]
f: Frequency [Hz]
λ: Wavelength [m]

If waves move by a distance of one wavelength (λ) in one period (T), then the wave speed (v) is
$V = \dfrac{\text{distance}}{\text{time taken}} = \dfrac{\lambda}{T} = \lambda \times \dfrac{1}{T} = \lambda f$

[Example 1]
If 100 waves are produced in 5 seconds, what is the frequency?

DATA	Solution
Number of waves = 100 Time taken = 5s	From Question: 100waves → 5s From definition: x waves → 1s $5x = 100$ $x = \dfrac{100}{5}$ $x = \underline{\underline{20Hz}}$

[Example 2]
A wave source of frequency 1000Hz emits waves of wavelength 0.10m.
(a) What is the period of wave?
(b) What is the speed of wave?

DATA	Solution
(a) DATA f = 1000Hz	Solution $f = \dfrac{1}{T}$ $T = \dfrac{1}{f} = \dfrac{1}{1000} = \underline{\underline{0.001s}}$
(b) DATA λ = 0.1m f = 1000Hz	Solution $v = f\lambda = 1000 \times 0.1 = \underline{\underline{100m/s}}$

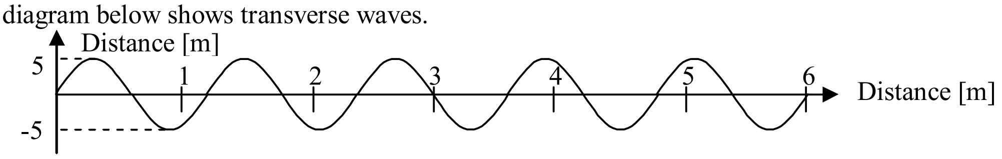
[EXERCISE]

(1) Waves are produced by a vibrator of a frequency 10Hz and the wavelength is 0.2m.
  (a) What is the period of the wave?
  (b) What is the speed of the wave?

(2) Waves travel at 30m/s through a certain medium. If 10waves pass a certain point per second, find
  (a) the frequency
  (b) the wavelength

(3) If 120 waves are produced per minute, find (a) the frequency and (b) the period.

(4) The diagram below shows transverse waves.



  (a) Find the number of waves.
  (b) Find the amplitude of waves.
  (c) Find the wavelength.
  (d) Find the speed of the wave if the number of waves in the diagram are produced in 2 seconds.

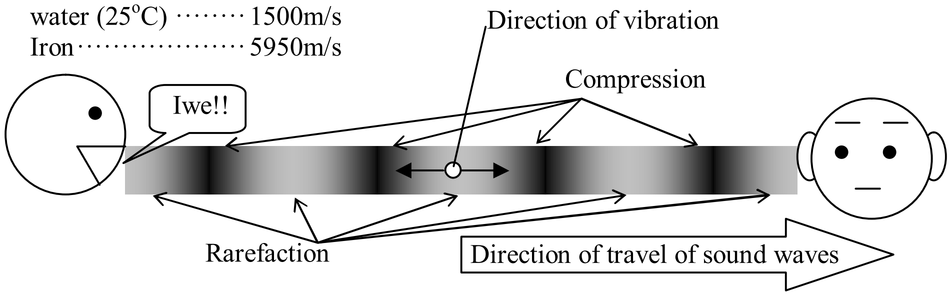
2.2. Sound

Properties of sound

When we talk to someone, the sound is transmitted in the air. In this case, some molecules of air are pushed, and some molecules of air are farther apart. This motion of molecules transmits the sound.

→ Molecules just vibrate to and fro. Molecules do not move across the medium.
→ A slightly higher-pressure place is called compression.
→ A slightly lower-pressure place is called rarefaction.
→ Sound wave is longitudinal wave because the direction of molecular vibration and the direction of traveling sound wave are the same.
→ Sound waves need any medium (solids, liquid and gas) when it is transmitted.
→ Sound cannot travel through a vacuum.
→ Sound travels faster in denser media. (It travels faster in liquids than in gases, and fastest in solids.)

e.g. air (15°C)············ 340m/s
water (25°C) ········ 1500m/s
Iron··················· 5950m/s

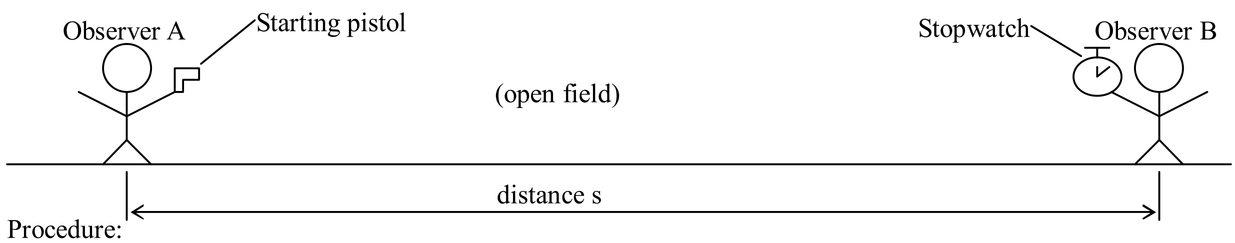


Speed of sound

In the air, sound travels at a speed of about 340m/s (15 °C).

Experiment To determine the speed of sound in air.

— Direct method

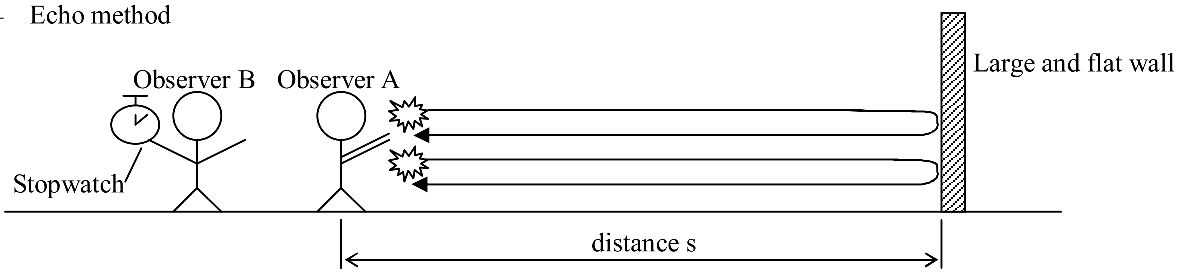


Procedure:

(1) Observer A and B stand at a known distance 's' apart in an open field. Record the distance 's' measured by measuring tape. (s must be set as far as possible. e.g. 500m,1000m)
(2) Observer A fires the starting pistol.
(3) When observer B sees the flash of the starting pistol, he starts the stopwatch.
(4) When he hears the sound, he stops the stopwatch. The time taken 't' is recorded.
(5) The speed of sound v can be calculated by;

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

— Echo method



Procedure:

(1) Observer A and B stand at a distaance 's' from a large and flat wall. Measure and record 's' measured by measuring tape.
(2) Observer A claps hands and listen to the echo. Repeat the clap on hearing the echo.
(3) Observer B start the stopwatch and counting from Zero to the 50th clap. The time taken t_1 is recorded.
(4) The time interval t between each clap can be calculated by;

$$t = \frac{t_1}{50}$$

(5) The speed of sound v can be calculated by;

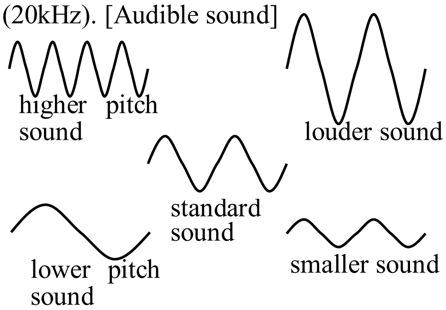
$$v = \frac{2s}{t}$$ (Total distance covered by the echo is 2s. Go and Come)

Pitch of sound

→ The pitch of sound shows how high or low is. For example, girl's voice is high pitched but boy's voice is low pitched.
→ The pitch of sound depends on the frequency. Low pitch is low frequency and high pitch is high frequency.
→ A man can listen sound waves with frequencies ranging from 20Hz to 20000Hz (20kHz). [Audible sound]

Loudness of sound

→ The loudness of sound wave depends on the amplitude of the wave.
→ A sound wave with larger amplitude contains more energy and therefore louder.



[EXERCISE]

(1) Find the speed of a sound in the air if it has a frequency of 1120Hz and a wavelength of 30cm.
(2) A pupil stands 85m in front of a wall. He claps his hands and repeats the claps when he listens the echo. The other pupil who stands with clapping pupil starts a stopwatch at the 10^{th} clap and stops at the 50^{th} clap. The time taken for the all the claps is 20s. Find the speed of sound.

[TRY]

Under the temperature of 15 °C, the speed of the sound is 340m/s. What if the temperature becomes higher?

2.3. Light

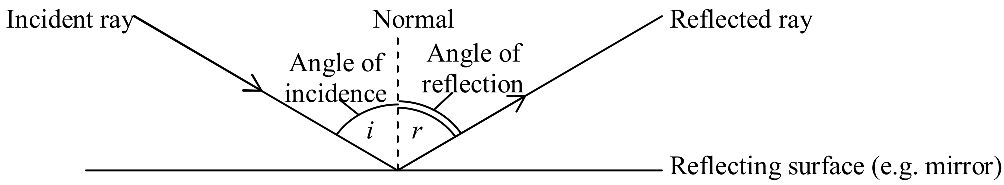
Property of light

→ The light from an object travels in a straight line.
→ There are two way to change the direction of light.
— Reflection
— Refraction

Reflection of light

When a light ray from a light source reaches on the surface of an object, the ray bounces off on it. Then the ray enters our eyes. This is the reason why we can see an object. Especially, the ray bounces of in a regular way on the polished surface such as a mirror.
This bouncing phenomenon of light is called **reflection of light**.

→ The ray that falls on the reflecting surface is called the **incident ray**.
→ The ray that leaves the reflecting surface is called the **reflected ray**.
→ The point where the ray strikes the reflecting surface is called the point of **incidence**.
→ The line drawn at right angles to the reflecting surface at the point of incidence is called the **normal**.
→ The angle between the incident ray and the normal is called the **angle of incidence**.
→ The angle between the reflected ray and the normal is called the **angle of reflection**.



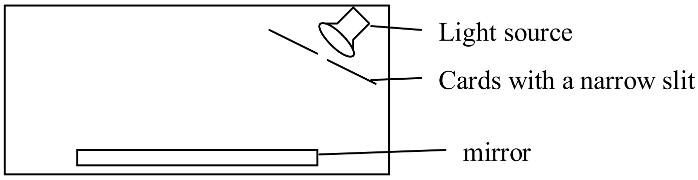
Law Laws of Reflection

1. The angle of incidence is equal to the angle of reflection.
$i = r$
2. The incident ray, the reflected ray and the normal all lie in the same plane.

Experiment To verify the raw of reflection, $i = r$.

Apparatus: Light source (Torch, Sun), Plain paper, flat mirror, cards (notebooks)

Experimental set up:



Procedure:

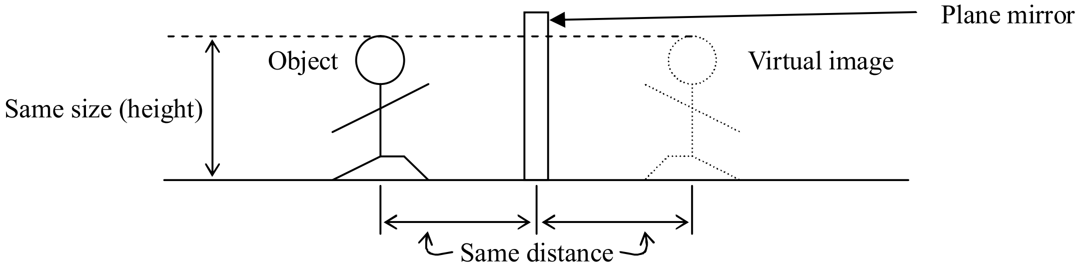
(1) Arrange the apparatus as shown in the diagram.
(2) Mark the position of the mirror with a straight line.
(3) Turn on the torch (The light ray comes through the slit to the mirror.)
(4) Mark the paths of the light before and after reflection by putting a pencil dot at two places each as far apart as possible.
(5) Join each pair of dots with a straight line and extend the line to the mirror position.
(6) Draw a normal on meeting the rays.
(7) Measure and compare the angle of incidence and the angle of reflection.

Conclusion: The angle of incidence and the angle of reflection are equal.

Virtual image (in the plane mirror)

The image which cannot be formed on a screen is called the virtual image. You can see your virtual image in a mirror. In a plane mirror, the properties of the virtual image are shown below.

— The virtual image in a mirror is the same size as the object.
— The virtual image in a mirror appears at the same distance behind the mirror as the object is in front.
— The virtual image in a mirror is laterally inverted. (Right and left are opposite.)



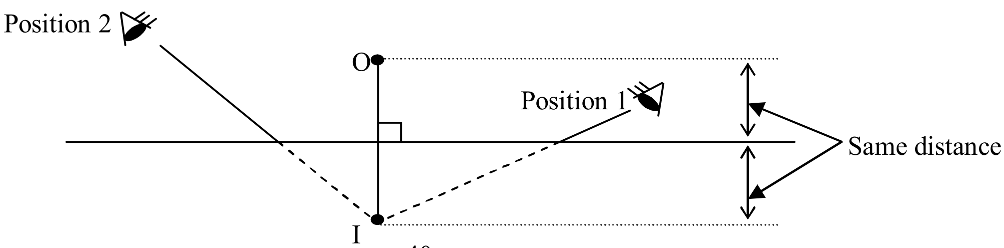
(↔ The image which appears on a screen is called the real image. e.g. pine hole camera, movie)

How to locate the virtual image formed by a plane mirror

(1) Stand a mirror on a plain paper.
(2) Draw the position of the mirror with a straight line.
(3) Stand the object (such as pin) O in front of the mirror and locate the image behind the mirror.
(4) View the image in the mirror from some convenient position 1.
(5) Draw the straight line in front of the mirror from the eye to the image.
(6) Repeat the process (4) and (5) from another position 2.
(7) Remove the mirror and extend those lines behind the mirror with the dotted line.
(8) The intersection of those lines, I, is the position of the image you observed from each position.
(9) Join O and I with a straight line and measure the distance from mirror to O and to I.

→ The distance from the mirror to O is equal to the distance from the mirror to I.

