# Physics Paper 1 (Combined Higher)

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# 1. Energy stores and systems

**Energy System**

**System:**
An object or group of objects.
When a system changes there are changes in the way energy is stored within it.

**Closed system:**
Where neither matter nor energy enters or leaves.

**Conservation of energy:**
Energy is not created or destroyed but may be transferred between different energy stores.

The energy in a system can be transferred between different stores when work is done by:
- Heating
- Forces
- Current flowing

| Energy Store | Example |
|---|---|
| Thermal | Cup of hot tea |
| Kinetic | Moving car |
| Gravitational Potential | Water in a reservoir at the top of a mountain |
| Elastic Potential | Stretched bungee cord |
| Chemical | Battery, food |
| Magnetic | Two opposing north poles on bar magnet |
| Electrostatic | Two electrons repelling each other |
| Nuclear | The energy available to be released by fission when splitting an atom |

# 2. Kinetic Energy and Elastic Potential Energy

## Kinetic Energy

Kinetic energy of an object depends on the:
- mass
- speed

**Kinetic energy (J) = 0.5 x mass (kg) x velocity$^2$ (m/s)**

**$E_k$ = 0.5mv$^2$**

**Unit conversions:**
kJ to J:     x 1000
g to kg:     ÷ 1000

## Elastic Potential Energy

A force acting on an object may cause the shape of an object to change.

Elastic objects can store elastic potential energy if they are stretched or squashed. For example, this happens when a catapult is used or a spring is stretched.

Objects can also store elastic potential energy when they are squashed.

**Elastic potential energy (J) = 0.5 x spring constant (N/m) x extension$^2$ (m)**

**Unit conversions:**
kJ to J:     x 1000
cm to m:   ÷ 100

# 3. Work Done

Example: How much work is done by the brakes if a 7000N braking force is used to stop a car over 20m?



Braking Force 7000N

20 metres

**A car braking to slow down**
The friction force from the brakes does work. Energy is transferred from the car's kinetic store to the thermal store of its brakes, the brakes then transfer heat to the surroundings.

Energy transferred = work done
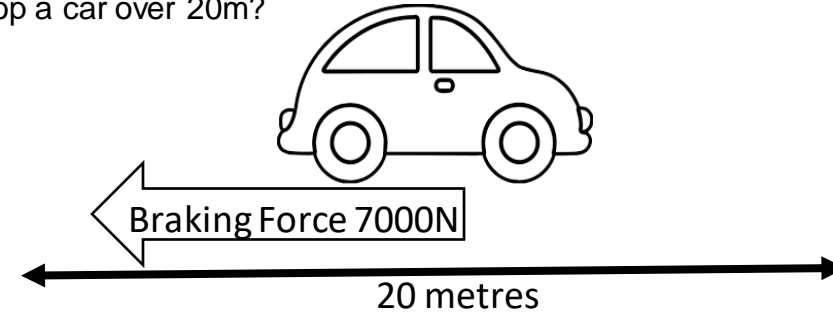
**work done (J) = force (N)  x distance (m)**

**W = Fs**

**Unit conversions:**
kJ to J:     x 1000
cm to m:    ÷ 100
km to m:   x 1000

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units

E          W = F x s
V          F = 7000 N and s = 20 m
E          W = 7000 x 20
R          W = 140 000
Y          J

W = 140000J or 140 kJ

| Kinetic energy store of moving car | Transfers energy to → | Thermal store of brakes | Transfers energy to → | Thermal store of surroundings |
|---|---|---|---|---|
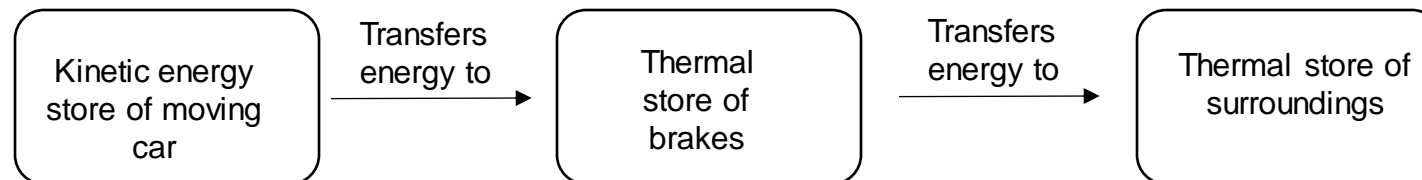
# 4. Gravitational Potential Store ($E_p$)

Raising an object off the ground increases its gravitational potential energy store.

The amount of energy depends on the mass and height of the object and strength of the gravitational field it is in.

**Gravitational = mass x gravitational field x change in height (m)**
**potential          (kg)     strength**
**energy                      (N/kg)**
**store (J)**

**$E_p$ = mgh**

**Unit conversions:**
kJ to J:      x 1000
cm to m:    ÷ 100
km to m:    x 1000
g to kg:      ÷ 1000

Note: weight = mass x gravitational field strength

W = m x g

Therefore, we have a second formula for $E_p$

$E_p$ = Weight x change in height

$E_p$ = W x $\Delta$h

Example: What is the gravitational energy required to lift a 100 kg mass up by 100 m?
Gravitational field strength = 9.81N/kg

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
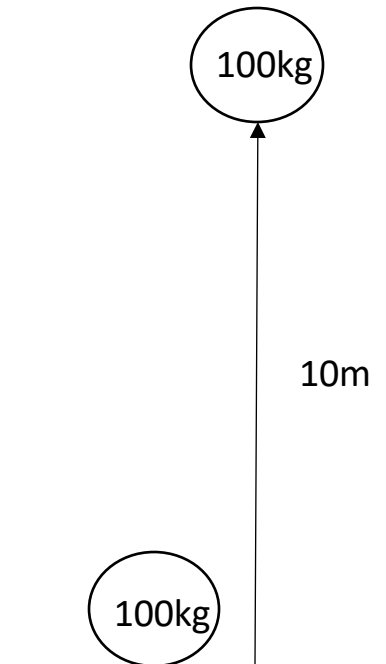R = result
Y = units

E          $E_p$ = m x g x h
V          m = 100 kg; g = 9.81; h = 100 m
E          $E_p$ = 100 x 9.81 x 100
R          $E_p$ = 98100
Y          J

$E_p$ = 98100 J



100kg

10m

100kg

# 5. Specific Heat Capacity (c) and Power

The amount of energy needed to raise the temperature of 1 kg of a substance by 1 °C.

**Change in = mass (kg) x specific x change**
**thermal                    heat          in**
**energy (J)                capacity    temperature**
**                               (J/kg°C)     (°C)**

**ΔE = mcΔT**

**Unit conversions:**
kJ to J:     x 1000
g to kg:     ÷ 1000

Example: How much energy is released into the surroundings when a cup of tea holding 250g of fluid cools from 90°C to 20°C? c = 4200 J/kg°C

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units

E          $\Delta E = m \times c \times \Delta\theta$
V          m = 250 g = 0.25 kg; c = 4200; $\Delta\theta$ = 90-20 = 70
E          $\Delta E = 0.25 \times 4200 \times 70$
R          73 500
Y          J

$\Delta E$ = 73500J or 73.5 kJ

**Power**

Power is the rate at which energy is transferred and is measured in watts.

1 watt = 1 joule of energy transferred per second.

**Power (W) = energy transferred (J) ÷ time (s)**

**Power (W) = work done (J) ÷ time (s)**

**P = E ÷ t**

**Unit conversions:**
kJ to J:                    x 1000
minutes to seconds:    x 60
hours to seconds:       x 3600
W to kW:                   ÷ 1000

Example. Calculate the power of a motor that uses 60,000 J of energy to lift an object in 20 seconds. Give your answer in kW.

E          P = E ÷ t
V          E = 60 000J; t = 20 s
E          P = 60 000 ÷ 20
R          3000
Y          W

P = 3000W or 3kW

A more powerful device can transfer more energy in a given time or will transfer the same amount of energy in a faster time.

# 6. Conservation of Energy

| | |
|---|---|
| **Dissipation of energy** | Wasting energy. |
| | More energy needs to be put into appliance to account for dissipated energy. |
| | Useful dissipation of energy example: back of a fridge |
| | Example of dissipation of energy is bad: light bulbs, engines and TV's as heat |
| **Conservation of energy** | Energy can be transferred usefully, stored or dissipated, but it cannot be created or destroyed |
| **Heat** | When an object is heated, thermal energy is being transferred to it |
| **Temperature** | A measure of hot or cold something is |

**Reducing Wasted Energy (dissipated energy)**

| | |
|---|---|
| Friction | Between two moving objects causes thermal energy to be dissipated. It can be reduced by lubrication. |
| Lubrication | • Friction between two moving objects causes energy to be dissipated as sound and to the thermal store. |
| Insulation | Reduces energy transfer by heating |
| Cavity wall insulation | Fills the air gap between the inner and outer wall reducing heat loss by convection. |
| Loft insulation | Reduces heat loss by convection. |
| Double glazing | • Creates an air gap between the two panes of glass to reduce energy loss by conduction.<br>• Gases are good insulators |
| Draught excluders | Reduce energy loss by convection when placed around windows and doors. |

# 7. Efficiency

| Appliance | Useful Energy | Dissipated (wasted) Energy |
|---|---|---|
| Light bulb | Light | • Heating the bulb and surroundings |
| Hair Dryer | • Kinetic energy of the fan to push air<br>• Heating of the air | • Sound of the motor.<br>• Heating of the dryer and surroundings |
| Electric Motor | • Kinetic energy of objects driven by motor.<br>• Gravitational potential energy of objects lifted by motor | • Heating of the motor and surroundings.<br>• Sound of the motor turning |

**Efficiency**

An efficient device wastes less energy than a less efficient device. It can be calculated as a decimal or multiplied by 100 to give a percentage.

**Efficiency = useful energy output**
**total energy output**

**Efficiency = useful power output**
**total power input**

Example:. Calculate the wasted power and efficiency of a motor that has a rated power of 500W and transfers 300W usefully.

Wasted power = input power - output power = 500 – 300 = 200W

$$\text{Efficiency} = \frac{300}{500} = 0.6 \text{ 0r } 60 \%$$

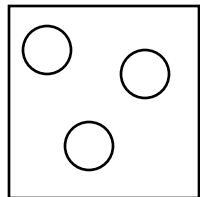# 8. Methods of Heat Transfer Overview
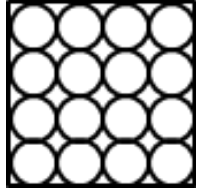
**Methods of heat transfer**

**Solids**

Have **strong forces** between particles or molecules, holding them close together in a **fixed**, **regular** arrangement. The particles can only vibrate around fixed positions.