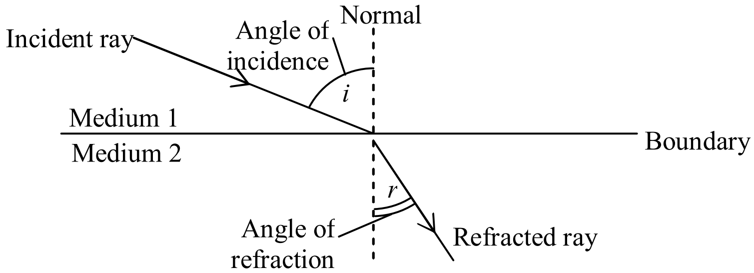
→ The line OI is at a right angle to the line of the mirror.



Refraction of light

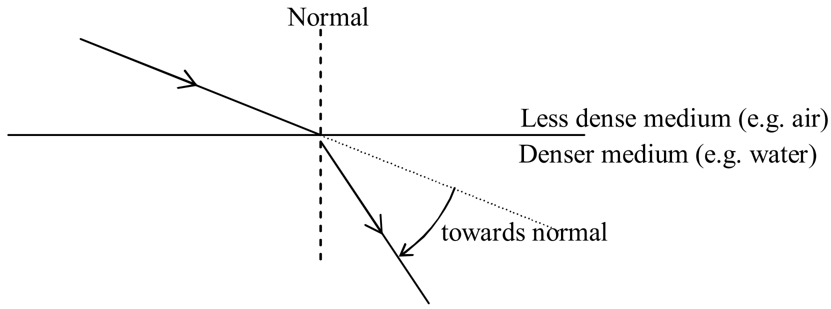
The bending of light as it crosses the boundary between two different media is called **refraction of light**.

→ The ray that falls on the boundary between the two media is called the **incident ray**.
→ The ray bent at the boundary is called the **refracted ray**.
→ The line drawn at right angles to the boundary is called the **normal**.
→ The angle between the incident ray and the normal is called the **angle of incidence**.
→ The angle between the refracted ray and the normal is called the **angle of refraction**.

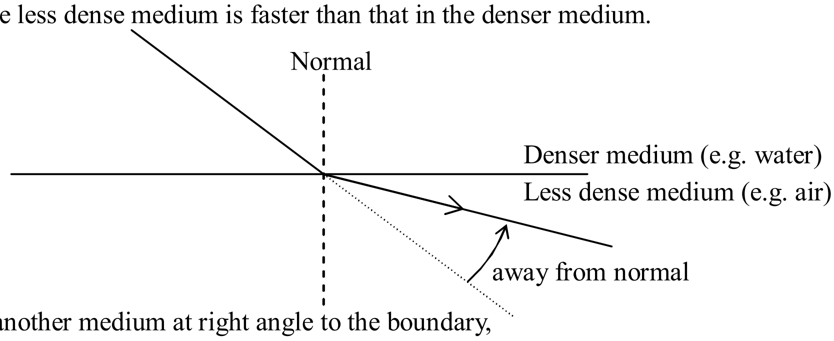


→ Refraction is due to the different speeds of light as it travels from one medium to another.

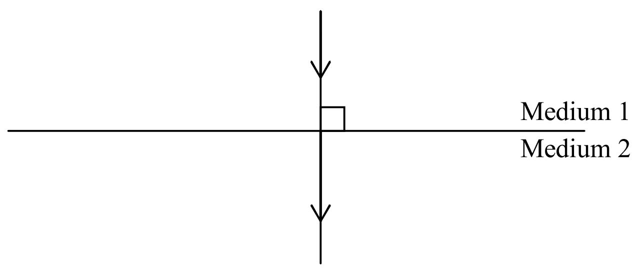
(a) When light travels form less dense to denser medium,
 → light is refracted towards the normal
 → the speed in the denser medium is slower than that in the less dense medium.



(b) When light travels form denser to less dense medium,
 → light is refracted away from the normal
 → the speed in the less dense medium is faster than that in the denser medium.



(c) When light enters another medium at right angle to the boundary,
 → light is not bent.
 → the speed also changes. It depends on media.



Law Laws of Refraction

1. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

Formula $$\frac{\text{Sin } i}{\text{Sin } r} = \text{constant (n)}$$

 → The constant number 'n' is called the **refractive index**.
 → This law is called Snell's law

Examples of refractive index
-water: 1.33
-glass: 1.52
-diamond: 2.42

2. The incident ray, the reflected ray and the normal are in the same plane.

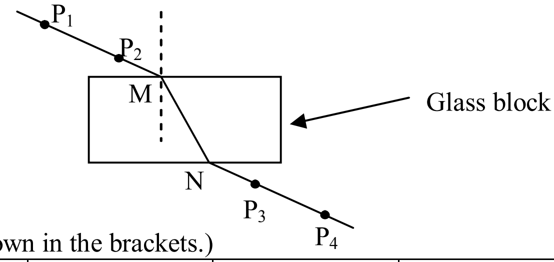
Experiment To verify the raw of refraction (Snell's law).

Apparatus: 4 pins (pens), rectangular glass block, plain paper

Procedure:

(1) Put a rectangular glass block on the plain paper.
(2) Draw the outline of the block.
(3) Put 2 pins on one side of the block. (P_1 and P_2)
(4) Connect P_1 and P_2 with a straight line, and extend it to the surface of the block.
(5) Look at the pins through the block from the opposite side.
(6) Put another pins in line with P_1 and P_2 through the block on the opposite side. (P_3 and P_4)
(7) Connect P_3 and P_4 with a straight line, and extend it to the surface of the block.
(8) Draw a straight line between two boundaries N and M.
(9) Draw the normal at M.
(10) Measure the angle of incidence, *i*, and the angle of refraction, *r*.
(11) Find sine *i*, sine *r* and calculate the refractive index.
(12) Repeat (3) to (11) with different positions.

Experimental set up:



Result: (Samples of results are shown in the brackets.)

i	*r*	sin *i*	sin *r*	$\frac{\text{Sin } i}{\text{Sin } r}$
(39°)	(29°)	(0.6293)	(0.4695)	(1.34)
(57°)	(33°)	(0.8387)	(0.5446)	(1.54)
(17°)	(12°)	(0.2924)	(0.2079)	(1.41)

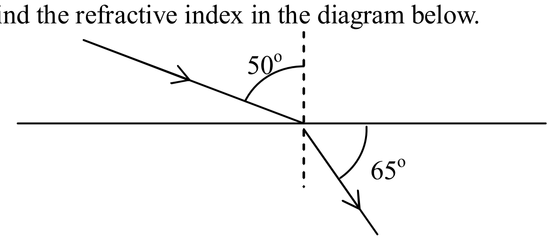
Conclusion:

— The refractive indexes of two fixed materials are almost constant numbers.

— Line P_1P_2 are parallel to the line P_3P_4

[Example 1]

Find the refractive index in the diagram below.



DATA	Solution
$i = 50°$ $r = 90\text{-}65 = 25°$ n = ?	$n = \frac{\sin i}{\sin r} = \frac{\sin 50°}{\sin 25°} = \frac{0.77}{0.42} = \underline{\underline{1.83}}$

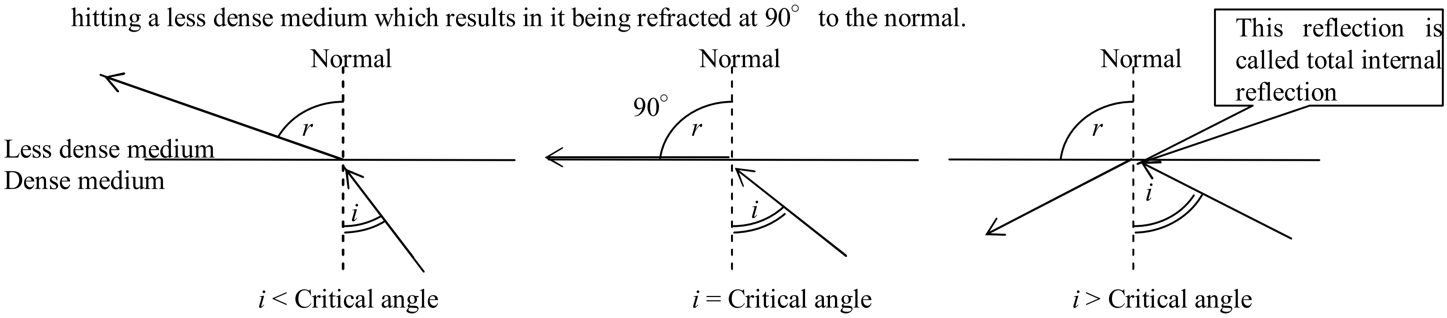
[Example 2]

A ray of light travels from air into water at an angle of incidence 60°. Find the angle of refraction if the refractive index of water is 1.33.

DATA	Solution
$i = 60°$ $r = ?$ n = 1.33	$n = \frac{\sin i}{\sin r}$ $\sin r = \frac{\sin i}{n} = \frac{\sin 60°}{1.33} = \frac{0.87}{1.33} = 0.65$ $r = \sin^{-1}(0.65) = \underline{\underline{41°}}$

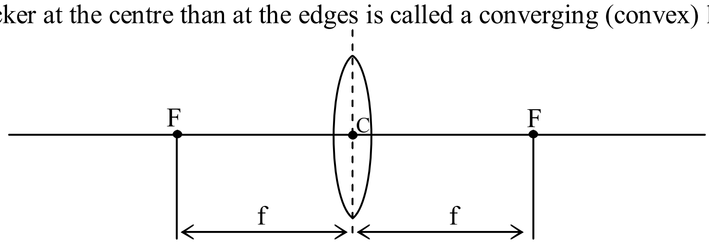
Critical angle

Definition **Critical angle** is the particular angle of incidence of a ray hitting a less dense medium which results in it being refracted at 90° to the normal.



Thin converging lens

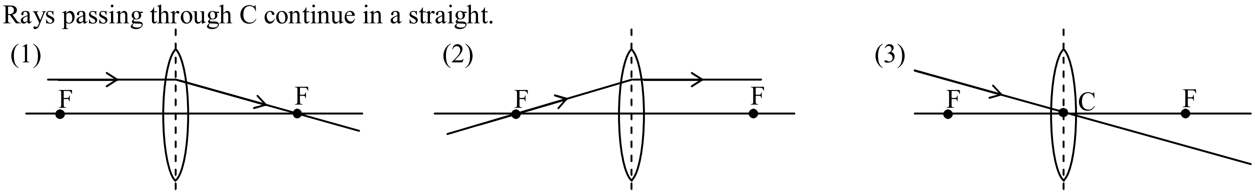
A lens that is thicker at the centre than at the edges is called a converging (convex) lens.



→ The centre of lens is called the **optical centre** (C).
→ The line passing through C and perpendicular to the plane of the lens is called the **principal axis**.
→ The point where rays parallel to the principal axis converge is called the **principal focus** (F).
→ The distance from the optical centre (C) to the principal focus (F) is called the **focal length** (f).

Rules to draw the ray diagram through lens

(1) Rays parallel to principal axis are refracted through F.
(2) Rays passing through F are refracted parallel to the principal axis.
(3) Rays passing through C continue in a straight.

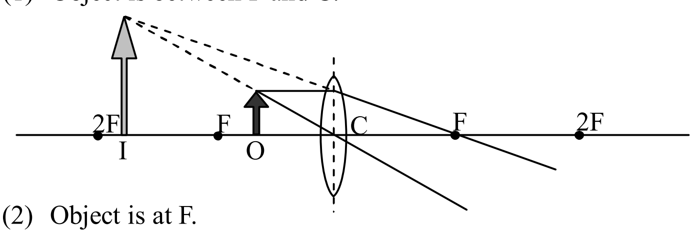


How to locate the image through a lens

(1) Use any two of the rules. (Any two of the rules are enough for locating the image.)
(2) Find the intersection of the refracted rays. It gives the position of the image.
    → If the refracted rays intersect at any point, the image is real.
    → If the refracted rays extend behind the object and the extended lines intersect at any point, the image is virtual.
    → If the refracted rays do not intersect at any point, the image is infinity.

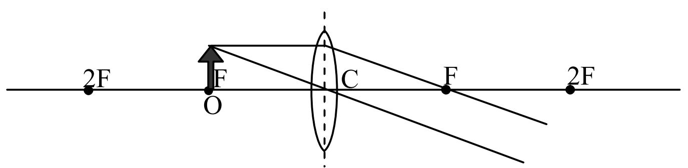
Various image formed by convex lens

(1) Object is between F and C.



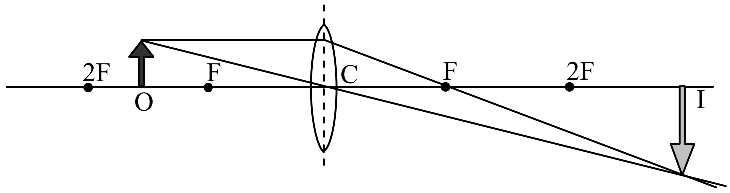
→The image is between F and 2F.
→The image is virtual.
→The image is upright.
→The image is magnified.

(2) Object is at F.



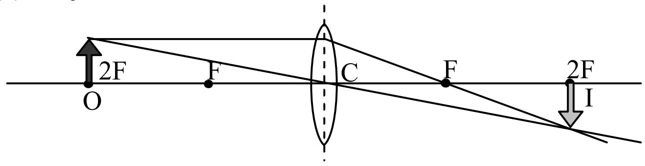
→The image is at infinity.

(3) Object is between 2F and F.



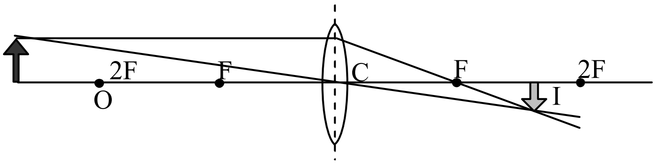
→The image is beyond 2F.
→The image is real.
→The image is inverted.
→The image is magnified.

(4) Object is at 2F.



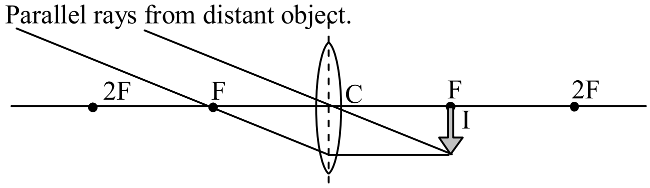
→The image is at 2F.
→The image is real.
→The image is inverted.
→The image is the same size as the object.

(5) Object is beyond 2F.



→The image is between F and 2F.
→The image is real.
→The image is inverted.
→The image is diminished.

(6) Object is at infinity.



→The image is at F.
→The image is real.
→The image is inverted.
→The image is diminished.