**Liquids**

Have **weaker forces** between particles so although the particles are close together they can **flow** over each other at low speeds in random directions.
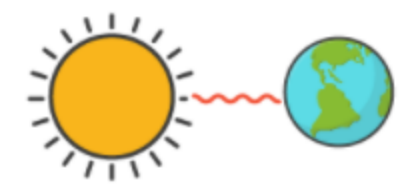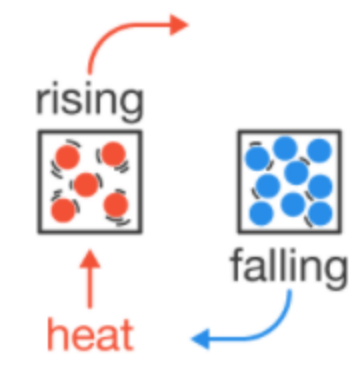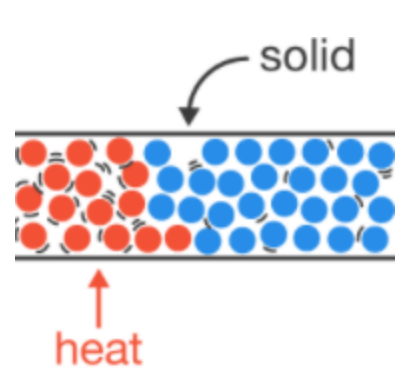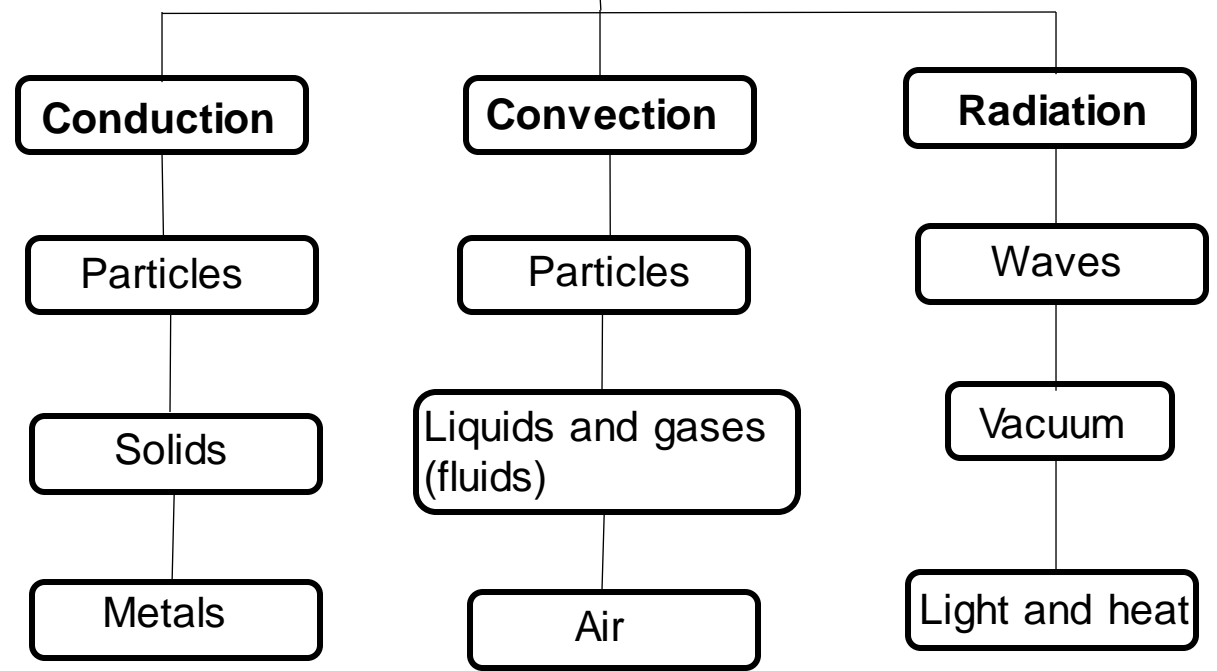
**Gases**

Have almost **no forces** between particles. Have **more energy** and are **free to move** in random directions and speeds.

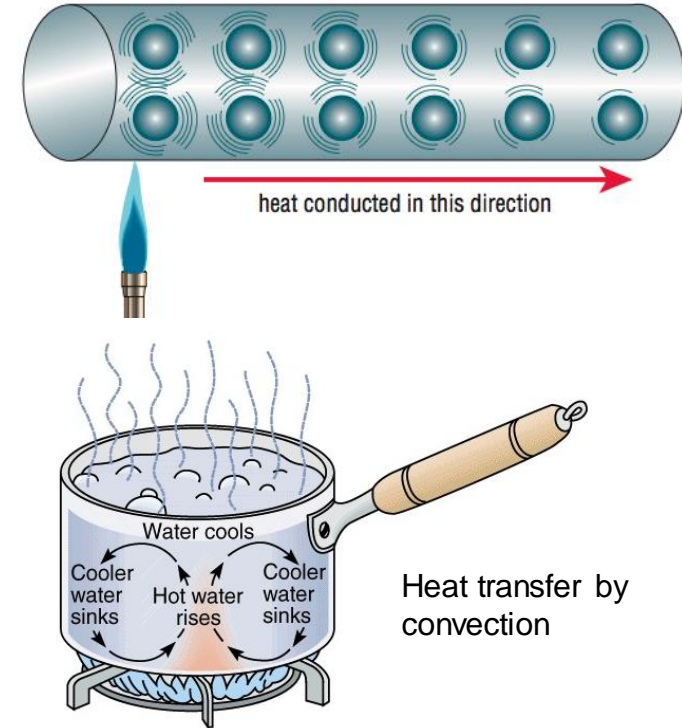|  | **Conduction** | **Convection** | **Radiation** |
|---|---|---|---|
| **TRAVELS VIA** | Particles | Particles | Waves |
| **MEDIUM** | Solids | Liquids and gases (fluids) | Vacuum |
| **EXAMPLE** | Metals | Air | Light and heat |

solid

heat

rising

heat

falling
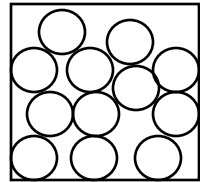
# 9. Methods of Heat Transfer

| Heat Transfer Method | Description |
|---|---|
| **Conduction**<br>(Occurs in solids) | When heated particles vibrate more with an increase in their kinetic energy.<br><br>They collide more with surrounding particles transferring the heat |
| **Convection**<br>(Occurs in liquids and gases) | Particles are free to move (in a liquid and gas).<br>Increase in their kinetic store.<br>Particles move faster.<br><br>The space between the particles increases, so the density decreases.<br><br>The warmer less dense region rises and the cooler, denser regions sink. |
| **Infrared Radiation**<br>(Occurs in all objects) | The hotter an object the more infrared radiation it emits in a given time.<br><br>An object at constant temperature emits and absorbs infrared radiation at the same rate<br><br>A perfect black body absorbs all the infrared radiation that falls upon it and then emits it back at the same rate as it absorbs it. |

heat conducted in this direction

Water cools

Cooler water sinks   Hot water rises   Cooler water sinks

Heat transfer by convection

# 10. Non-Renewable Energy Resources

Renewable energy resources will never run out.  It is an energy resource that can be replenished quickly.

Non-renewable resources will one day run out (fossil fuels). Fossil fuels are coal, oil and natural gas.

| Energy Resource | Uses | Advantages | Disadvantages |
|---|---|---|---|
| Coal | Electricity generation, heating, steam trains in some countries | • Reliable energy resource<br>• Low extraction costs<br>• High energy per kg | All fossil fuels are running out. Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming. $SO_2$ found in coal leads to acid rain when burned. |
| Oil | Electricity generation, heating, basis for petrol and diesel | • Reliable energy resource<br>• Low extraction costs<br>• High energy per kg | Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming. |
| Gas | Electricity generation, heating, cooking | • Reliable energy resource<br>• Gas fired power stations can be started quickly to meet changing energy demands | Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming. |
| Nuclear | Electricity generation<br>Fuel: Uranium or plutonium | • Reliable energy resource<br>• It has the highest energy density per kg of any fuel.<br>• Does not require combustion and therefore does not release carbon dioxide into the atmosphere | The waste products from nuclear plants is dangerous radioactive waste which needs to be stored safely for hundreds of years. |

# 11. Renewable Energy Resources 1

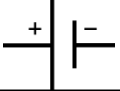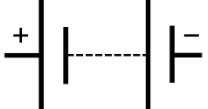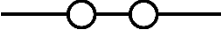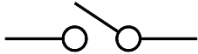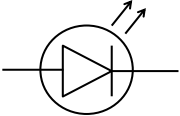| Energy Resource | Uses | Advantages | Disadvantages |
|---|---|---|---|
| Solar Energy | • Heating domestic hot water.<br>• Photovoltaic cells can create electricity to charge batteries.<br>• Electricity generation in large scale solar power plants | • No atmospheric pollution due to burning of fossil fuels<br>• In sunny countries it is more reliable (during the day)<br>• Useful for remote places not supplied by the national grid.<br>• No fuel costs and minimal running costs | • Cannot increase supply to match demand<br>• High initial costs<br>• Unreliable |
| Wind Power | Electricity generation | • No atmospheric pollution due to burning of fossil fuels<br>• No fuel costs and minimal running costs<br>No permanent damage to the landscape when removed.<br>• Fast start-up | • Visual and noise pollution<br>• Cannot increase supply to match demand<br>• High initial costs<br>• Cannot generate electricity if there is too little wind<br>• Unreliable |
| Geothermal | • Electricity generation<br>• Heating | • Reliable<br>• No atmospheric pollution due to burning of fossil fuels | • Few suitable locations (only possible in volcanic areas)<br>• High cost to build power station |
| Bio-fuels | • Electricity generation<br>• Heating<br>• Fuel for transport | • Carbon neutral (if plants are grown at the same rate as being burned).<br>• Reliable as crops grow quickly | • High costs to refine the fuel<br>• Space for growing food taken up<br>• Forests cleared to make space – decay and burned vegetation release $CO_2$ and methane. |
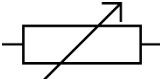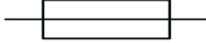
# 12. Renewable Energy Resources 2

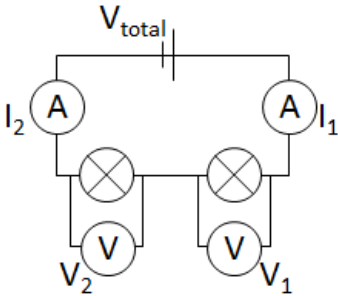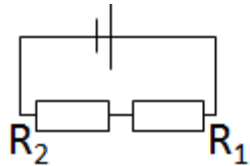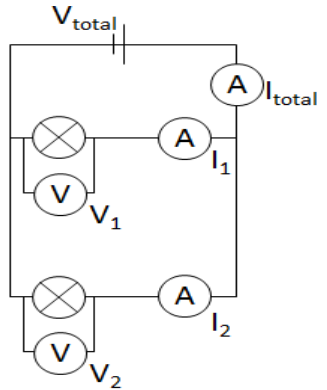| Energy Resource | Uses | Advantages | Disadvantages |
|---|---|---|---|
| Hydro-Electric | Electricity generation | • Can respond immediately to increased demand, fast start-up.<br>• Reliable (except if there is a drought)<br>• No fuel costs and minimal running costs<br>• Potential to be used as part of **pumped storage** scheme | • Requires land to be flooded to create a dammed reservoir<br>• Loss of animal habitats<br>• Relies on rainfall to keep reservoir full unless part of pumped storage system |
| Tidal barrage | Electricity generation | • No atmospheric pollution due to burning of fossil fuels<br>• No fuel costs and minimal running costs | • Visual pollution<br>• Difficulty providing access for boats / wildlife<br>• Initial costs are high<br>• Environmental impact during building phase due to multiple vehicles and large amounts of concrete being used |
| Wave power | Electricity generation | • No atmospheric pollution due to burning of fossil fuels<br>• Smaller solution for limited populations | • Unreliable<br>• Few suitable locations |