Electromagnetic spectrum

Visible light consists of some colours, red, orange, yellow, green, blue, indigo and violet. When you see the rainbow, you can experience a light band. This band of coloured light is called the spectrum. The colours are in order of their wavelength.

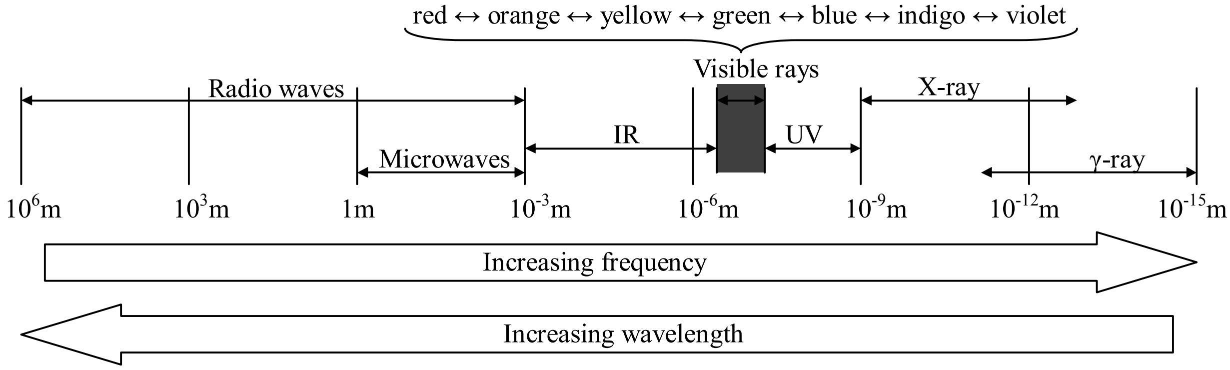
And visible light is one of electromagnetic waves. Electromagnetic waves are named in the order of the ranging of wavelength. They are Radio waves, Microwaves, Infra-red rays (IR), Visible rays, Ultra-violet rays (UV), X-rays and γ(gamma)-rays. This band of electromagnetic waves is called the electromagnetic spectrum.

Properties of electromagnetic waves

Electromagnetic waves have some common properties shown below.

— They transfer energy from one place to another.
— They are all transverse waves.
— They can all travel through a vacuum.
— They all travel at 3×10^8m/s (300,000,000 m/s) in a vacuum.
— The equation ($v=f\lambda$) applies to all of them.

But they have different wavelengths, frequencies and applications.



— γ-ray
They are the most energetic and the most penetrating rays. They are dangerous but also useful for the medical treatment such as radiotherapy.

— X-ray
X-rays have a considerable penetrating power through matter and they also affect photographic films. These two properties make them suitable for use in seeing through objects, e.g. X-ray photographs for bones and metallic structure.

— Ultraviolet rays
The sun emits a lot of ultraviolet rays. However, much of them is absorbed by a layer of ozone in the upper atmosphere of the earth. If much of them reaches our bodies, it can cause damages such as heavy sunburn, eye damage and skin cancer.

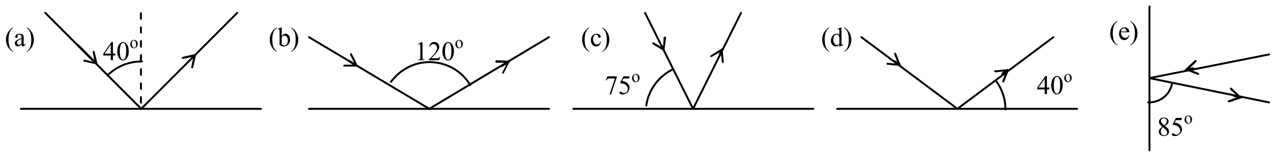
— Infra-red rays
It transfers heat energy but it is invisible. It can be detected by the infra-red photograph (which is used as Night photography) and the thermopile.

— Microwaves
Microwaves are kinds of radio waves. They are used in radar systems, mirowave oven and the communication with satellites.

— Radio waves
Raio waves are used for the broadcasting of radio or TV programmes and cellphones.

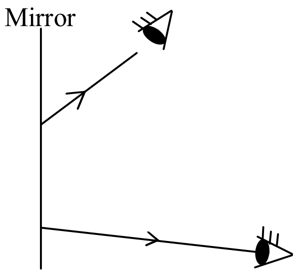
[EXERCISE]

(1) Find the angle of reflection in the diagram below.

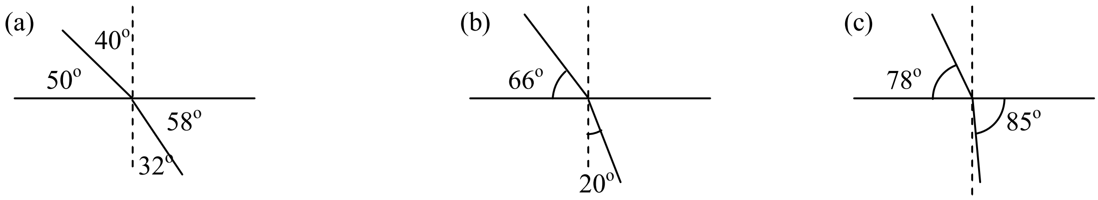


(2) A pupil stands 2m in front of the mirror. Find the distance from the pupil to the image.

(3) The diagram below shows reflected rays of an object from a mirror to your eyes at two positions.
  (a) Locate the image of an object in the mirror and label I on it.
  (b) Find the position of the object and label O on it.



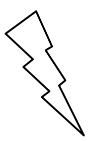
(4) Find the refractive index in the diagram below.



(5) Alight ray travels from air into water at an angle of 50° between the boundary and the incident ray. The angle of refraction is 29°.
  (a) Calculate the refractive index
  (b) Calculate the angle of refraction if the angle between the boundary and the incident ray changes into 70°.

[TRY]

Explain why lightning comes faster than thunder.



3. ELECTRICITY

3.1. Static electricity

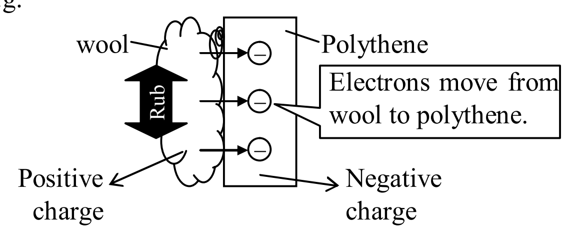
Static charge

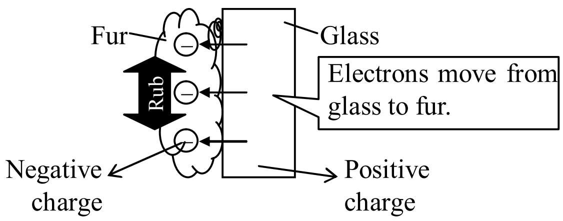
An object can store electric charges that cannot flow. These charges are called **static charges** (**Static electricity**).
For example, when you wear or take off a sweater in very cold and dry season, you can get small amount of electric shock. It is caused as a result of the sweater being charged.

— When is an object charged?
  → When two different substances are rubbed, they are charged.

— How are they charged by rubbing?
  → The atoms of all substances consist of protons, electrons and neutrons. Usually, the atoms have the same numbers of protons and electorons, therefore are electrically neutral. When one object is rubbed with another object, some electrons escape from one object and move on to the other object. One object decreases in electrons. It is positively charged. Otherwise, the other object increases in electrons. It is negatively charged.

e.g.

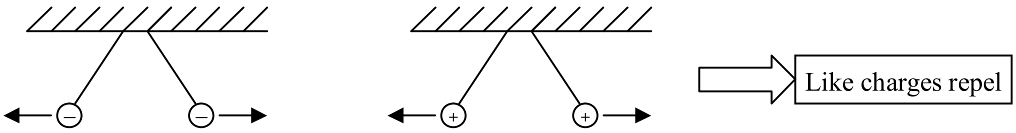




Another example of charge, when you rub a pen by a tissue or your hair, it is also charged. Then, if some small pieces of tissue are placed near the pen, they are attracted.

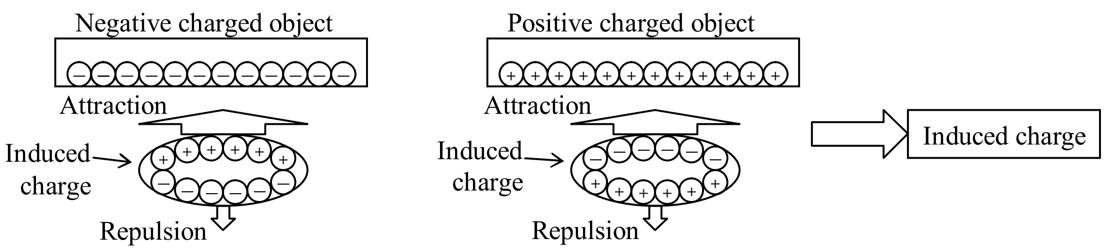
— Why does rubbed pen attract pieces of tissue?
  → If two objects have the same charges, they repel each other. It is called 'like charges repel'(1). Otherwise, if they have different charges, they attract each other. It is called 'unlike charges attract'(2). And any charged object (positive or negative) can attract uncharged objects because charges are induced in an uncharged object. This separate charge in an object is called 'induced charge'(3).
  If a pen is charged, it induces charges on pieces of tissue. Therefore, the pen attracts pieces of tissue.

(1) Repulsion



(2) Attraction

(3) Attraction by induced charge



Lightning

In a thunderstorm, the clouds are charged by friction with airflow. Lightning is the discharge of electrons occuring between two charged clouds or between a charged cloud and the earth. Due to the huge amount of charges on the cloud, it can produce heat which can burn forests, damage houses and kill people.

[EXERCISE]

(1) Two balls, A and B, are brought near each other with the following static charges. Complete the table.

Charge on ball A	Charge on ball B	Attract of repel
+	+	(a)
+	—	(b)
—	(c)	Repel
—	(d)	Attract
+	uncharge	(e)
—	uncharge	(f)

(2) A and B are two balls which carry electric charges. Initially, A has a charge of +4 units and B has a charge of –2 units.
   (a) If 1 unit of positive charge are added to both of them, what will be the direction of the force on A and B?
   (b) If 4 units of negative charge are added to both of them, what will be the direction of the force on A and B?

3.2. Electrical circuit

Current

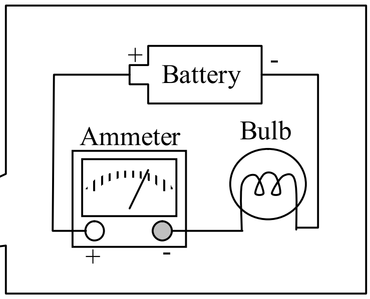
When we use electrical appliances, electric current flows in the circuit. The flowing current means that the electrons flow in thecircuit.

Definition **Current** is defined as the rate of the flow of charge.

The unit of current is ampere [A].
The unit of charge is coulomb [C].

Formula $I = \dfrac{Q}{t}$ (or $Q = It$)

I: Current [A]
Q: Charge [C]
t: time [s]



Instrument for measuring the current → Ammeter

→ An ammeter must be connected to a componnent in series.
→ The positive terminal (usually red terminal) must be connected to the positive terminal of the battery.
→ The negative terminal (usually black terminal) must be connected to the negative terminal of the battery.

[Example 1]

A motor uses a current of 20A for 10s. How much charge flows through it?

DATA	Solution
I = 20A Q = ? t = 10s	$Q = It = 20 \times 10$ $= \underline{\underline{200C}}$

Electromotive force

Definition **Electromotive force (e.m.f.)** of a cell (or battery) is defined as the energy supplied to each coulomb of charge within it.

The unit of e.m.f. is volt [V]. (1V = 1J/C)

Formula $\text{e.m.f.} = \dfrac{E}{Q}$

e.m.f.: Electromotive force [V]
E: Energy supplied by the cell [J]
Q: Charge flow through the cell [C]

Potential difference

Energy carried by charge form a cell or a battery is consumed in electrical components like resistor, lamp, bulb or heater of the circuit. For example, when the charges flow through the bulbs in a circuit, their energy is converted to light and heat energy. This consumed energy is called the potential difference across the component.

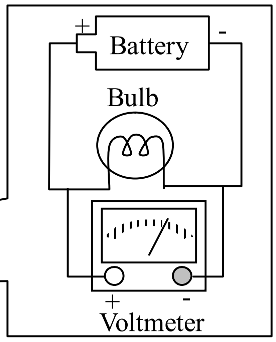
Definition **Potential difference (p.d.)** is defined as the energy converted per unit charge passing through a component.

The unit of p.d. is volt [V].

Formula $$V = \frac{E}{Q}$$

V: Potential difference [V]
E: Energy converted to other forms in the component [J]
Q: Charge flow through the component [C]

Instrument for measuring p.d.→ Voltmeter



→ A voltmeter must be connected across a component in a circuit (parallel to a component).
→ The positive terminal (usually red terminal) must be connected to the positive terminal of the battery.
→ The negative terminal (usually black terminal) must be connected to the negative terminal of the battery.

[Example 1]

60 C of charge flow through a bulb which transfers 180J of energy into light. What is the potential difference?

DATA	Solution
Q = 60C V = ? E = 180J	$V = \frac{E}{Q} = \frac{180}{60} = \underline{\underline{3V}}$

[Example 2]

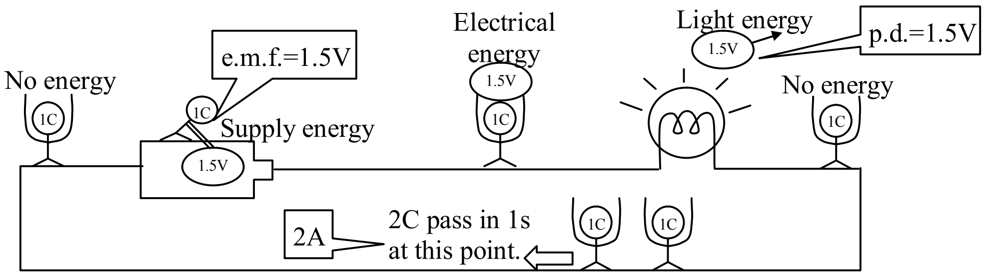
When a current of 2.5A flows for 8s through a bulb, 240J of energy are consumed.
(a) How much charge flows through the bulb?
(b) What is the potential difference across the bulb?

DATA	Solution
(a) Q = ? t = 8s I = 2.5A	$Q = It = 2.5 \times 8 = \underline{\underline{20C}}$
(b) Q = 20C V = ? E = 240J	$V = \frac{E}{Q} = \frac{240}{20} = \underline{\underline{12V}}$

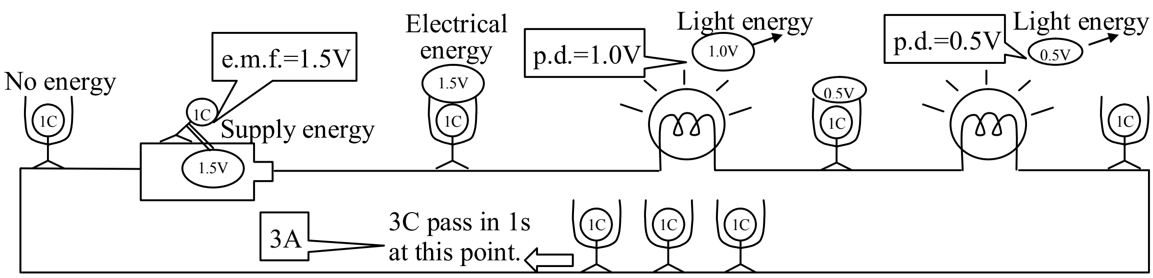
The following example may help the understanding of e.m.f., p.d. and current.

[Example]

(1) If a 1.5Vcell is connected to a 1.5V bulb and 2A of current flows in the circuit.
- → The e.m.f. of the cell is 1.5V. ---------- 1.5J of energy is supplied to one coulomb.
- → The current is 2A. ----------------------- 2C of charges flows in one second at certain point.
- → The p.d. of the bulb is 1.5V.------------ 1.5J of energy is consumed by one coulomb.



(2) If a 1.5Vcell is connected to a 1.0V bulb and a 0.5V bulb, and 3A of current flows in the circuit.
- → The e.m.f. of the cell is 1.5V. --------------------- 1.5J of energy is supplied to one coulomb.
- → The current is 2A. --------------------------------- 3C of charges flows in one second at certain point.
- → The p.d.s of bulbs are 1.0V and 0.5V. ----------- 1.0J of energy is consumed by one coulomb at the first bulb.
  ------------ 0.5J of energy is consumed by one coulomb at the second bulb.



Resistance

Definition The **resistance** in a circuit is the opposition to the flow of current.

The unit of resistance is Ohm [Ω].

→ Some components in a circuit such as a bulb or a heater have resistance.

→ A device which provides some resistance in the circuit is called a resistor.

→ A resisitor which can vary resistance is called the rheostat.

Formula $$R = \frac{V}{I} \qquad \text{(or } V=IR\text{)}$$

R: Resistance [Ω]
V: Potential difference [V]
I: Current [A]

→ This relationship is called **Ohm's law**.

[Example 1]

A current of 2A flows through a conductor. The conductor has the p.d. of 12V. Find the resistance of the conductor.

DATA	Solution
I = 2A R = ? V = 12V	$R= \frac{V}{I} = \frac{12}{2} = \underline{\underline{6\Omega}}$

[Example 2]

Find the p.d. across a 1.5Ω resistor when a current of 4A flows through it.

DATA	Solution
R = 1.5 Ω V = ? I = 4A	$V= IR = 4 \times 1.5 = \underline{\underline{6V}}$

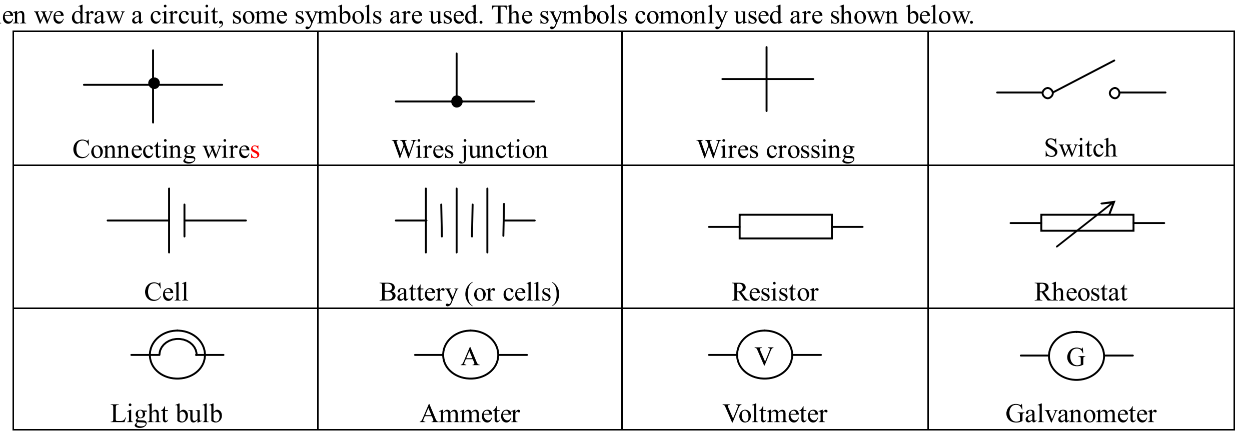
[Example 3]

Find the current flowing through a 5 Ω resistor that has 20V across it.

DATA	Solution
R = 5 Ω I = ? V = 20V	$I= \frac{V}{R} = \frac{20}{5} = \underline{\underline{4A}}$

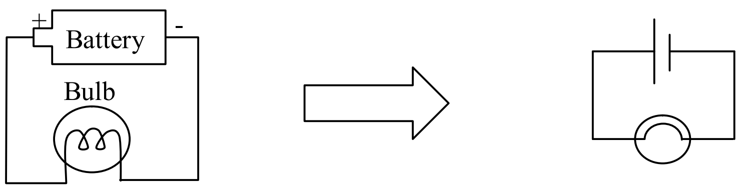
Symbol of electrical component

When we draw a circuit, some symbols are used. The symbols comonly used are shown below.

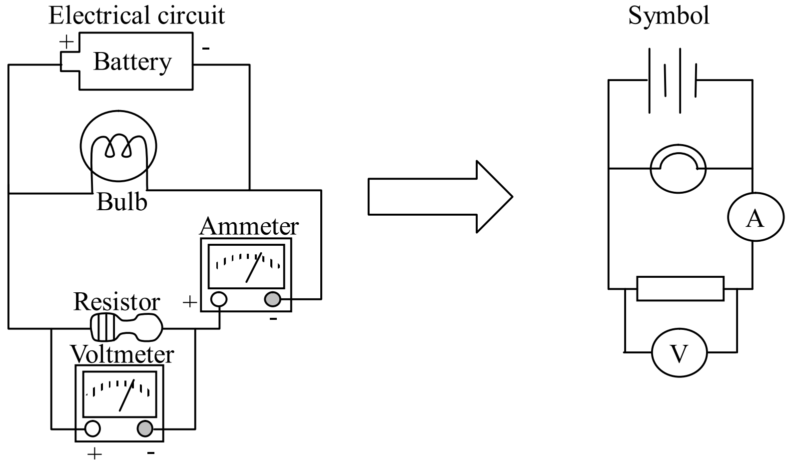


[Example 1]

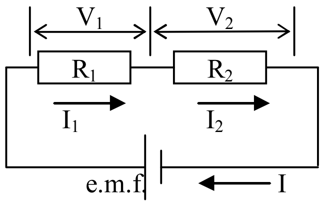
Electrical circuit   Symbol



[Example 2]



Series circuit



→The current is the same at all points in the series circuit.

$$I = I_1 = I_2$$

→The sum of the p.d. V across the resistors (the total resistance) is the same as the e.m.f.

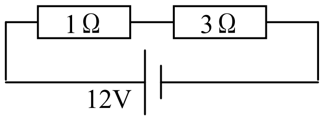
$$\text{e.m.f} = V_1 + V_2 = V$$

→The total resistance, R, of the components connected in series circuit is equal to the sum of the separate resistances.

$$R = R_1 + R_2$$

[Example]

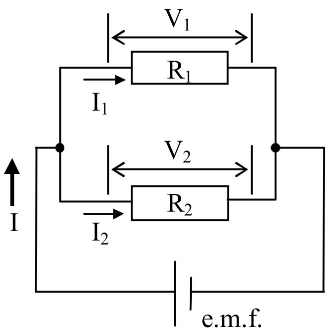
Find (a) the total resistance.
(b) the current through the cell
(c) the p.d. of 1 Ω resistor.
(d) the p.d. of 3 Ω resistor.



	DATA	Solution
(a)	$R_1 = 1\,\Omega$ $R = ?$ $R_2 = 3\,\Omega$	$R = R_1 + R_2 = 1 + 3 = \underline{\underline{4\,\Omega}}$
(b)	$V = V_1 + V_2 = \text{e.m.f.} = 12V$ $R = 4\,\Omega$ $I = ?$	$I = \frac{V}{R} = \frac{12}{4} = \underline{\underline{3A}}$
(c)	$R_1 = 1\,\Omega$ $V_1 = ?$ $I_1 = I = 3A$	$V_1 = I_1R_1 = 1 \times 3 = \underline{\underline{3V}}$
(d)	$R_2 = 3\,\Omega$ $V_2 = ?$ $I_2 = 3A$	$V_2 = I_2R_2 = 3 \times 3 = \underline{\underline{9V}}$

(d) Another method
$\text{e.m.f.} = V_1 + V_2$
$V_2 = \text{e.m.f.} - V_1$
$= 12 - 3$
$= \underline{\underline{9V}}$

Parallel circuit



→The current in the main circuit is the sum of the currents in the separate branches.

$$I = I_1 + I_2$$

→Each component (resistor) in a parallel arrangement has the same p.d. across it.

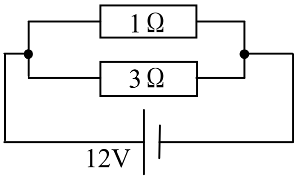
$$V = V_1 = V_2 \ (= \text{e.m.f.})$$

→The reciprocal of the total resistance is equal to the sum of the reciprocal of individual resistances.

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

[Example]

Find (a) the total resistance.
(b) the p.d. of 1 Ω resistor.
(c) the p.d. of 3 Ω resistor.
(d) the current through 1 Ω resistor.
(e) the current through 3 Ω resistor.
(f) the current through the cell.



	DATA	Solution
(a)	$R_1 = 1\,\Omega$ $R_2 = 3\,\Omega$ $R = ?$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1} + \frac{1}{3} = \frac{4}{3}$ $4R = 3$ $R = \frac{3}{4} = 0.75\,\Omega$
(b)	e.m.f. =12V	V_1 = e.m.f. = 12V
(c)	e.m.f. =12V	V_2 = e.m.f. = 12V
(d)	$V_1 = 12V$ $I_1 = ?$ $R_1 = 1\,\Omega$	$I_1 = \frac{V_1}{R_1} = \frac{12}{1} = 12A$
(e)	$V_2 = 12V$ $I_2 = ?$ $R_2 = 3\,\Omega$	$I_2 = \frac{V_2}{R_2} = \frac{12}{3} = 4A$
(f)	$I_1 = 12A$ $I = ?$ $I_2 = 4A$	$I = I_1 + I_2 = 12 + 4 = 16A$

(f) Another method

DATA	Solution
$R = 0.75\,\Omega$ $V = 12V$ $I = ?$	$I = \frac{V}{R} = \frac{12}{0.75} = 16A$

[EXERCISE]

(1) A resistor uses a current of 25A for 6s. Find the charge that flows through the resistor.

(2) In a circuit, a charge of 16C passes through a point in 4s. Find the size of the current.

(3) A current of 5A flows through a cell which supplies 120J of energy in 16s.
(a) How much charge flows through the cell?
(b) What is the e.m.f. of the cell?

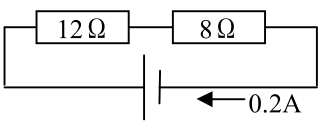
(4) Find the p.d. of a resistor which consume 690J of energy when a current of 3A flows in 10s.

(5) How much current would flow through a resistor of 60 Ω if its p.d. is 150V?

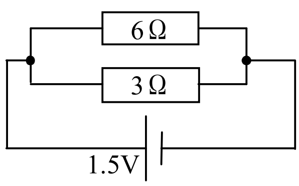
(6) A light bulb has 4 Ω resistance. When 3.5A of current passes through it, what is the p.d. of the bulb?

(7) If 1.8A of current flows through a resistor which has the p.d. of 3.6V, what is the resistance?

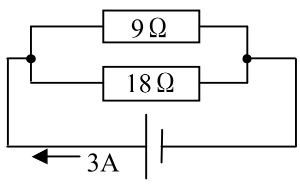
(8) The diagram shows the series circuit. Find
(a) the resistance of the series combination.
(b) the p.d. through the 12 Ω resistor.
(c) the p.d. through the 8 Ω resistor.
(d) the e.m.f of the cell



(9) The diagram shows the paralleled circuit. Find
(a) the total resistance.
(b) the current through the 3 Ω resistor.
(c) the current through the 6 Ω resistor.
(d) the current through the cell



(10) The diagram shows the paralleled circuit. Find
(a) the resistance of the parallel combination.
(b) the e.m.f. of the cell.
(c) the current through the 18 Ω resistor.
(d) the current through the 9 Ω resistor.



[TRY]

Electricity at home is in parallel circuit..Suggest the reason.

3.3. Practical electrical circuit

Electrical power

Examples of electrical power (W)
-cooker: 8000
-heater: 3000
-iron: 700
-TV: 120
-bulb: 60 and 100

$\boxed{\text{Definition}}$ **Electrical power** is defined as the rate of using electrical energy.
The unit of electrical power is watt [W].
→ A bulb of 60W converts 60J of electrical energy into light and heat energy per second.

$\boxed{\text{Formula}}$ $P = VI$

P: Electrical power [W]
V: Potential difference [V]
I: Current [A]

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

$P = \frac{VI\cancel{t}}{\cancel{t}}$

$P = VI$

Since $Q = It$ and $Q = \frac{E}{V}$

$It = \frac{E}{V}$

$E = VIt$

[Example 1]
A 12V battery is giving off a current of 2A to a resistor. Find the power dissipated in the resistor.

DATA	Solution
V = e.m.f. = 12V I = 2A P = ?	$P = VI = 12\times 2 = \underline{\underline{24W}}$

[Example 2]
A p.d. of 12V is applied across the 4Ω resistor. Find the power dissipated in the resistor.

DATA	Solution
V = 12V R = 4Ω I = ? P =?	$I = \frac{V}{R} = \frac{12}{4} = 3A$ $P = VI = 12\times 3 = \underline{\underline{36W}}$

Cost of electrical energy

When you use the electricity supplied by ZESCO, you have the electricity meter. In the meter, you can find the unit of kilowatt-hours (kWh). By using this unit, the cost of electrical energy is calculated. 1kWh is called 1 unit.