# 13. Electrical Terms

| Keyword | Definition |
| --- | --- |
| Ampere (A) | Unit of electric current. |
| Current (I) | The flow of electrical charge.  Measured in Amps (A) |
| Direct potential difference | Potential difference in one direction |
| Electric circuit | A collection of electronic components connected by a conductive wire that allows for electric current to flow. |
| Ohm (Ω) | Unit for resistance. |
| Potential difference (V) | The force that pushes the charge around.  Measured in volts (V). |
| Resistance (R) | Reduces the flow of current.  Measured in ohms (Ω). |
| Resistor | Component that prevents the flow of electric current. |
| Volt (V) | The standard unit of measure for electric potential (voltage). |
| Watt (W) | The standard unit of measure used for electric power. |

# 14. Electrical Components

| Component | Circuit symbol | Function |
|---|---|---|
| Cell | | 'Pushes' the electrons around a complete circuit. |
| Battery | | |
| Closed switch | | Break and complete a circuit, so turn on and off. |
| Open switch | | |
| Variable resistor | | Allows the current in a circuit to be varied. Placed in series within the circuit. |
| Light emitting diode (LED) | | Emits light when current passes through it. Placed in series within the circuit. |
| Ammeter | | Used to measure current through a circuit. Placed in series within the circuit. |
| Fuse | | A glass or ceramic canister containing a thin wire that melts if the current gets too high. Placed in series within the circuit. |
| Voltmeter | | Used to measure potential difference (voltage) across a component. Placed in parallel within the circuit. |

# 15. Series and Parallel Circuit Rules

|  | Series Circuit | Parallel Circuit |
|---|---|---|
| **Number of loops** | 1 | 2+ |
| **Current** | Same all the way round | Shared across the components<br>$I_{total} = I_1 + I_2 +...$ |
| **Potential difference** | Shared across the components<br>$V_{total} = V_1 + V_2 +...$ | Same across the components<br>$V_1 = V_2 =...$ |
| **Resistance** | Add together<br>$R_{total} = R_1 + R_2 + ...$ | Total resistance will decrease if two or more resistors are added in parallel.<br>Resistors in parallel have the **same pd** across them as the power supply. Adding another loop to the circuit means the current has more than one way it has to go. The **total current** around the circuit **increases**. An increase in current means a **decrease** in **resistance** ($V = IR$) |
|  | $V_{total} = IR_{total}$ | $R_1 = V_{total} / I_1$<br><br>$I_1$ = current flowing through $R_1$<br>$R_1$ = Resistance of lamp 1 |
| **Example of a circuit** |  |  |

# 16. Current, potential difference and resistance

The current (I) through a component depends on both the resistance (R) of the component and the potential difference (V) across the component.

The resistance of an electrical component can be found by measuring the electric current flowing through it and the potential difference across it.

Ohm's Law, shows the relationship between potential difference, current and resistance:

**Potential difference (V) = Current (A) x Resistance (Ω)**

**V = IR**

**Resistance** is the opposite to current:

The higher the resistance of a circuit, the lower the current

Good conductors have a **low** resistance and insulators have a **high** resistance

The current through a component depends on both the resistance $R$ of the component **and** the potential difference $V$ across the component

The **greater** the resistance $R$ of the component, the **lower** the current for a given potential difference $V$ across the component

The **lower** the resistance $R$ of the component, the **greater** the current for a given potential difference $V$ across the component

# 17. I-V Characteristics and Circuit Devices 1

**Fixed Resistor**
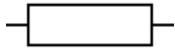
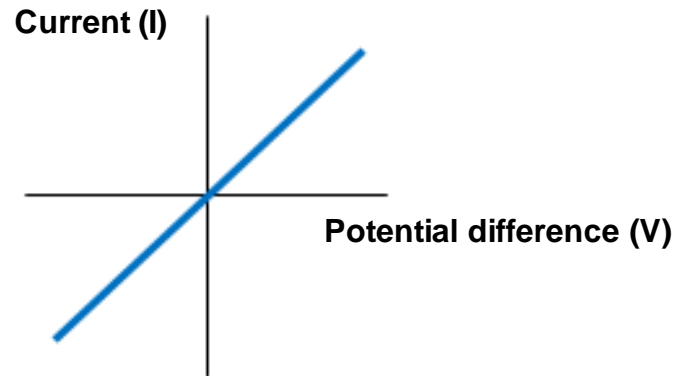**Purpose**: Limits the current in a circuit.

At a constant temperature, the potential difference is **directly proportional** to the current.

If the potential difference increases, the current increases.

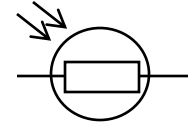The resistance doesn't change when the current changes.

Obeys Ohm's law. It is an ohmic conductor.

Obeys V = IR

**Current (I)**

**Potential difference (V)**

If the temperature changes, the resistance will change.

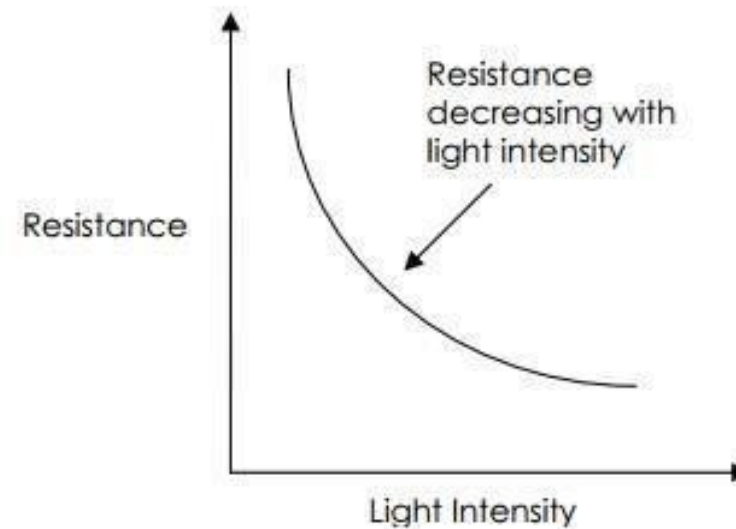**Light Dependent Resistor (LDR)**

**Used for**: Automatic night lights

Bright light – low resistance

Darkness – high resistance

Resistance

Resistance decreasing with light intensity

Light Intensity

# 18. I-V Characteristics and Circuit Devices 2

**Filament bulb**

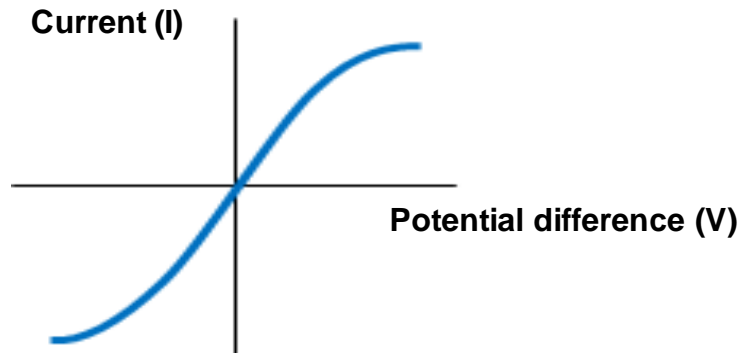**Property**: Emits light when current flows through it.

As the current increases, the filament wire gets hotter. The
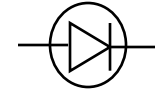higher the current, the higher the temperature.
Resistance increases.
Harder for current to flow.
Graph gets less steep.
It is a non-ohmic conductor

**Diode**

**Property**: allows current through in only one direction

The resistance depends on the direction of the current. As a diode
only lets current flow in one direction, it has a very high resistance
in the opposite direction, which makes it hard for the current to flow
that way.
It is a non-ohmic conductor

**Current (I)**

**Potential difference (V)**

**Current (I)**

**Potential difference (V)**
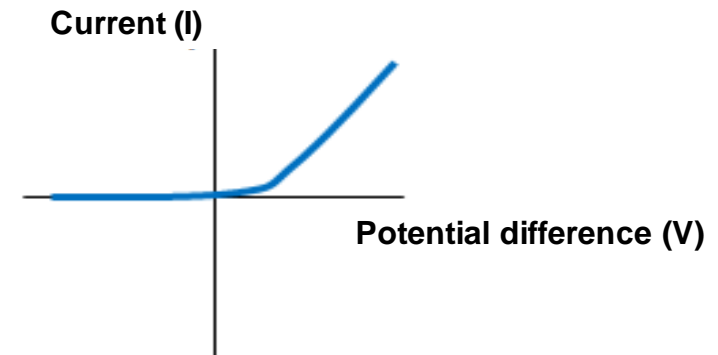
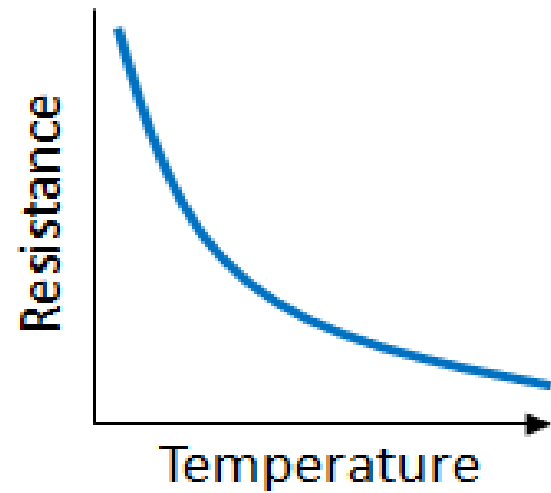# 19. I-V Characteristics and Circuit Devices 3

**Thermistor**
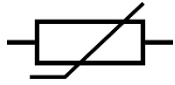
**Use**: central heating thermostats

High temperature– low resistance

Cold temperature – high resistance

# 20. National Grid and AC DC supply

**National Grid:** A network of cables and transformers that connect power stations to consumers.

**How step up transformers makes the National Grid efficient:**

- Increases the potential difference

- Decreases the current

- Less energy loss

A huge amount of power is needed.

**Increase efficiency:** Use a high potential difference but a low current.

A high current would cause the wires to heat up, wasting a lot of energy (dissipated as heat).