How to calculate the cost of electrical energy

(1) Calculate the energy consumed in kwh.

E= Pt
E Energy consumed [kWh]
P: Power of electrical components [kW]
t: time taken [hr]

(2) Calculate the cost of electrical energy by crossmultiplication.

e.g. If electrical energy costs K50 per unit, what is the total cost by using 1000kwh?

1unit → K50
1000unit → x
x = 50 × 1000 = K50,000

[Example 1]
A light bulb of 100W is used for 7hours. What is the energy cost if the energy costs K50 per unit?

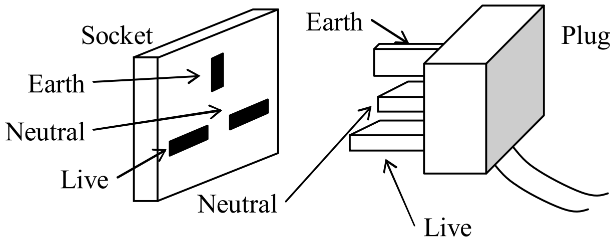
DATA	Solution	
P = 100W = 0.1kW t = 7hrs E = ?	step (1) $E = Pt = 0.1\times 7$ $= 0.7kWh$	step (2) 1unit → K50 0.7unit → x $x = 50\times 0.7 = \underline{\underline{K35}}$

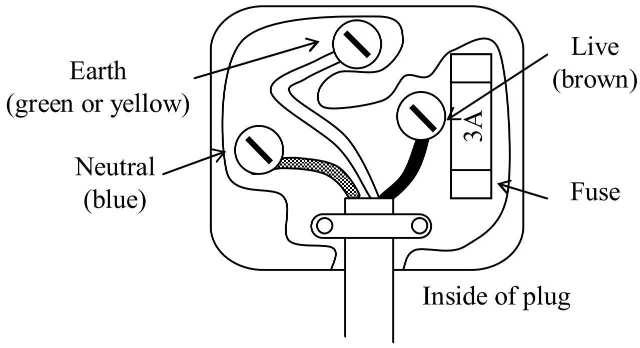
[Example 2]
4-security lights of 120W are turned on for 30days. What is the energy cost if it costs K60 per unit?

DATA	Solution	
$P = 120W\times 4 = 480W = 0.48kW$ $t = 30days = 30days\times 24hrs = 720hrs$ E = ?	step (1) $E = Pt = 0.48\times 720$ $= 345.60kWh$	step (2) 1unit → K60 345.6unit → x $x = 60\times 345.6 = \underline{\underline{K20736}}$

Use of electricity in the house

When we use an electrical appliance in our house, a plug of the appliance is connected to a soket. Zambia uses three pin plugs. (Japan uses two pin plugs.)

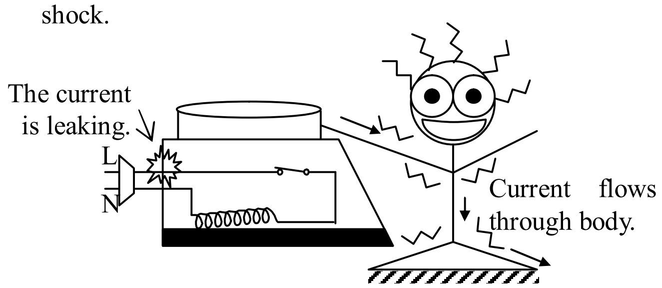


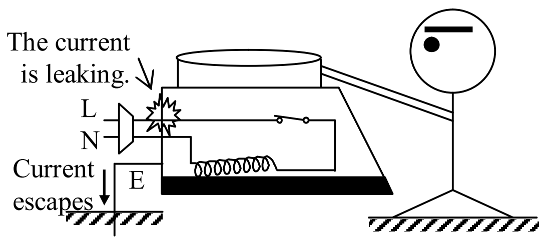


→ Live wire is a brown wire. It supplies the electrical energy to the appliance. The line has a high voltage. If you touch this line, it is dangerous because the current flows through your body. You may die of electric shock.

→ Neutral wire is a blue wire. It makes the circuit complete in the electrical appliance.

→ Earth wire is a green or yellow wire. This wire is connected to the metal casing of an electrical appliance. If live wire is in contact with the metal casing due to any accident, the user gets the electric shock from the metal casing. If earth wire is connected to the metal casing, the current eacapes from the earth wire. It protects the user from the electric shock.





Dangers of electricity

Contacting electricity (especially the live wire) is dengerous and causes some accidents.

→ It causes the electric shock to human beings. A large current can be fatal (die).

→ It may cause fires or burns in an electrical appliance, the plug and the socket.

Dangers of electricity can be caused by three cases shown below.

— Damaged insulation
The electrical wires (cables) are insulated. If those insulators are removed by the deterioration, the live wire can be contacted to somewhere and it can cause electric shock and fire.

— Overheating of cables
If a large current flows in the wires or components, it can cause overheating. Then it can melt the insulation and start a fire. A short circuit or overloading is easy to cause this accident.

— Damp condition
In damp condition such as a wet bathroom, the current flows through the human body easily. Because the body's resistance depends on whether the skin is wet or dry.

Safe use of electricity in the house

To use the electricity safely, there are some electrical components. They are shown below.

— Earth wire
See the explanation above.

— Double insulation
Some electrical appliances are double insulated. It makes the leakage of current difficult.

— Switch
The function of switch is to turn on or off the electrical appliance. In the case of leakage, the switch can be used as the safety device to cut off the current. The switch should be installed on the live wire so that the electrical appliance is disconnected from high voltage when the switch is open.

— Fuse
If too much current flows through an electrical component, the component can overheat or start a fire. The fuse prevents too much current from flowing through it. If too much current flows through a fuse, a wire in the fuse melts

and it intercepts too much current from live wire. Therefore it is installed on the live wire.

Fuse rating

The fuse rating is the maximum current that the fuse can carry without melting. We should choose a proper fuse rating.

→ If we choose a large fuse rating, it allows too much current to flow.
→ If we choose a small fuse rating, the electrical appliance doesn't work.
→ The fuse rating should be slightly larger than the working current of an appliance under normal operation.
→ Available fuse ratings are 3A, 5A, 13A, 15A or 30A.

[Example]

A refrigerator is rated at 240V 480W. Which fuse should be used, 3A or 13A?

DATA	Solution
$V = 240V$ $P = 480W$ $I = ?$	$P = VI$ $I = \frac{P}{V} = \frac{480}{240} = 2A$ 3A is a proper fuse rating.

[EXERCISE]

(1) 5A of current flows in a 12V bulb. Find the power of the bulb.

(2) Two bulbs with resistance of 4Ω and 6Ω are connected in series. In the circuit, 2A of current flows.
  (a) Calculate the p.d. of each bulbs.
  (b) Calculate the power dissipated by each bulb.

(3) A TV of 150W is switched on for 6hours. Calculate the cost assuming it costs K50 per unit.

(4) A heater of 5kW and a cooker of 3kW run for 15hours. If a unit costs K60, what is the total cost?

(5) An electrical cooker of 1kW uses an electrical supply of 240V. Which fuse should be used, 3A, 5A, 13A or 30A?

[TRY]

(1) Two identical bulbs are connected in parallel and series. In which type of circuit are the bulbs brighter? Give a reason in terms of electrical power.

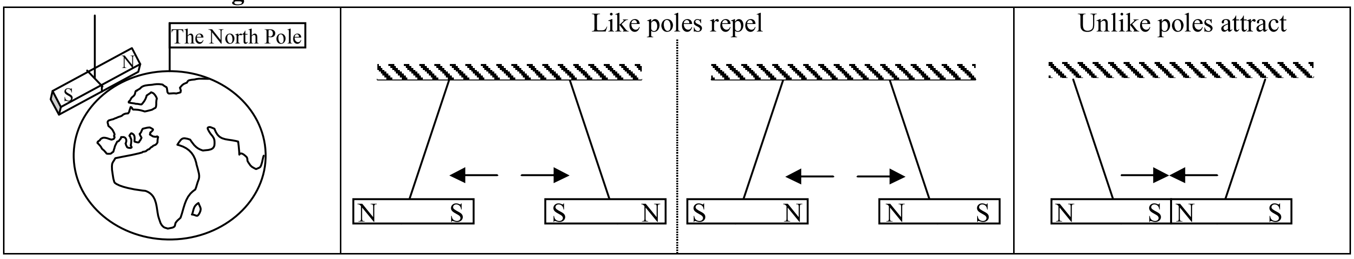
(2) When two bulbs, 60W and 100W, are connected in parallel, which one of them is brighter? What if connected in series? Explain the reason in terms of electrical power.

4. MAGNETISM

4.1. Simple phenomenon of magnetism

Properties of magnetism

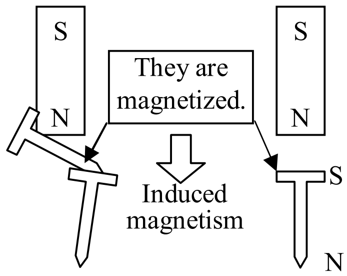
- → The end of a magnet is called the **pole**.
  - → If a light magnet hangs on a string, one end points towards the North. This end is called **the North pole**.
  - → The other end points towards the South. This end is called **the South pole**.
- → The same poles (North and North pole, South and South pole) repel. It is called '**Like poles repel**'.
- → The different poles (North and South pole) attract. '**Unlike poles attract**'.
- → Magnets attract some materials, e.g. iron, cobalt, nickel, steel… These materials that can be attracted to a magnet are called **magnetic materials**. Other materials, e.g. copper, plastic, paper, wood, that can't be attracted to a magnet are called **non-magnetic materials**.



Induced magnetism

Definition **Induced magnetism** is the temporary magnetisation of a magnetic material when it is placed near to or in contact with a magnet.

- → If a nail is placed in contact with a permanent magnet, the nail is magnetised. And it also attracts another nail.
- → The end of a nail nearer (connected) to the North pole of a permanent magnet becomes the induced South pole, and the other end becomes the induced North pole.

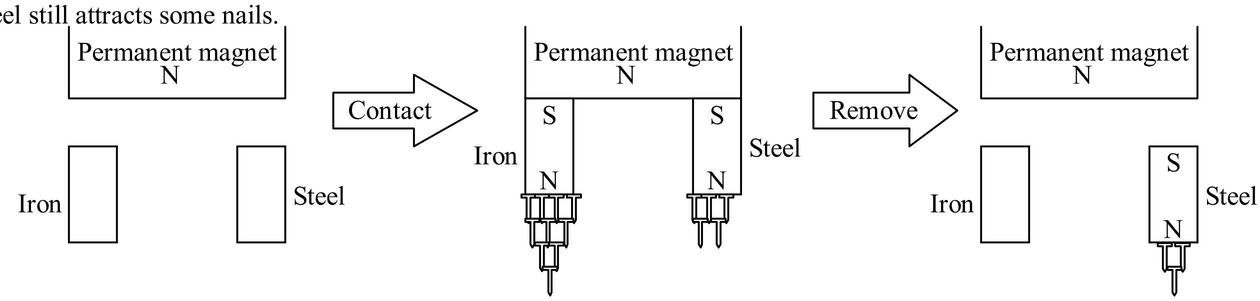


Magnetic materials (Iron and Steel)

Iron and steel are common magnetic materials. But they have different properties as shown below.

Material	Iron	Steel
Magnetise	Easy and strong	Hard and weak
Demagnetise	Easy	Hard
Application	Electromagnet	Permanent magnet
Example	Transformer, Electric bell	D.C. motor Generator
Named	Soft magnetic material	Hard magnetic material

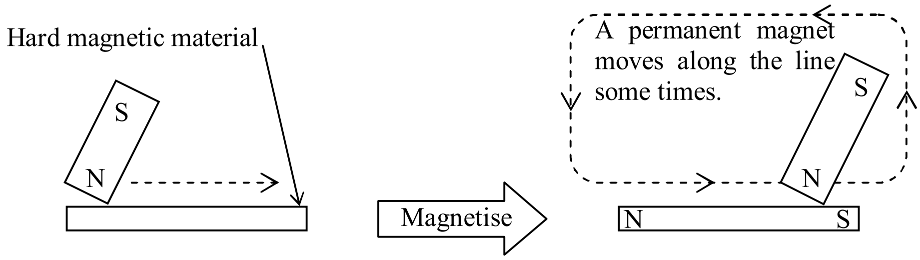
If iron and steel are placed in contact with a permanent magnet, they are induced. Then, they attract some small nails. Iron attracts more nails than steel. And then, if they are removed from the permanent magnet, iron releases the nails soon but steel still attracts some nails.



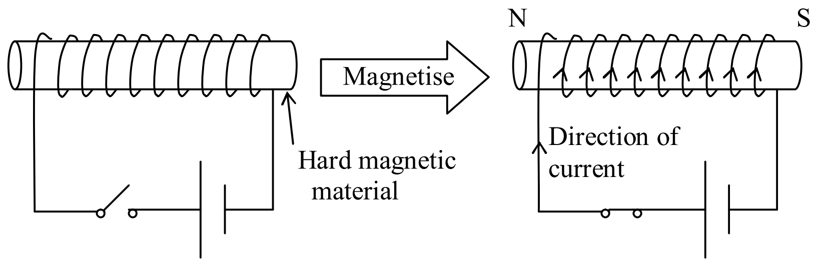
Magnetise

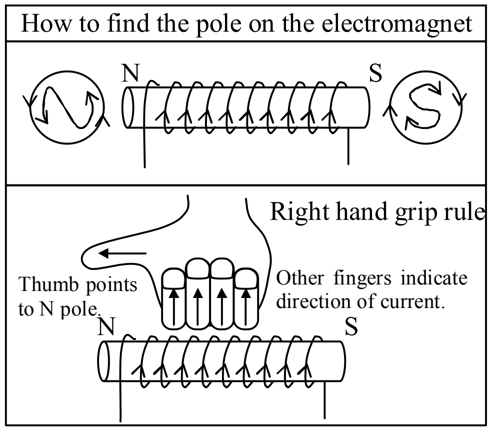
How to make a permanent magnet (How to magnetise a hard magnetic material)

— Stroking method
If permanent magnets are stroked along a hard magnetic material, the hard magnetic material is magnetised and it is changed into a permanent magnet.



— Electrical method
If a hard magnetic material is palaced into a solenoid (Direct current), a hard magnetic material is magnetised and it is changed into a permanent magnet.





→ This is the best method to make powerful magnets.
→ The magnet which is made with a solenoid is called the electromagnet.
→ In the boxes, it shows how to find (decide) the poles.

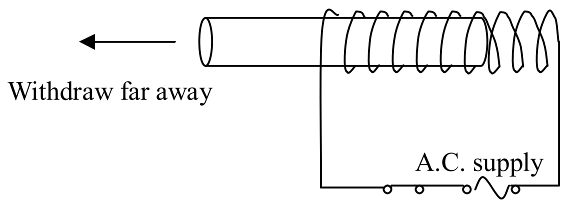
Demagnetise

How to demagnetise a hard magnetic material

— Heating
If a magnetised material (magnet) is heated to a higher temperature, it will lose its magnetism very quickly.

— Hammering
If a magnetised material (magnet) is hammered many times, the magnetism becomes weaker and weaker.

— Use alternating current and the solenoid
A magnet is placed inside a solenoid which has an A.C. supply. When the magnet is withdrawn far away from the solenoid, this process is repeated, the magnet is demagnetised.



Electromagnet

→ Iron is commonly used as the core of electromagnets because it is easy to magnetise and also demagnetise. (It is easy to control the magnetism.)
→ The strength of magnetism depends on
  — the current
  — the number of turns per unit length of the solenoid
  — the material of core

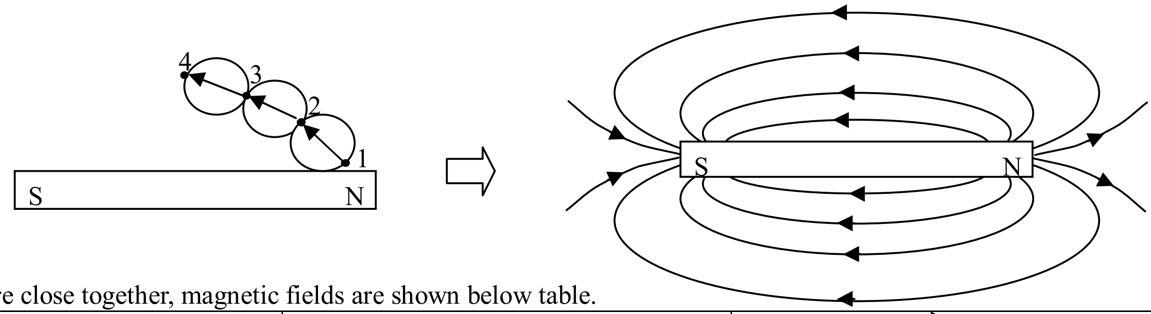
Magnetic field

Definition **Magnetic field** is defined as the region around a magnet where magnetic effect can be detected.

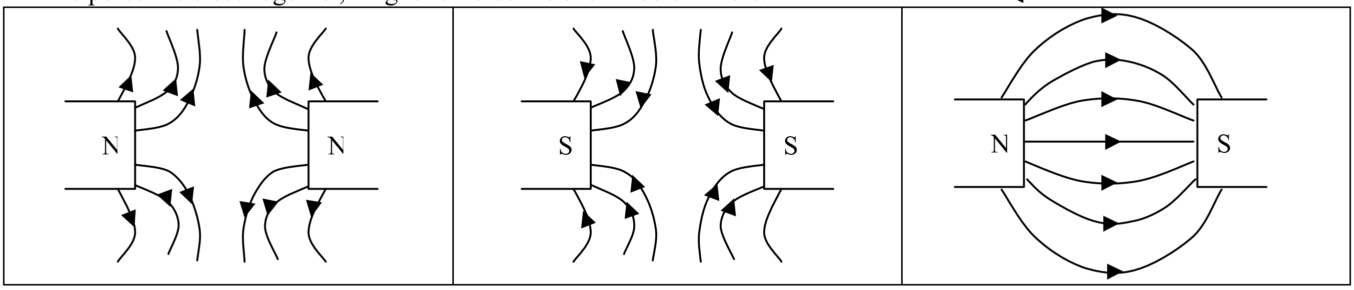
How to draw the magnetic field lines

(1) Place a bar magnet on a plane paper.
(2) Place the compass near one end of the magnet.
(3) Plot two dots (1 and 2) at the ends of the needle.
(4) Move the compass to the position where the previous dot 2 is with another pole.
(5) Plot one dot (3) at the other end of the needle.
(6) Repeat (4) and (5) until the compass reaches to the other pole of the magnet.
(7) Connect dots from one end of magnet to another

(8)



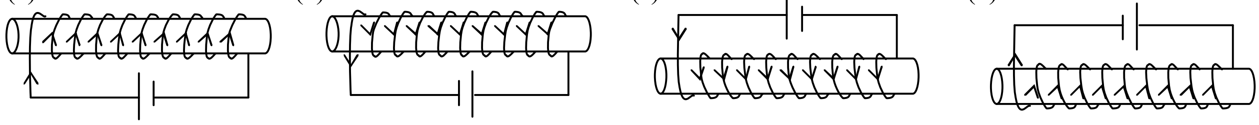
If two poles are close together, magnetic fields are shown below table.



[EXERCISE]

(1) Draw the Magnetic field of a U-magnet around the poles.

(2) Find the North pole of the electromagnet below. The arrows show the direction of current.



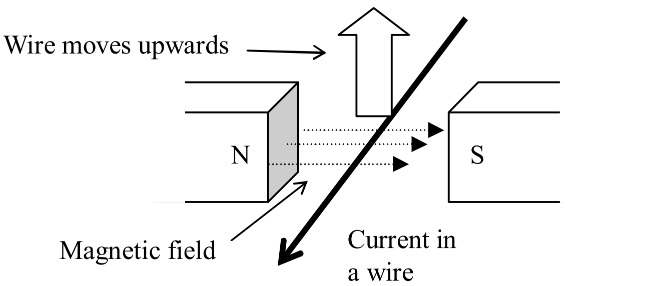
(3) If you make an electrical bell, which material is best for it, iron or steel. Give the reason for your answer.

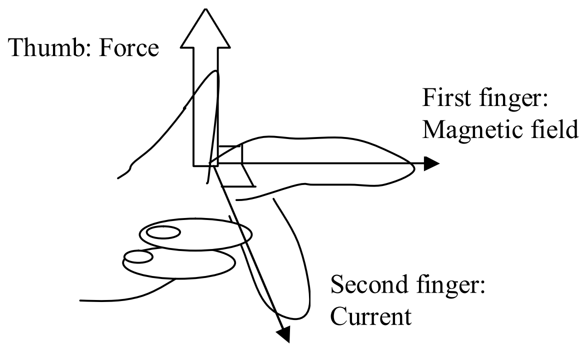
4.2. Electromagnetic effect

Fleming's left-hand rule

If a current flows in a wire, in a magnetic field, a force acts on the wire.

→ The direction of force can be found by Fleming's left hand rule.. <Fleming's left hand rule>





Electromagnetic induction

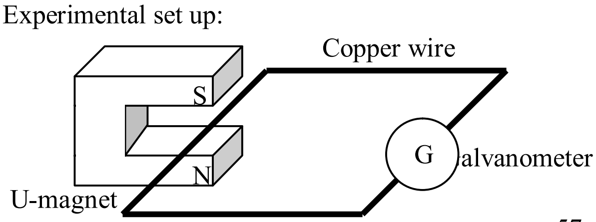
Definition If any electrical conductor (e.g. copper wire) move in the magnetic field and cut the magnetic flux, an e.m.f. is induced in the conductor. This is called **Electromagnetic induction**.

Law The strength of the induced e.m.f. is proportional to the rate of change of the magnetic flux.

→ This law is called Faraday's law of electromagnetic induction.

Experiment To observe the electromagnetic induction

Experimental set up:



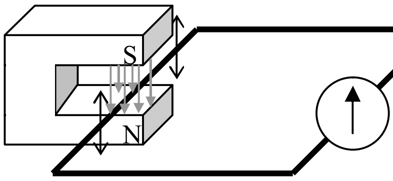
Operations:

(1) Move the wire up and down between ends of U-magnet.

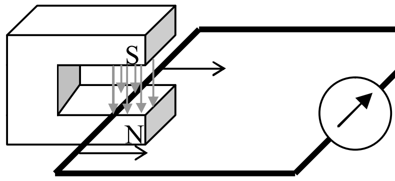
(2) Withdraw the wire from U-magnet.

Result:

(1) The pointer in the galvanometer doesn't deflect.



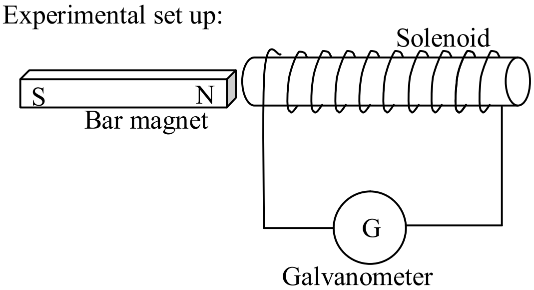
(2) The pointer in the galvanometer deflects.



Conclusion: When the copper wire cut the magnetic flux (the wire moves perpendicular to the direction of magnetic field), an e.m.f. is induced in the wire.

Experiment To observe the electromagnetic induction by the solenoid

Experimental set up:

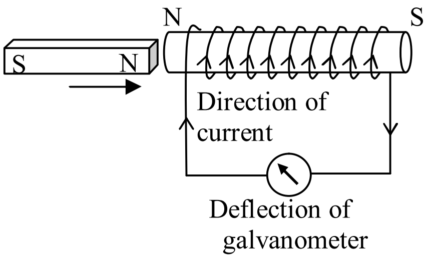


Operations:

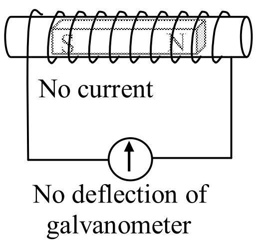
(1) North pole of the magnet move into the solenoid.
(2) The magnet is stationary in the solenoid.
(3) North pole of the magnet move away from the solenoid.
(4) South pole of the magnet move into the solenoid.
(5) South pole of the magnet move away from the solenoid.

Result:

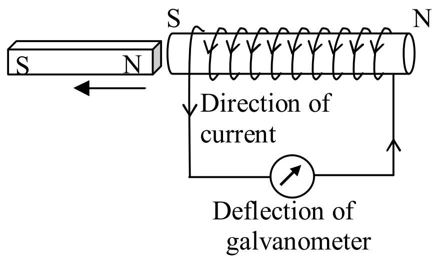
(1) North pole of the magnet moves into the solenoid.



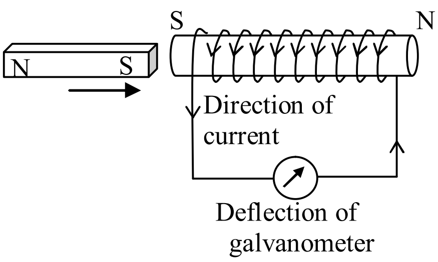
(2) The magnet is stationary in the solenoid.



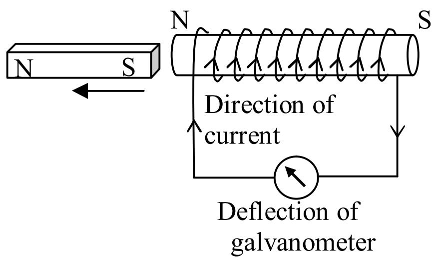
(3) North pole of the magnet moves away from the solenoid.



(4) South pole of the magnet moves into the solenoid.



(5) South pole of the magnet moves away from the solenoid.



Conclusion: If a magnet moves towards a solenoid, the solenoid makes a magnetic field tending to repel it.
If a magnet moves away from a solenoid, the solenoid makes a magnetic field tending to attract it.
Then current flows according to their magnetic field.
This law is called Lenz's law.

To increase the e.m.f (induced current),

— move the magnet at higher speed.
— use a stronger magnet.
— increase the number of turns in the coil.

Simple A.C. generator

→ A.C. Generators generate alternate current by electromagnetic induction.
→ Alternate current is the current which changes its direction a number of times per second.
→ The structure of a simple A.C. generator is shown in the diagram.
→ The components and functions are shown below.

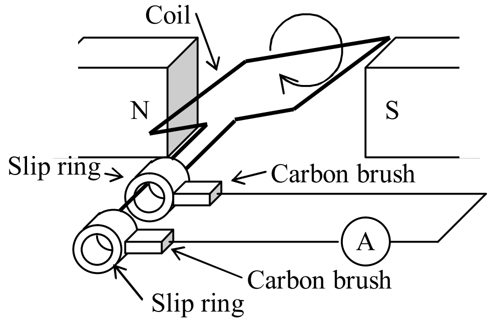
— Coil
Coil produces electricity by electromaagnetic induction.

— Permanent magnet
Permanent magnets produce the magnetic field.

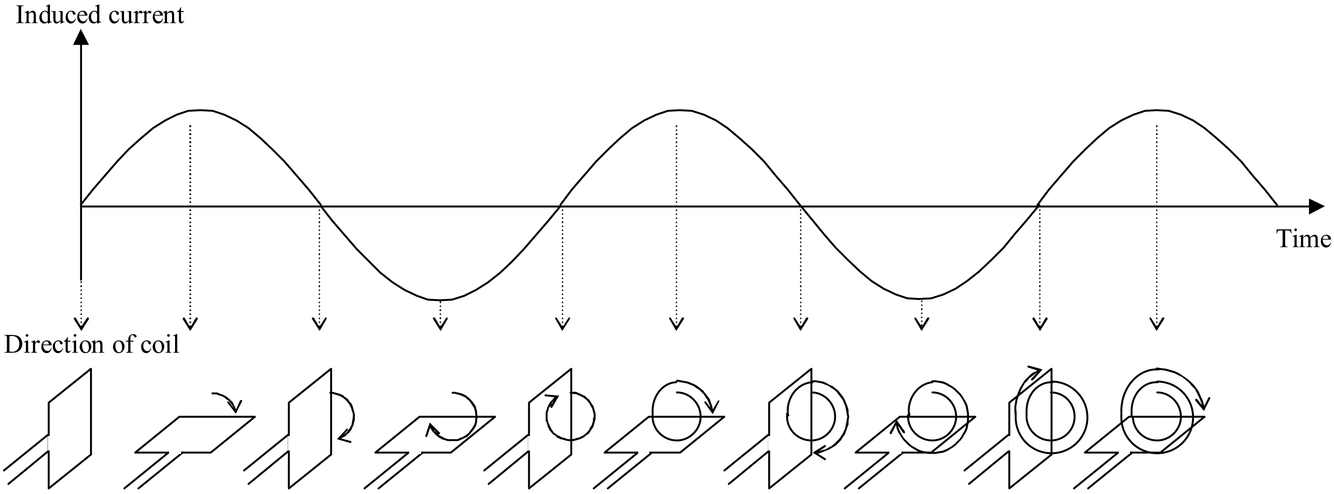
— Carbon brush
Carbon brushes keep the contact with the rings continuously.
Then coil is electrically connected to the outer circuit.