**Power station** — **Step-up transformer** — **Transmission cables** — 400kV+ — **Step-down transformer** — **Houses**

25kV — 230V

## Alternating Current (AC)

The current constantly changes direction. It is produced by an alternating voltage where the positive and negative ends keep alternating.

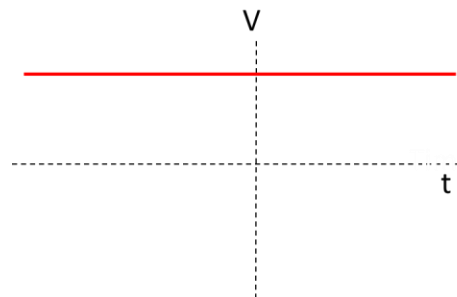The UK mains supply is AC at 230V.

It has a frequency of 50Hz.
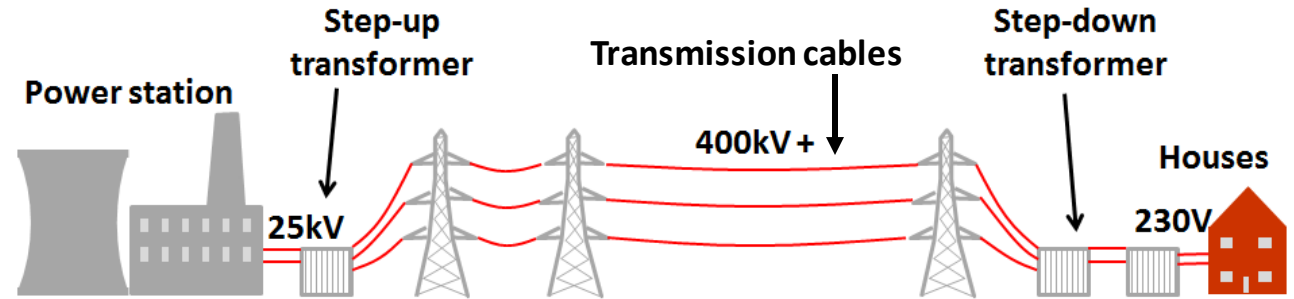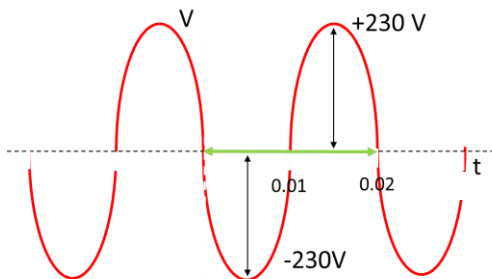


## Direct Current (DC)

The current always flows in the **same direction**.

**Batteries** produce a DC voltage.



|  | Underground cables | Overground cables |
|---|---|---|
| **Advantages** | No visual pollution Less affected by the weather | No need to dig up the ground. Easy to repair |
| **Disadvantages** | Bigger disturbance to the land Difficult to access to repair | Visual pollution Affected by the weather |

# 21. Electricity in the home

## Electrical Wiring

Most electrical appliances are connected to the mains with a three-core cable (3 copper wires coated in insulating plastic).

| Wire | Colour | Voltage (V) | Purpose |
|---|---|---|---|
| Live | Brown | 230 | Provides an alternating potential difference |
| Neutral | Blue | 0 | Completes the circuit carrying the current out of the appliance |
| Earth | Green and yellow | 0 | A safety feature. Prevents the appliance becoming live if there is a fault so does not normally carry a current. |
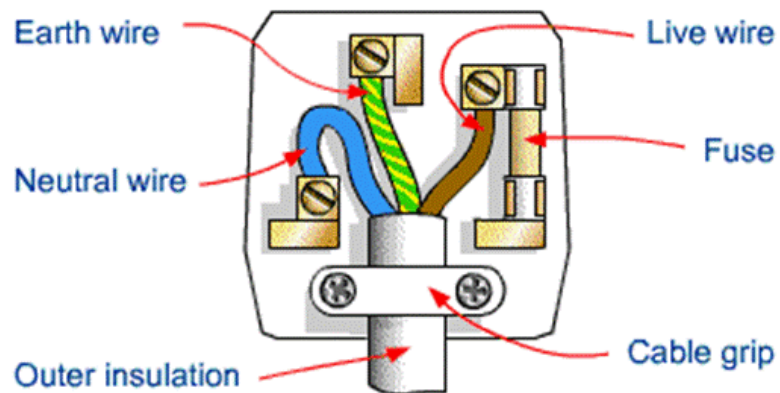


## Live Wire

If you touch the live a large pd is produced across your body and the current flows through you.

This electric shock can injure or kill you.

A connection between the live and earth creates a low resistance path to earth so a large current will flow.

This could cause a fire.

**Fuses** are placed in series with the live wire to limit the amount of current flowing in a circuit. If a fault occurs the current can be very high, so a fuse is used for safety.

A fuse is a thin piece of wire which all the current flows through, it gets hot and melts if too high a current flows through it, preventing any current flow.

## Double Insulated Appliances

Some appliances have no earth wire.

They have a plastic non-conducting outer case and are designed so that the live and neutral wires cannot come into contact with the external casing.

This can be done by placing the wire terminals inside a plastic surrounding box.

# 22. Electrical power and charge

**Power**

Energy in an electrical circuit is transferred by a moving charge. The charge has to work against resistance, so work is done.  Work done is the same as energy transferred and depends upon power.

**Energy transferred (J) = Power (W) x Time (s)**

**E = Pt**

e.g. How much energy is transferred by a 3kW kettle in 2 minutes.

| | |
|---|---|
| E | E = Pt |
| V | P = 3 kW = 3000W and t = 2 min = 120s |
| E | E = 3000 x 120 |
| R | E = 360 000 |
| Y | J |

E = 360 000J or 360 kJ.

**Power Calculations**

**Power (W) = Current (A) x Potential difference (V)**

**P = IV**

**Power (W) = Current$^2$ (A) x Resistance (Ω)**

**P = I$^2$R**

**Charge**

**Energy transferred (J) = Charge (C) x Potential difference (V)**

**E = QV**

**Charge (C) = Current (A) x Time (s)**

**Q = It**

An amp is the amount of charge flow per second.
1 amp = 1 coulomb per second.

**Unit conversions**
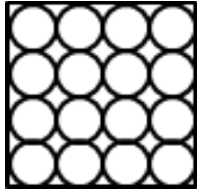
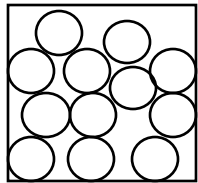| | |
|---|---|
| kJ toJ | x 1000 |
| minutes to seconds | x 60 |
| hours to seconds | x 3600 |

# 23. The particle model

**Solids**

Have **strong forces** between particles or molecules, holding them close together in a **fixed**, **regular** arrangement. The particles can only vibrate around fixed positions.

**Liquids**

Have **weaker forces** between particles so although the particles are close together they can **flow** over each other at low speeds in random directions.
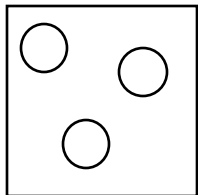
**Gases**

Have almost **no forces** between particles. Have **more energy** and are **free to move** in random directions and speeds.

**Density**

Closer the particles, the denser the material

**Density (kg/m$^3$) = mass (kg) ÷ volume (m$^3$)**
**Density (g/cm$^3$) = mass (g) ÷ volume (cm$^3$)**
**$p$ = m ÷ v**

e.g. What is the density of 1kg of water?
Volume of 1kg of water = 0.001m$^3$.

E           $p$ = m ÷ v
V           m = 1kg and v = 0.001m$^3$
E           Density = 1 ÷ 0.001
V           1000
Y           kg/m$^3$

23

# 24. Internal Energy

If we increase the energy of the particles, it will either:

•Increase the temperature of the substance

•Change its state i.e. change from a solid to a liquid

| Internal energy (energy stored by particles in a system) | = | Kinetic energy of particles (e.g. vibration of atoms) | + | Potential energy of particles (spacing between the particles) |

Temperature is a measure of the average kinetic energy of the particles.

A temperature change depends on the mass of substance, what it is made from and the energy input (see specific heat capacity).

If the substance is heated sufficiently particles have enough energy in their kinetic stores to break the bonds holding them together and so a change in state occurs.

All changes of state do not affect the kinetic energy of the particles so are constant temperature processes.

**Evaporation of a liquid:** The particles at a liquid's surface sometimes gain enough energy to leave the surface as a gas

**Increase rate of evaporation by:**

-Increasing the surface area of liquid.

-Increasing the temperature of the liquid.

-Creating a flow of air across the liquid's surface.

Condensation of a gas: The water molecules that are in the air can hit a cool surface, cool down and therefore stay there.

**Increase rate of condensation by:**

-Increasing surface area

-Reducing surface temperature

# 25. Specific latent heat

**Specific Latent Heat** – the energy needed to change the state of 1kg of a substance

**Thermal energy (J) = mass (kg) x specific latent heat (J/kg)**
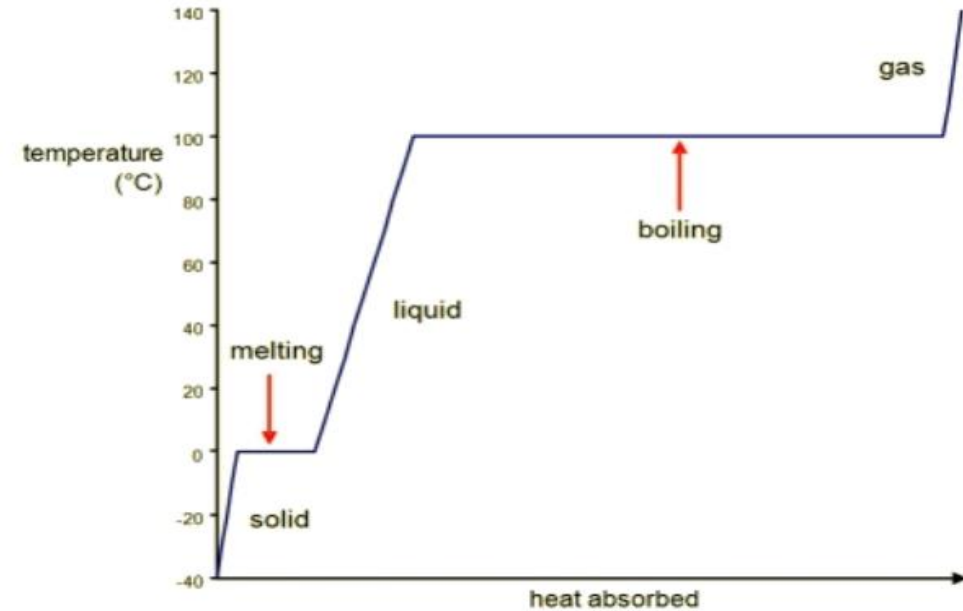
**E = ml**

e.g. How much energy is required to melt 1.5kg of ice. $L_f$ water = 334 kJ/kg.