— Slip ring
Slip rings are fixed to the coil.
All of them are drivers rotating in a body by the outside power source like an engine or a turbine.

→ If slip rings are replaced with split ring commutators, the generator becomes a direct current generator.



→ The diagram below shows the relationship between the induced current and directions of the coil in the A.C. generator.



→ To increase the induced current(e.m.f.),
— the coil should rotate faster.
— a stronger magnet should be used.
— the number of turns in the coil should be increased.
— the coil should be wound around a soft iron core.

→ The frequency of the induced current is the number of revolutions of the coil per second.
→ Zambia uses the power supply of 240V 50Hz. This means the induced current has 50waves per second. This also means that the coil rotates 50 times in one second.

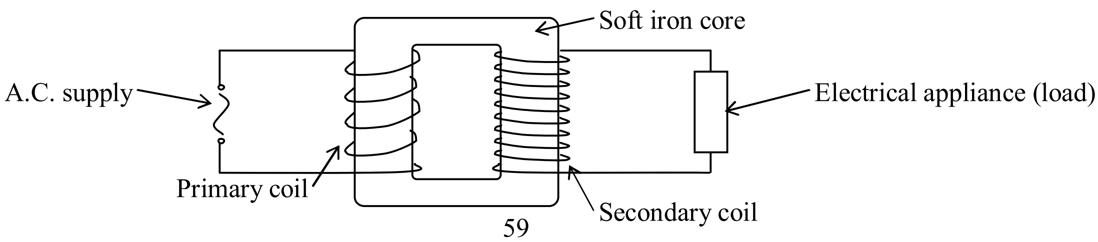
Transformer

Definition **Transformer** is a device used to vary the voltage of an a.c. supply.

→ When the electricity is generated at the power plant, its voltage is higher than the useful voltage for our houses. Some transformers are connected between the power plant and our houses, and vary the voltage of supply from the plant to the houses.

→ Each country has each voltage of a.c. supply for the houses. For example, Zambia has the a.c. supply of 240V. But Japan has the a.c. supply of 100V. If Japanese electrical appliance is used in Zambia, a transformer is needed to change the voltage of a.c. supply 240V to 100V. If it is connected to Zambian direct power supply, it may break because the voltage of supply is too high for the Japanese electrical appliance.

→ A transformer consists of a primary coil, a secondary coil and a soft iron core.



→ Operation

(1) The primary coil is connected to a.c. supply, and the secondary coil is connected to loads (electrical appliances).

(2) When the alternate current is supplied to the primary coil, it produces magnetic field and changes the direction of magnetic field frequently.

(3) An induced e.m.f. of the same frequency is produced in the secondary coil.

→ The voltage of secondary coil is decided by the voltage of primary coil, the number of turns in the primary coil and the number of turns in the secondary coil. The formula is given as below.

Formula
$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

V_s: Voltage of secondary coil [V]
V_p: Voltage of primary coil [V]
N_s: Number of turns in secondary coil [Turns]
N_p: Number of turns in primary coil [Turns]

→ Step-up transformer

— The voltage in the secondary coil (output voltage) is higher than the voltage in the primary coil (input voltage).

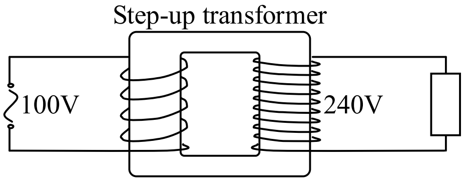
— The number of turns in the secondary coil is greater than the number of turns in the primary coil.

→ Step-down transformer

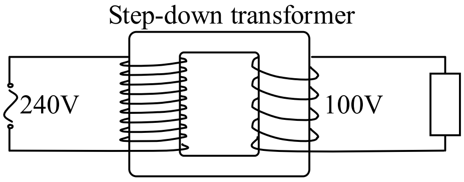
— The voltage in the secondary coil (output voltage) is lower than the voltage in the primary coil (input voltage).

— The number of turns in the secondary coil is fewer than the number of turns in the primary coil.

Step-up transformer



Step-down transformer



→ If a transformer has the efficiency of 100% (called the ideal transformer),

$P_s = P_p$

$V_s I_s = V_p I_p$

Formula
$$\frac{V_s}{V_p} = \frac{I_p}{I_s}$$

V_s: The voltage of secondary coil [V]
V_p: The voltage of primary coil [V]
I_s: The current in the secondary coil [A]
I_p: The current in the primary coil [A]

[Example]

A step-up transformer increases the voltage of a.c. supply from 110V to 220V. The primary coil dissipates the power of 1.1kW. And the efficiency of transformer is 100%.

(a) If the turns in the primary are 400, how many turns are in the secondary?

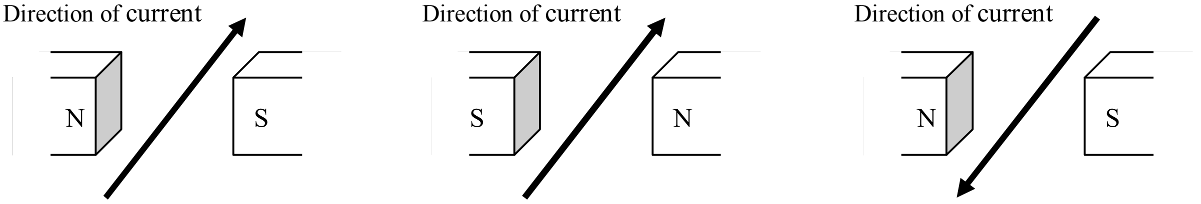
(b) How much current flows in each coil?

(a) DATA $V_p = 110V$ $V_s = 220V$ $N_p = 400$ $N_s = ?$	Solution $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ $N_s = \frac{V_s}{V_p} N_p = \frac{220}{110} \times 400 = \underline{\underline{800 \text{turns}}}$
(b) DATA $V_s = 220V$ $V_p = 110V$ $P_p = 1.1kW$ $= 1100W$ $I_p = ?$ (i) $I_s = ?$ (ii)	Solution $P_p = V_p I_p$ (i) $I_p = \frac{P_p}{V_p} = \frac{1100}{110} = \underline{\underline{10A}}$ (ii) $\frac{V_s}{V_p} = \frac{I_p}{I_s}$ $I_s = \frac{V_p}{V_s} I_p = \frac{110}{220} \times 10 = \underline{\underline{5A}}$

[EXERCISE]

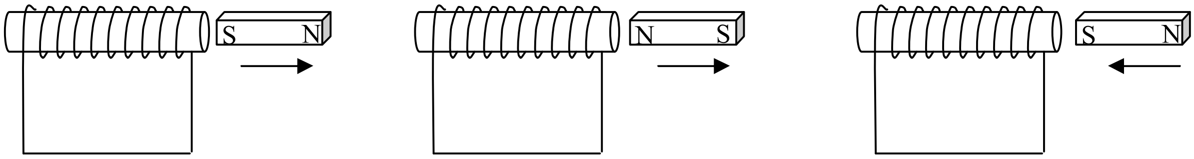
(1) Find the direction of the force actiong on a wire in each situation.

(a) (b) (c)



(2) Draw the direction of an induced current in each situation.

(a) (b) (c)



(3) A transformer has a primary coil of 8400 turns and a secondary coil of 3500 turns. Find the output voltage if 240V is supplied to the primary coil.

(4) A power plant supplies 25kV voltage of a.c. supply. The voltage increases to 230kV through a step-up transformer.
   (a) If 15000 turns coil is in the primary, calculate the number of turns in the secondary.
   (b) 230kV of voltage is transformed again through a step-down transformer. The turns ratio of the primary coil to the secondary coil in the transformer is 115 to 6. Calculate the voltage of the secondary coil.

(5) 240V of voltage is supplied to the primary coil and 5A of current flows through it. Find the current flowing through the secondary coil if the output voltage is 120V and the efficiency is 100%.

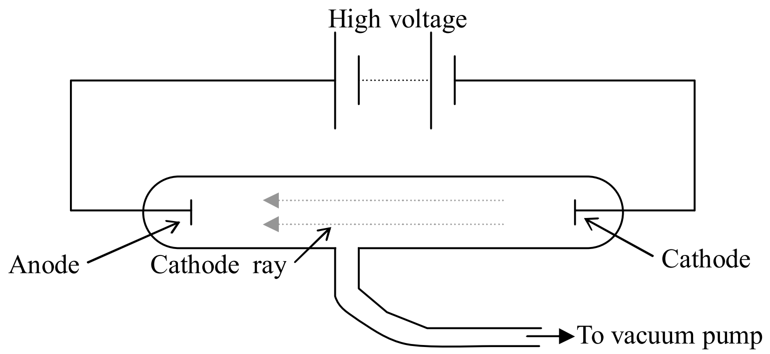
(6) A refrigerator that is rated at 120V 480W is connected to the transformer. The transformer is connected to the power supply of 240V. Assuming that the efficiency is 100%. Calculate;
   (a) the current through the refrigerator.
   (b) the current from the power supply.
   (c) If the turns in the primary are 8500, how many turns are in the secondary?

5. INTRODUCTORY ELECTRONICS

5.1. Electron

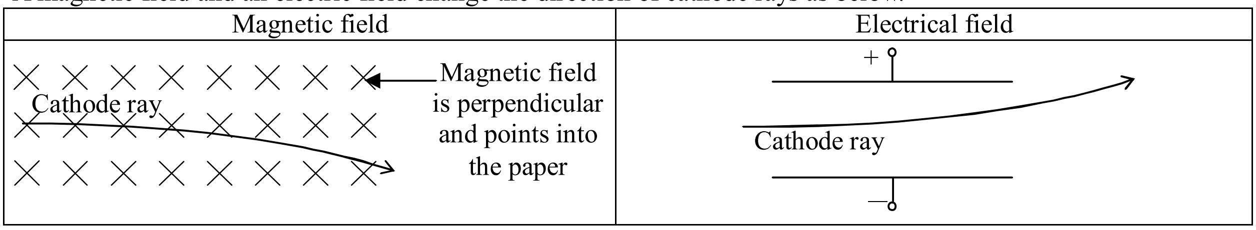
Emission of electron

→ If electorodes (cathode and anode) are set in vacuum and connected to high voltage of power supply, **electrons** are emitted from the **cathode** (Negative side of circuit) and flow to the **anode** (Positive side of circuit).
→ A hot surface emits electrons. This emission of electrons from a hot surface is called **thermionic emission**.
→ The flowing of electrons from cathode to anode is called the **cathode ray**.

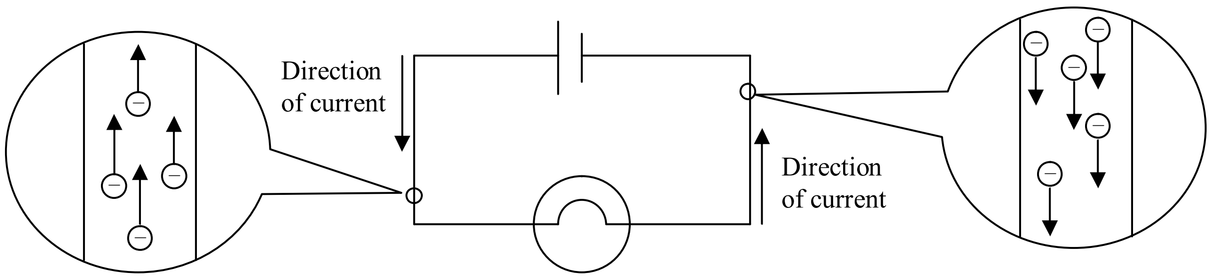


Characteristics of an electron

→ An electron has a smaller mass than a proton or a neutron.
→ Cathode rays travel in straight lines.
→ A magnetic field and an electric field change the direction of cathode rays as below.



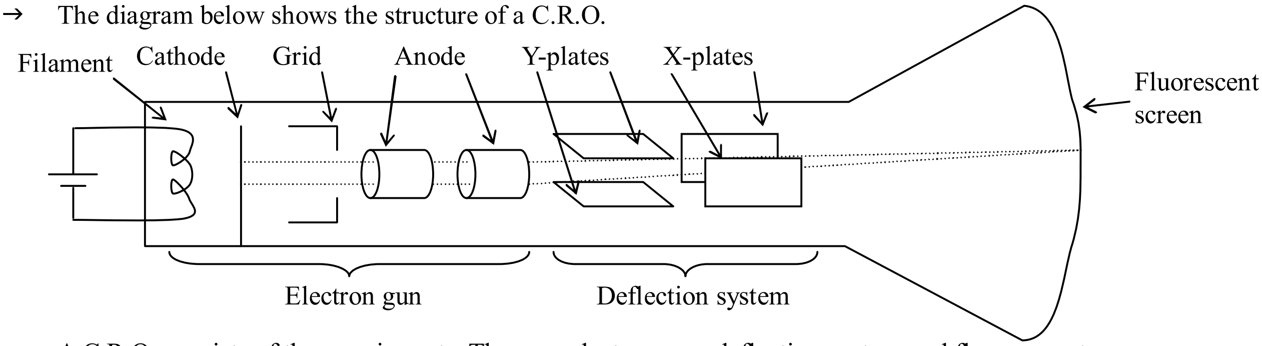
→ Electrons are negatively charged so that they attract to anode (positive side).
→ The flow of electrons is opposite to the direction of current in the circuit.
The current is called convenitional current.



5.2. C.R.O.

Structure of Cathode Ray Oscilloscope (C.R.O.)

→ The diagram below shows the structure of a C.R.O.



→ A C.R.O. consists of three main parts. They are electron gun, deflection system and fluorenscent screen.
→ An electron gun sends electrons through the vacuum to a fluorescent screen and a light spot appears on the screen.

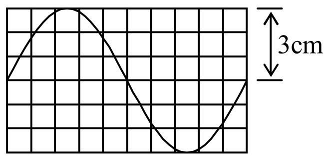
→ Each part has its function as shown in the table below.

Name	Function
Filament	Heating up cathode
Cathode	Emitting electrons by thermionic emission
Grid	Brightness control by controlling amount of electrons passing through it
Anode	Focusing and accelerating of electorn beam
Y-plate	Deflecting the electron beam up or down
X-plate	Deflecting the electron beam left or riight
Fluorenscent screen	Display of waveforms

Measuring voltage

→ The C.R.O. can be used as a voltmeter.
→ It can measure both A.C. and D.C. voltages.
→ It measures the peak voltage of A.C. input signal.
→ Y-gain setting indicates the voltage applied in order to deflect the beam by 1cm on the screen in the vertical direction. If Y-gain setting is 5V/cm, it means that 1cm of the height on the screen shows 5V of input signal.

[Example 1]
The diagram shows the screen of C.R.O. Y-gain setting is 3V/cm.
What is the peak voltage applied to the Y-input of the C.R.O.?



Solution

Y-gain 3V/cm: 3V → 1cm

Peak voltage: x V → 3cm

x = 3×3 = 9 V

[Example 2]
The gain control of a C.R.O. is set at 2V/cm. If the horizontal trace is deflected upwards by 5cm, what is the unkown voltage applied to the Y-input of the C.R.O.?

Solution

Y-gain 2V/cm: 2V → 1cm

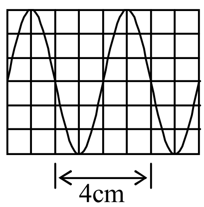
Unkown voltage: x V → 5cm

x = 2×5 = 10 V

Measuring short time interval

→ C.R.O. can be used to measure short time interval.
→ Time base setting indicates the time needed for the light spot to sweep through 1cm on the screen in the horizontal direction.
If the time base setting is 5ms/cm, it means that 1cm of the horizontal length on the screen shows 5ms (millisecond).

[Example]
The diagram shows the screen of C.R.O. The time base is set to 5ms/cm.
(a) What is the period of the input a.c. signal?
(b) What is the frequency of the input a.c. signal?



(a) Solution

Time base 5ms/cm: 5ms → 1cm

Period: x ms → 4cm

x = 5×4 = 20ms

(b) DATA	Solution
T = 20ms = 0.020s f =?	$f = \frac{1}{T} = \frac{1}{0.020} = 50Hz$

[EXERCISE]

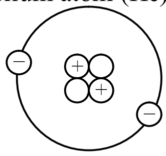
(1) The gain control of a C.R.O. is set at 0.2V/cm. If the horizontal trace is deflected upwards by 4cm, what is the unkown voltage applied to the Y-input of the C.R.O.?
(2) The time base is set to 2ms/cm in a C.R.O. If one wave has a length of 5cm, what are the period (a) and frequency(b)?

6. ATOMIC PHYSICS

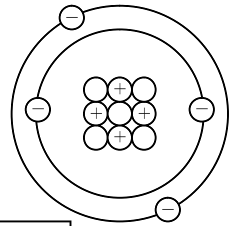
6.1. Nucleus

Composition of atom

Helium atom (He)



Beryllium atom (Be)



→ An atom consists of **proton**, **neutron** and **electron**.
→ A Proton is positivery charged.
→ An electron is negatively charged.
→ A neutron is neutral.
→ The structure of atom is shown in the right diagram.
→ Protons and neutrons are bound together in the **nucleus**.
→ Protons and neutrons is called the **nucleon**.
→ Electrons move round the nucleus in different orbits called shells.
→ Electrons and protons carry equal numbers in an atom.
→ If atom is neutral, the number of electrons is the same as the number of protons.

⊕	: Proton
○	: Neutron
⊖	: Electron

Atomic number and Mass number

→ The number of protons in an atom is called the **atomic number** or **proton number** (Z).
→ The total number of nucleons in a nucleus is called the **mass number** or **nucleon number** (A).
→ If the number of neutrons in the nucleus is N,

Formula $A = Z + N$

A: Mass number
Z: Atomic number
N: Number of neutrons

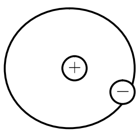
→ An element of chemical symbol X with a mass number A and an atomic number Z is expressed,

$${}^{A}_{Z}X$$

[Example]

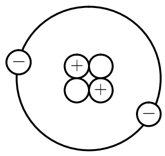
Express the following elements by the symbol of ${}^{A}_{Z}X$.

(a)Hydrogen atom (H)



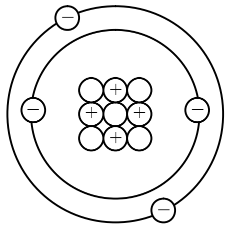
Atomic number: 1
Mass number: 1
${}^{1}_{1}H$

(b) Helium atom (He)



Atomic number: 2
Mass number: 4
${}^{4}_{2}He$

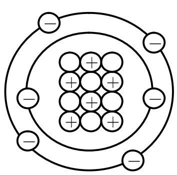
(3) Beryllium atom (Be)



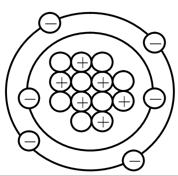
Atomic number: 4
Mass number: 9
${}^{9}_{4}Be$

Nuclide and Isotopes

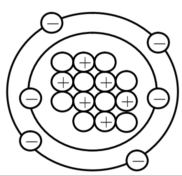
→ Each different form of nucleus is called a **Nuclide**.
→ Atoms which have the same atomic number but different mass numbers are called **Isotopes** of an element.
e.g. carbon



Atomic number: 6
Mass number: 12
${}^{12}_{6}C$



Atomic number: 6
Mass number: 13
${}^{13}_{6}C$



Atomic number: 6
Mass number: 14
${}^{14}_{6}C$

→ Carbon is an element.
→ ${}^{12}_{6}C$ is a nuclide, ${}^{13}_{6}C$ is a nuclide and ${}^{14}_{6}C$ is a nuclide.

→ $^{12}_{6}C$, $^{13}_{6}C$ and $^{14}_{6}C$ are isotopes of carbon.

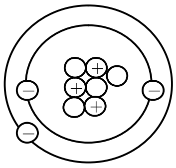
[EXERCISE]

(1) Find the number of (i)protons, (ii)neutrons and (iii)electrons if it is neutral.

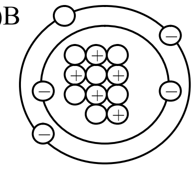
(a) $^{14}_{6}C$ (b) $^{35}_{17}Cl$ (c) $^{3}_{1}H$ (d) $^{210}_{84}Po$ (e) $^{238}_{92}U$

(2) Express the following elements by the symbol of $^{A}_{Z}X$.

(a) Li



(b)B



6.2. Radioactivity

Radioactivity

→ Some elements which radiate energy of itself without any excitation from outside is called **radioactive elemnts**, e.g. Uranium, Radium, Thorium and Polonium.

→ This phenomenon of matter radiating energy of itself is called the **natural radioactivity**.

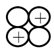
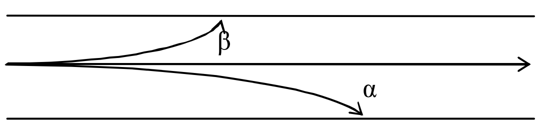
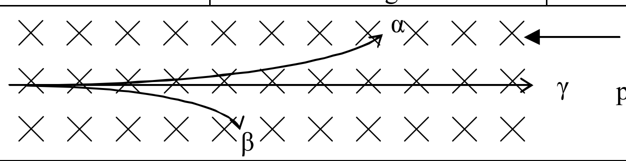
→ Experiments show that radioactive elements emit three types of radiation.

— Alpha (α) particle

— Beta (β) particle

— Gamma (γ) ray

Characteristics of the three types of radiation

	α-particle	β-particle	γ-ray
Nature and Charge	2 protons + 2 neutrons Helium nucleus  Positive +2	Electron ⊖ Negative -1	Electromagnetic wave Zero (Neutral)
Approximate mass	4 proton masses	1/1800 proton mass	Zero
Ionizing effect	strong	Weak	very weak
Range in air	Very short	Short	long
Penetrating power	Very weak	Weak	Strong
Absorbed by	a sheet of paper	5mm of aluminium	5cm of lead
Deflection in electric field	Small	Large	Undeflected
			
Deflection in magnetic field	Small	Large	Undeflected
			Magnetic field is perpendicular and points into the paper

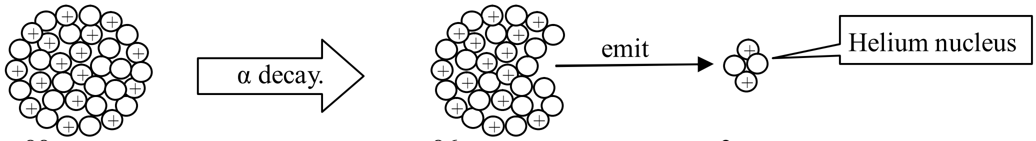
Radioactive decay

A nucleus, which has too many or too few neutrons gains extra energy, and becomes unstable. It tends to emit radiation such as α-particles, β-particles and γ-rays until a stable atom is reached. This emission ofα-particles or β-particles is called **Radioactive decay**.

— **α(alpha) decay**

→ The radioactivitive decay emitting α-particle from the nuleus is called α(alpha) decay.

e.g.) If ${}^{226}_{88}Ra$ emits an alpha particle (2 protons and 2 neutrons) from the nuleus, the mass number changes from 226 to 222 and the atomic number changes from 88 to 86. Therefore, Radium changes into Radon (Rn) that has the mass number of 86 from the periodic table.



88 protons 138 neutrons	86 protons 138 neutrons	2 protons 2 neutrons

$${}^{226}_{88}Ra \rightarrow {}^{226}_{86}Rn + {}^{4}_{2}He$$

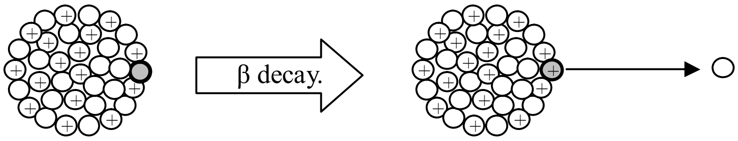
Parent nuclide — Daughter nuclide — α particle

General equation $\quad {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

— **β(Beta) decay**

→ The radioactivitive decay emitting β-particle from the nuleus is called β(beta) decay.

e.g.) If ${}^{241}_{94}Pu$ emits a beta particle (1 electron) from the nuleus, the mass number doesn't change but the atomic number changes from 94 to 95 because 1 neutron changes to a proton. Therefore, Plutonium changes into Am (Americium) that has the mass number of 95 from the periodic table.



94 protons 147 neutrons	95 protons 146 neutrons	1 electron

$${}^{241}_{94}Pu \rightarrow {}^{241}_{95}Am + {}^{0}_{-1}e$$

Parent nuclide — Daughter nuclide — βparticle

General equation $\quad {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$

— **γ(Gamma) radiation**

→ When some nucleus emit an α or β particle, they leave the nucleus in unstable energy condition. Therefore, the nucleus emits an extra energy, a γ-ray.

→ The atomic number and the mass number do not change, the daughter nuclide is the same element as the parent nuclide.

General equation $\quad {}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma\text{-ray.}$

<u>Activity and Half-life</u>

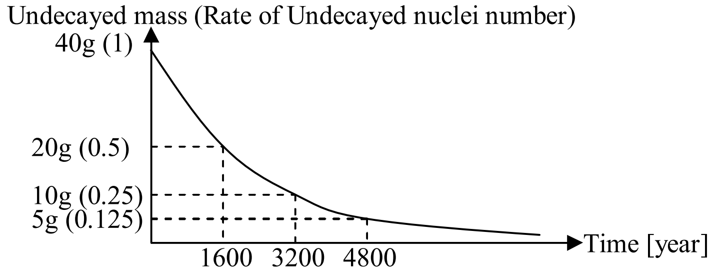
Definition **Half-life** of a sample of radioactive element is defined as the time taken for half of the unstable nuclei to decay.

→ For example, the half-life of radium is 1600years. If there are 40g of radium initially, half of radium(20g) is decayed in first 1600 years. Next 1600 years, half of 20g radium (10g) is decayed. After next 1600years, half of 10g radium (5g) is decayed.

Time	0 years later	1600 years later	3200 yaers later	4800 years later
Undecayed mass of Ra	40g	20g	10g	5g

Half-life Mass becomes half	Half-life Mass becomes half	Half-life Mass becomes half

→ The graph shows a decay curve for above example.



[Example1]

There is 1kg of Strontium (Sr) that has the half-life of 30years.

(c) How many grams of Strontium are remained after 60years?
(d) If 125g of strontium are remained, how long does it take?

Solution (a) and (b)

Time	0 years later	30 years later	60 yaers later	90 years later
Undecayed mass of Sr	1000g (1kg)	500g	250g	125g

Answer (a)

125g of strontium are remained 60years later.

Answer (b)

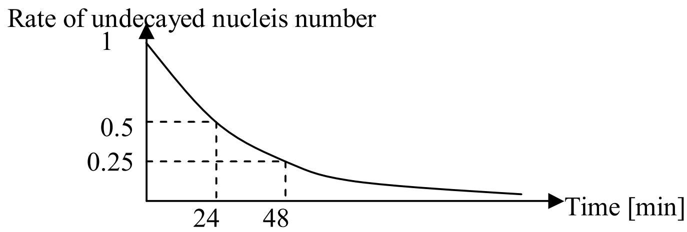
90years later.

[Example2]

The diagram shows the decay curve of Uranium (^{239}U).
What is the half-life?

Answer

Rate of undecayed nucleis number become half in 24 minutes. The half-life is 24minites.



Dangers of radiation

Radiation (α-particle, β-particle, γ-ray) can cause the following to human being.

— Damage to living cells
— Genetic changes in living cells.
— Cancer

Safety precautions

— Avoid unneccessary exposure.
— Avoid direct contact with the source.
— Never point the source to any people.
— Radioactive sources must be stored in places out of reach of the public.
— Sources must be stored inside lead box to aboid leakage of radiations.
— Thick lead shields should be installed.
— Radiation symbols must be displayed at all places where radioacitive sources are used.
— Radiation workers have to wear special protective clothing and gloves.
— Use film badges to measure the amount of radiation the radiation workers receive during a certain period.

[EXERCISE]

(1) There are 500g of Cobalt-60 (^{60}Co) that has the half-life of 5years.
  (a) How many grams of Cobalt are remained after 15years?
  (b) If 125g of cobalt are remained, how long does it take?

(2) The diagram below shows the decay curve of Phosphorus (^{30}P).
There are 400g of Phosphorus initially.
  (a) What is the half-life?
  (b) How many grams of Phosphorus is there 30 days later?
  (c) If 25g of Phosphorus is remained, how long does it take?