E             E = ml
V             mass = 1.5kg and specific latent heat of fusion = 334kJ/kg
E             E = ml = 1.5 x 334 000
V             E = 501 000
Y             J

E = 501 000J or 501 kJ

**Specific latent heat of fusion ($l_f$)** = change of state from solid to liquid

**Specific latent heat of vaporisation ($l_v$)** = change of state from liquid to vapour

Gradient of the line = specific heat capacity of the substance.

Steeper the line, the higher the specific heat capacity of the substance

Horizontal line = specific latent heat

Longer the horizontal line = greater the specific latent heat of fusion/vaporisation

# 26. Particles in gases

**Gas Pressure:**

When the particles in a gas collide with the side of the container they exert a force on it. This force acts at right angles to the container walls.
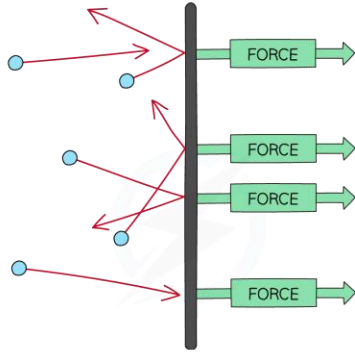


**Pressure = force exerted per unit of area.**

In a sealed container, the gas pressure is the total force of all the particles on the area of the container walls.

**Increasing the temperature** of the gas (whilst keeping the volume constant)

➢ increases pressure

➢ Increases the average kinetic energy of the particles. Particles move faster so collide with the sides more often and with more momentum

➢ A larger total force is exerted

➢ The pressure increases.

**Work Done**

Work is done when energy is transferred by applying a force.

Work done on a gas increases its internal energy. This can increase the temperature of the gas.

Pumping up a bike tyre does work mechanically. The gas exerts a force on the plunger (due to pressure). To push the plunger down against this force, work must be done. Energy is transferred to the kinetic stores of the gas particles, increasing the temperature.
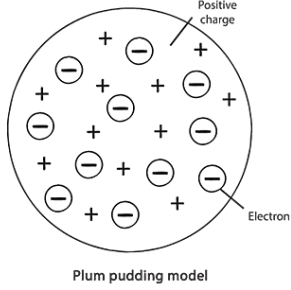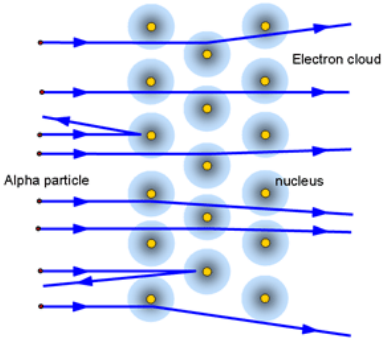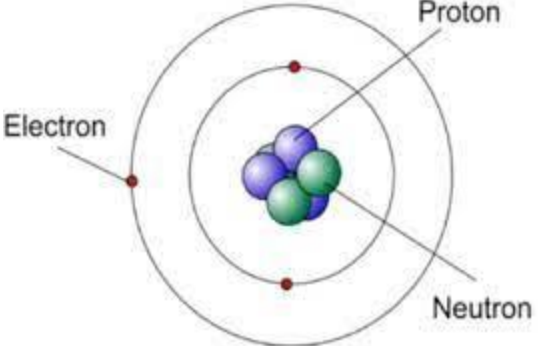
For a fixed mass of a gas held at a constant temperature:

**Constant = Pressure (Pa)  x volume (m³)**

- When the volume **decreases** (compression), the pressure **increases**
- When the volume **increases** (expansion), the pressure **decreases**
- The key assumption is that the **temperature** and the **mass** (and number) of the particles remains the same

By increasing the volume:

➢ The particles will bump into the container walls less frequently

➢ Particles must travel further between each impact with the container

➢ Reduces the total force per metre of surface area

➢ Pressure reduces.

# 27. Atomic models

| Atomic model | Plum pudding model | | Nuclear model | | |
|---|---|---|---|---|---|
| Diagram | \n\nPlum pudding model |  |  | | |
| Discovery | Electron | Positive nucleus in the centre of the atom | Electrons occupy shells | Neutrons | • Atomic radius: $1 \times 10^{-10}$ m\n• Radius of a nucleus is less than 1/10 000 of the radius of an atom.\n• Most of the mass of an atom is concentrated in the nucleus.\n• The electrons are arranged at different distances from the nucleus. |
| Description | The atom is a ball of positive charge with negative electrons embedded in it. | Positively charged alpha particles were fired at thin gold foil. Most alpha particles went straight through the foil. A few were scattered in different directions by the atoms in the foil. It showed that the mass of an atom was in the centre (the nucleus) and the nucleus was positively charged. | | Proved the existence of isotopes | |
| Discovered by | Thompson | Rutherford | Bohr | Chadwick | |

# 28. Isotopes and Radiation

**Isotopes**: Atoms of the same element that have different numbers of neutrons but the same number of protons and electrons.
They have the same chemical properties but different physical properties.

$^{16}_{8}O$      8 protons, 8 electrons and 8 neutrons

$^{18}_{8}O$      8 protons, 8 electrons and 10 neutrons

Isotopes that give out nuclear radiation are called radioactive isotopes.
Radioactive atoms have an unstable nucleus.

They give out (emit) radiation from their nucleus.
Doing this makes the atom more stable

.

Energy is released      Energy is absorbed by the atom.

Nucleus    Electron    Nucleus
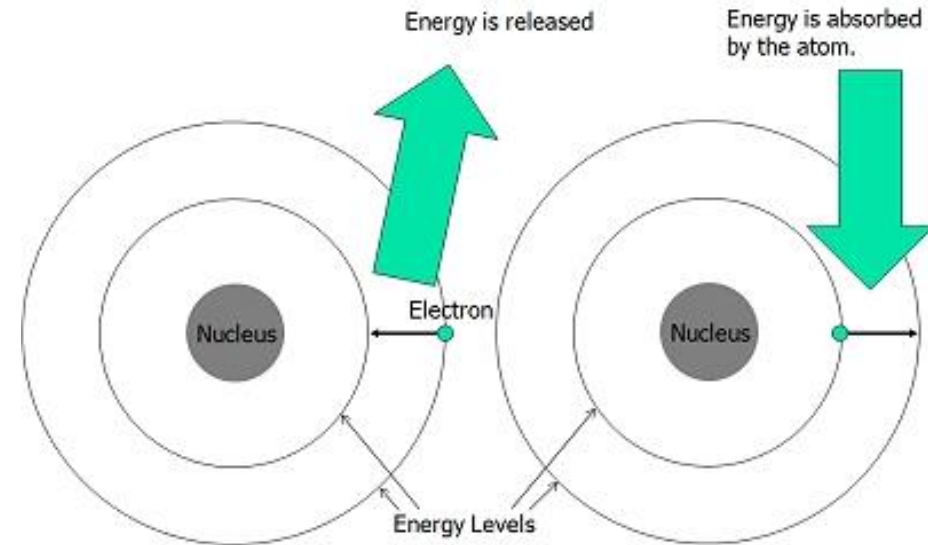
Energy Levels

When an electron moves to a lower energy level, the electron releases electromagnetic radiation (left hand picture).

When an electron moves to a higher energy level, the electron absorbs electromagnetic radiation (right hand picture).

# 29. Nuclear Radiation

| | Alpha | Beta | Gamma |
|---|---|---|---|
| Symbol | $_{2}^{4}\alpha$ | $_{-1}^{0}e$ | $_{0}^{0}\gamma$ |
| What is it? | Helium nuclei | Fast moving electron | Electromagnetic wave |
| Electrical charge | +2 | -1 | 0 |
| No. of protons | 2 | 0 | 0 |
| No. of neutrons | 2 | 0 | 0 |
| Stopped by | Paper, thin sheet of aluminium and lead | Thin sheet of aluminium and lead | Lead |
| Ionising power (how easy it is to form an ion) | Strong | Weak | Very weak |
| Penetrating power | Low | Medium | High |
| Range in air | Few cm | Several metres | Many metres |
| Uses | Smoke alarms | Monitor thickness of paper and detect leaks in pipes. | Treat cancer. Sterilise medical equipment. |
| Effect of electromagnetic field | Weakly deflected | Strongly deflected | Not deflected |

# 30. Nuclear equations and half lives

**Decay:** Radioactive decay is a random event.

**Man made source of radiation**:

**Alpha** decay causes the **charge** and **mass** of the nucleus to **decrease** as the nucleus releases the alpha particle

$$^{219}_{86}\text{radon} \longrightarrow\ ^{215}_{84}\text{polonium}\ +\ ^{4}_{2}\text{He}$$
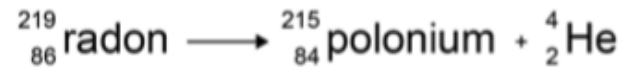
**Beta** decay causes the **charge** of the nucleus to **increase** but the mass remains the same. Within the nucleus a neutron is changed into a proton and releases an electron (beta particle)

$$^{14}_{6}\text{carbon} \longrightarrow\ ^{14}_{7}\text{nitrogen}\ +\ ^{0}_{-1}\text{e}$$
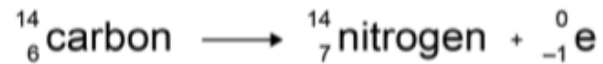
**Gamma** rays do not change the mass or charge of the atom they are emitted from

**Neutrons** can also be an emitted form of radiation

**Half-Life:**

The time taken for the number of radioactive nuclei in an isotope to halve.

Activity (the rate at which a source decays) is measured in Becquerel's Bq (1Bq = 1 decay per second).

e.g. if the initial activity of a sample is 600Bq what will it be after two half-lives?

1 half life = 600 ÷ 2 = **300Bq**

2 half lives = 300 ÷ 2 **= 150Bq**

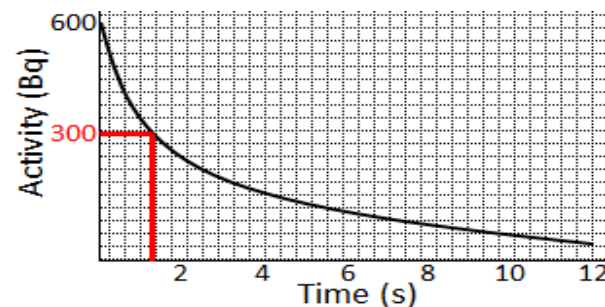e.g. What fraction remains radioactive after 40 years if the half-life of an isotope is 10 years?

Number of half-lives = 40/10 = 4 half-lives.

After 1 half life – ½ remains

After 2 half lives - ¼ remains

After 3 half lives – ⅛ remains

After 4 half lives - 1/16 remains or 6.25%



**Finding half-life from a graph:**

- Mark where half the activity level is.
- Find the corresponding time (1.8s in this example)

# 31. Applications of radiation, contamination and irradiation

| Applications of radiation | Radioactive contamination | Irradiation |
|---|---|---|
| Destruction of unwanted tissue (cancer) or imaging internal organs.<br><br>Radio-isotopes with a short half-life are used to limit any damage.<br><br>Alpha radiation cannot be used for imaging because it cannot penetrate body tissue and it is highly ionising.<br><br>Over exposure to ionising radiation can damage cells and lead to cancer | The unwanted presence of radioactive materials. The level of hazard depends on the type of radiation and the amount of time you are exposed.<br><br>Nuclear power plant fuel rods and medical equipment with radioactive sources can have sources that we need to store safely for long periods of time at the end of their useful life. | Where an object is deliberately exposed to a radioactive source.<br><br>Used to sterilise medical equipment and food.<br><br>The irradiated object does not become radioactive, so it is safe. |

| | |
|---|---|
| **Natural background radiation** | It comes from either natural sources such as cosmic rays or radioactive rocks. |
| **Man-made radiation** | Medical x-rays or radiotherapy<br>Nuclear testing or accidents e.g. Chernobyl |
| **Dose** | The amount of radioactivity we are exposed to.<br><br>Measured in sieverts (Sv).<br>1000 mSv = 1Sv<br><br>How big a dose you receive will depend on where you live and what your job is. |
| **Why radioactive waste should have a short half-life** | Activity decreases quickly<br>Risk of harm decreases quickly |

# 32. Required practical 1: Specific Heat Capacity



**Method**

1. Take a 1 kg block of copper.

2. Place an immersion heater in the larger hole in the block.

3. Connect the power supply to the joule meter (reset to read 0 Joules).

4. Connect the joule meter to the 12V immersion heater.

5. Place the thermometer into the other hole in the block.

6. Switch the power pack to 12 V. Turn it on.

7. After 1-minute record the temperature of the block and the reading from the joule meter.

8. Continue taking readings every minute until 10 minutes have passed.

**IV** - Work done – (energy transferred to block measured by joulemeter)

**DV** - temperature

**CV** – Copper block of 1kg mass

**Sources of Error**

Heat is lost to the surroundings due to lack of insulation

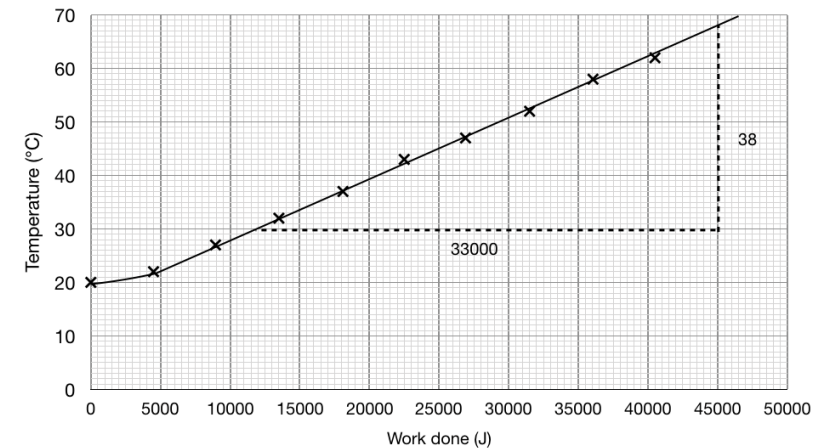The immersion heater is not fully immersed into the block

The graph may be curved at the start because it takes time for the

heater and block to transfer the energy
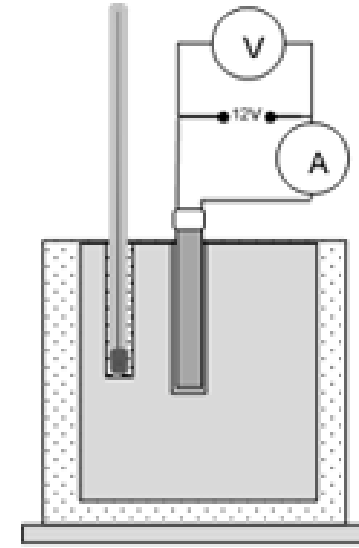
**Processing data**

Plot graph work done against temperature

Specific heat capacity = 1 ÷ gradient
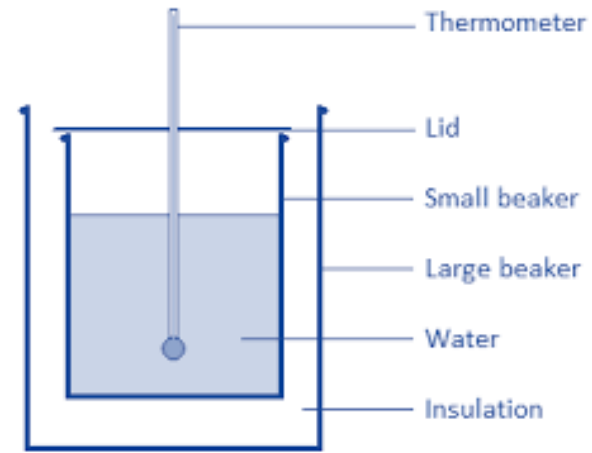
# 33. Required Practical 2: Thermal Insulation

**Method**

1. Pour 200 cm$^3$ of hot water into a 250 ml beaker with a single layer of insulating material around it.

2. Use a piece of cardboard as a lid for the beaker.

3. Insert the thermometer through the hole in the cardboard lid

4. Record the temperature of the water and start the stopwatch.

5. Record the temperature of the water every 30 seconds for 5 minutes.

6. Repeat steps **1–5** increasing the number of layers of insulating material wrapped around the beaker until you reach 4 layers.

7. Repeat the experiment with no insulation around the beaker.

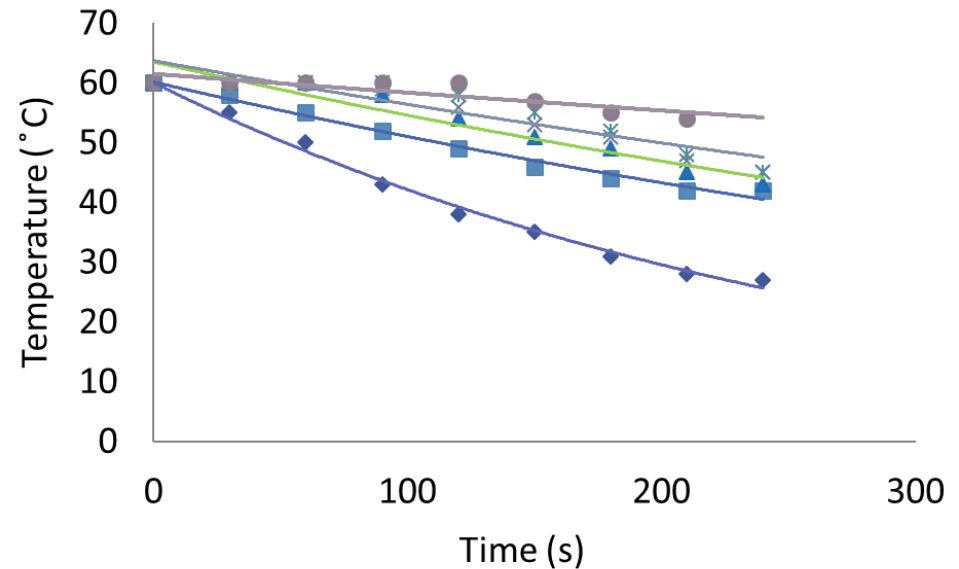7. Plot a graph of temperature versus time.

**IV –** Time (s)

**DV –** Temperature change

**CV –** Volume of water, material of insulation, starting temperature.



The more layers of insulation the longer it takes for the temperature to drop, indicating a better insulator.

# 34. Required Practical 3: Resistance of a wire

**Method:**

1. Set up equipment as shown in the diagram.

2. Connect the crocodile clips to the resistance wire, 100 cm apart.

3. Record the reading on the ammeter and on the voltmeter.

4. Move one of the crocodile clips closer until they are 90 cm apart.

5. Record the new readings on the ammeter and the voltmeter.

6. Repeat the previous steps reducing the length of the wire by 10 cm each time down to a minimum length of 10 cm.

7. Plot a line graph of length of wire (x axis) against resistance (y axis)
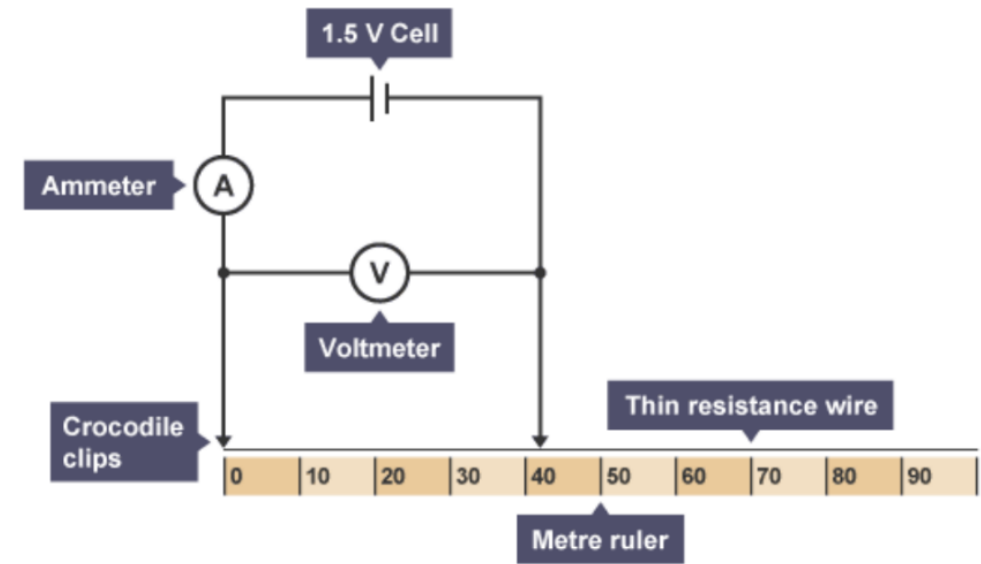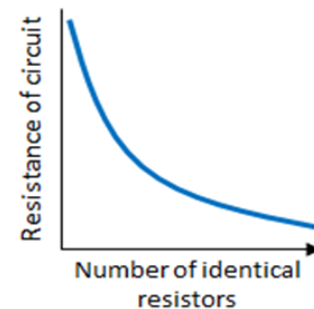
**IV**: length of the wire
**DV**: voltage and current
**CV**: type of wire, diameter of wire and the battery

**Resistors in series**
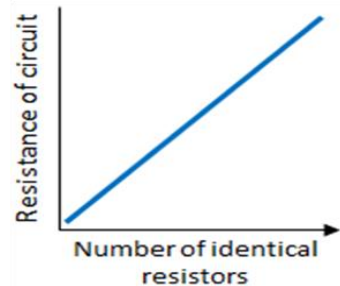


**Resistors in parallel**





**Reason for inaccuracy of readings:** The resolution of the length of wire is lower due to where the crocodile clips are attached to the wire
**Improve accuracy of readings:** Turn off the circuit between the readings. This will stop the wire heating up and the temperature changing

**Possible errors**: Wire heating up and increasing resistance, incorrect reading of ammeter and voltmeter and internal resistance of equipment

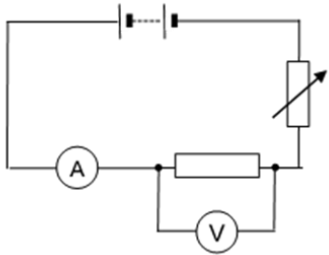**Conclusion**: The length of the wire is **proportional** to the resistance of the wire.

# 35. Required practical 4: Component IV characteristics

**IV**—Potential Difference (Volts)
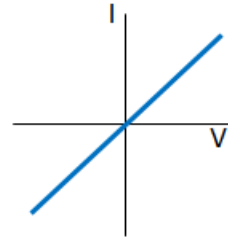
**DV**—Current (Amps)

**CV**— Same components, voltage from power pack, temperature – take the readings, immediately, Repeats to reduce the impact of outliers.
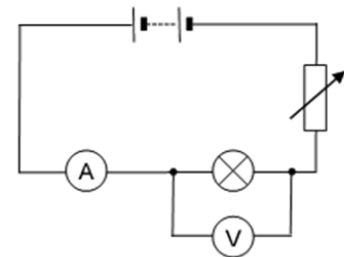
## Fixed Resistor

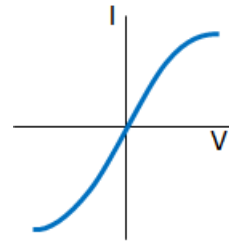At a constant temperature, the current is **directly proportion** to the voltage. This means it obeys Ohm's Law.
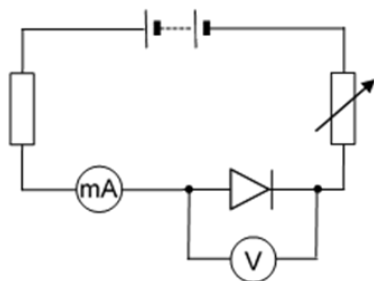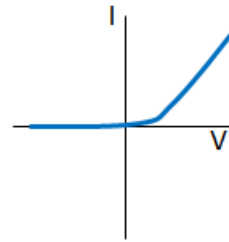
## Filament Bulb

As the voltage increases the current increases. This causes the filament to get hotter, meaning the resistance increases. Therefore as the voltage continues to increase the current levels off.

## Diode

The current can only flow in one direction because a diode has a very high resistance in the opposite direction.

### Method

1. Measure the current in the resistor using the ammeter.
2. Measure the potential difference across resistor using the voltmeter.
3. Vary the resistance of the variable resistor
4. Record a range of values of current and potential difference.
5. Ensure current is low to avoid temperature increase.
6. Switch circuit off between readings
7. Reverse connection of the resistor to the power supply.
8. Repeat measurements of I and V in negative direction.
9. Plot a graph of current against potential difference

### How to improve accuracy of readings:

- Circuit is switched off between readings
- Temperature does not change

35

# 36. Required practical 5: Calculating density

### Regular shaped object
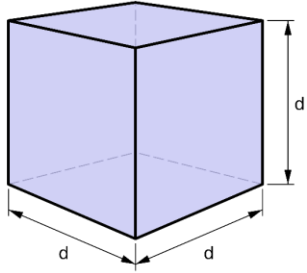


1. Measure the length, width and height using a ruler.

2. Calculate the volume (l x w x h)

2. Measure the mass using a balance.

3. Use the equation mass ÷ volume to calculate the density.

### Irregular shaped object



1. Using a balance, measure the mass of the object.

2. Fill a measuring cylinder with 100 cm$^3$ of water

3. Put object into measuring cylinder

4. Difference in volume of water is the volume of the object

5. Use the equation mass ÷ volume to calculate the density.

### Liquid
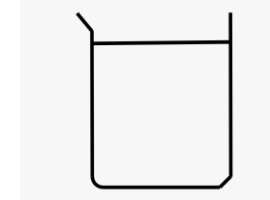


1. Using a balance, record the mass of a beaker

2. Pour 100 cm$^3$ of liquid into the measuring cylinder.

3. Pour liquid into a beaker and record the mass of the beaker and its contents

4. Difference in mass of (beaker + contents) from the beaker is the mass of the liquid.

5. Use the equation mass ÷ volume to calculate the density.

# Physics Paper 2 (Combined Higher)

# 37. Magnets

| | |
|---|---|
| **Magnetic metals** | Iron (steel), nickel and cobalt |
| **Permanent magnets** | Magnetic all the time. Produce their own magnetic field. |
| **Induced magnets** | Made from magnetic materials. Only turns into a magnet when held in a magnetic field e.g. core of an electromagnet |
| **North and south pole of a magnet** | The part of the magnet where the magnetic field is the strongest |
| **Magnetic field** | A region where force is experienced by magnetic materials |
| **Magnetism** | A non-contact force from a magnetic to a magnetic field |
| **Field lines** | Point away from north and show the direction a north pole would point of it was placed in a field. Closer the field lines in a magnetic field = stronger the magnetic force. Field lines run from north pole to south pole. |
| **Compass** | A small bar magnet that is free to move. Always points north in a magnetic field |
| **Evidence that the Earth's core is magnetic** | The Earth's iron core creates a magnetic field. The north poles of magnets are attracted to the geographic North Pole of the Earth. |
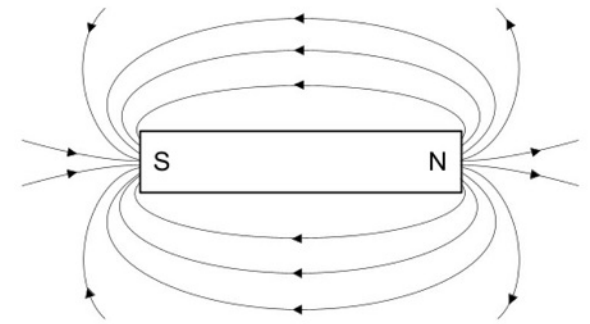


**Opposite poles attract**
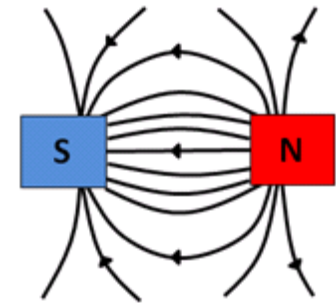


**Like poles repel**
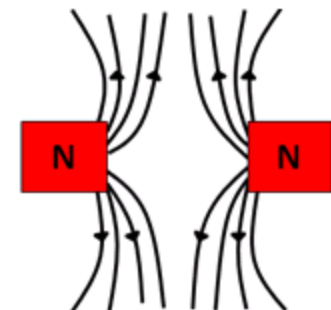
# 38. Compasses and magnets

| | Iron filings | Plotting compass |
|---|---|---|
| **Method** | Sprinkle iron filings on a piece of paper over the magnet | Use a plotting compass around the magnet with the needle showing the direction. |
| **Advantage** | Field lines easily seen | Direction of field lines shown |
| **Disadvantage** | Iron filings easily spilt and stick to magnet. Not permanent. | Compasses affected by magnets and do not always work so well. Takes longer. |

**Using a plotting compass to find the magnetic field of a bar magnet**

1. Place magnet on a sheet of (plain) paper
2. Place the compass near the north pole of the magnet
3. Mark the position that the compass needle points to
4. Move the compass so the opposite end of the needle is at this position and mark the new position where the compass tip settles
5. Repeat above until you reach the south pole, then connect the marks together to construct a field line .
6. Add arrows to field lines (pointing north to south).

# 39. Electromagnetism

**Magnetic Field around a Wire**
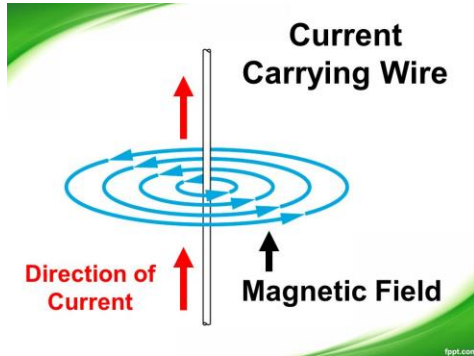


- Arrows on the field line show the direction of the magnetic field.
- Reverse the direction of the current, the direction of the magnetic field reverses.
- If the field lines are closer, there is a larger the current.
- Further away from the wire, the weaker the magnetic field

**Right Hand Grip Rule**
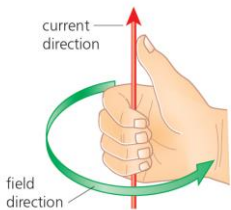


Your thumb points in the direction of the current.

Your fingers point in the direction of the magnetic field.

**Solenoid:** a coil of wire

**Outside solenoid:** Magnetic field lines are like a bar magnet

**Inside solenoid** Magnetic field is strong. Same strength and direction in all places. Field lines are parallel.

**Electromagnet:** a solenoid with an iron core

**Advantages of an electromagnet:**
Can be turned on or off. Strength of magnet can be increased or decreased.



North pole

South pole
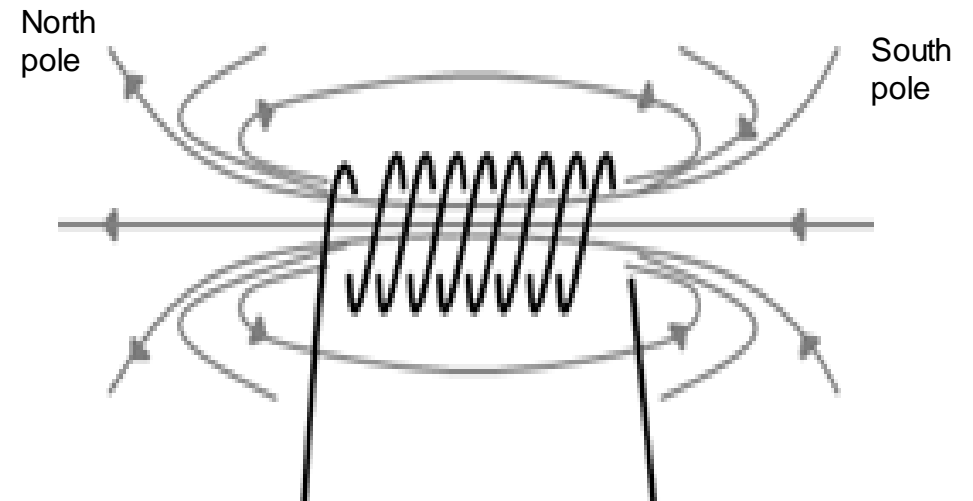
# 40. Investigating electromagnetism



## How to make an electromagnet

1. Set up equipment as shown in diagram
2. Wrap the wire around the nail
3. Connect the wire to the power supply
4. Switch on the power supply

## How to test the electromagnet

• the more paperclips suspended, the stronger the electromagnet is

• clamp the electromagnet at different distances from the paperclip(s)

• the further the distance from which paperclips can be attracted the stronger the electromagnet is

• use de-magnetised paper clips
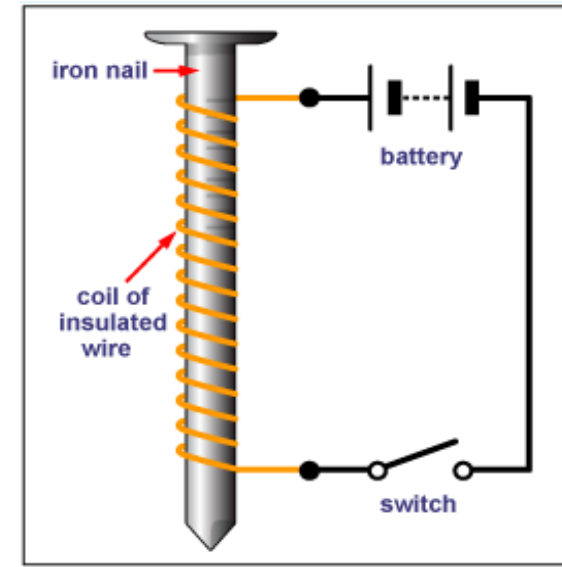
**IV**: Increase strength of electromagnet by (3 x Cs):

a)   Increase the number of **coils**

b)   Increase the **current**

c)   Change the **core**

**DV**: Number of paperclips picked up

**CV**: Same type of paperclip.

# 41. Uses for Electromagnets



Electromagnet

Blocks made from magnetic materials

Switch



Ignition switch

Electromagnetic switch

Pivot

Iron arm

Electromagnet

Starter motor contacts

Iron core

Starter motor

M

12 V
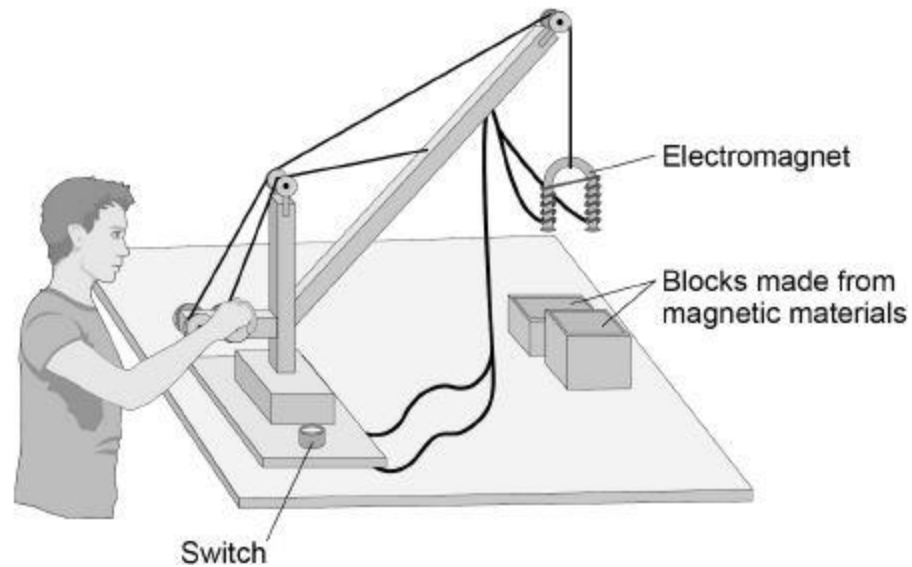
1. Completing the circuit turns the electromagnet on

2. There is a current in the coil

3. A magnetic field is produced around the coil

4. The iron core becomes magnetised

5. Move electromagnet towards the blocks

6. The block is attracted to the electromagnet

7. Moving the crane moves the block

8. Switching off the current switches off the electromagnet

9. Releasing the block
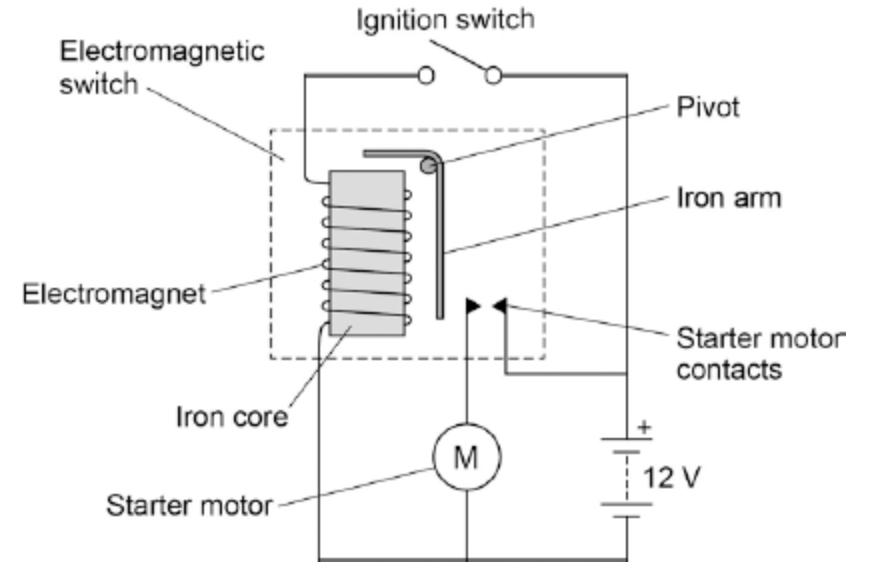
1. Closing the switch causes a current to pass through the electromagnet

2. The iron core of the electromagnet becomes magnetised

3. The electromagnet attracts the short side of the iron arm

4. The iron arm pushes the starter motor together

5. The starter motor circuit is complete

6. A current flows through the starter motor

# 42. Fleming Left Hand Rule

When a wire carrying a current is exposed to the magnetic field of another

magnet, then a force is produced on the wire at a right angle to the direction of

the magnetic field produced.

This is called the motor effect.

**force (N) = magnetic flux density (T) × current (A) × length (m)**

**F = B I *l***

•*F* is force in newtons (N)
•*B* is magnetic flux density (magnetic field strength) in tesla (T)
•I is current in amps (A)
•*l* is length in metres (m)

The force on a given length of wire in a magnetic field increases

when:

•the current in the wire increases

•the strength of the magnetic field increases

The force is greatest when the direction of the current is 90° to the

direction of the magnetic field.

There is **no** motor effect force if the current and magnetic field are

parallel to each other.

Use Flemings "left hand rule" to find the  direction of the force
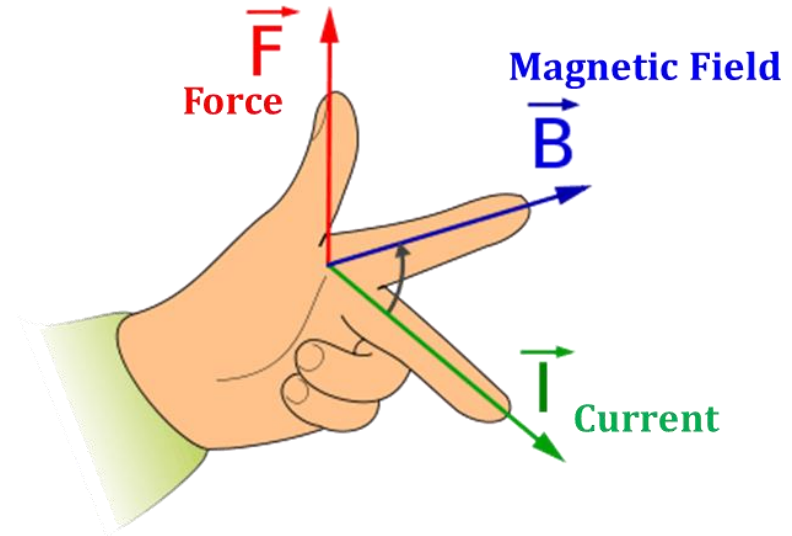


• Use your left hand

 • The angle between your index finger and middle finger should be a

right angle on the horizontal plane.

• The angle between your index finger and thumb should be a right

angle on the vertical plane.

• Your thumb represents the direction of the force.

• Your index finger represents the direction of the magnetic field.

• Your middle finger represents the direction of the current flowing

through the wire.

# 43. Motor Effect

•The motor effect can be used to create a simple d.c electric motor.

•Electricity is used to create motion

•The simple d.c. motor consists of a coil of wire (which is free to rotate) positioned in a uniform magnetic field.

When the current is flowing in the coil at 90° to the direction of the magnetic field:

- The current creates a magnetic field around the coil

- The magnetic field produced around the coil interacts with the field produced by the magnets

- This results in a force being exerted on the coil

- As current will flow in opposite directions on each side of the coil, the force produced from the magnetic field will push one side of the coil up and the other side of the coil down
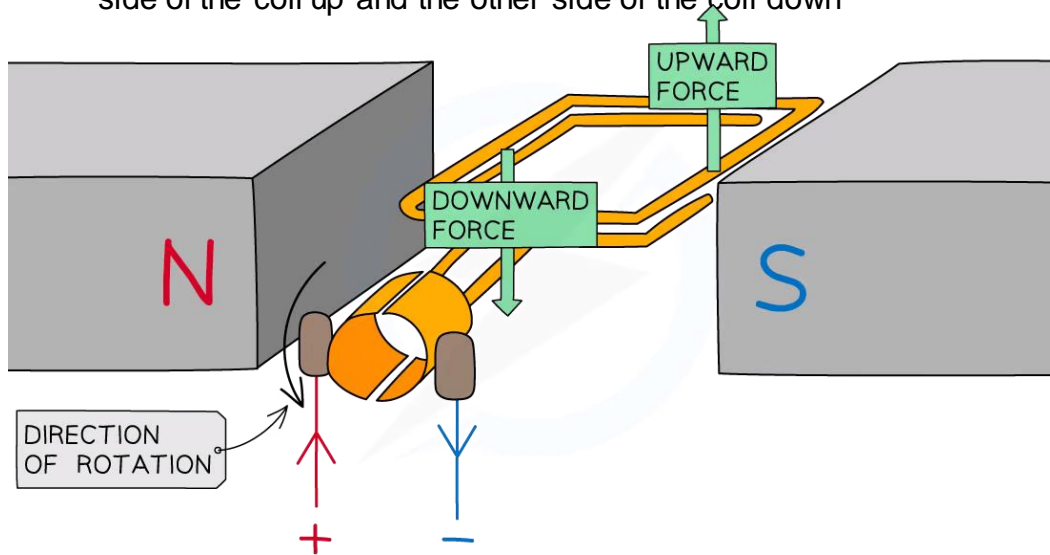
The **split ring commutator** swaps the contacts of the coil. This reverses the direction in which the current is flowing.

The two halves of the split ring commutator ensure that the current supplied to the wire changes direction each half-turn (or that the current supplied is the same direction on each side of the motor) and as a result, the force produced maintains a constant rotation in one direction overall.

Reversing the direction of the current will also reverse the direction in which the forces are acting. As a result, the coil will continue to **rotate**
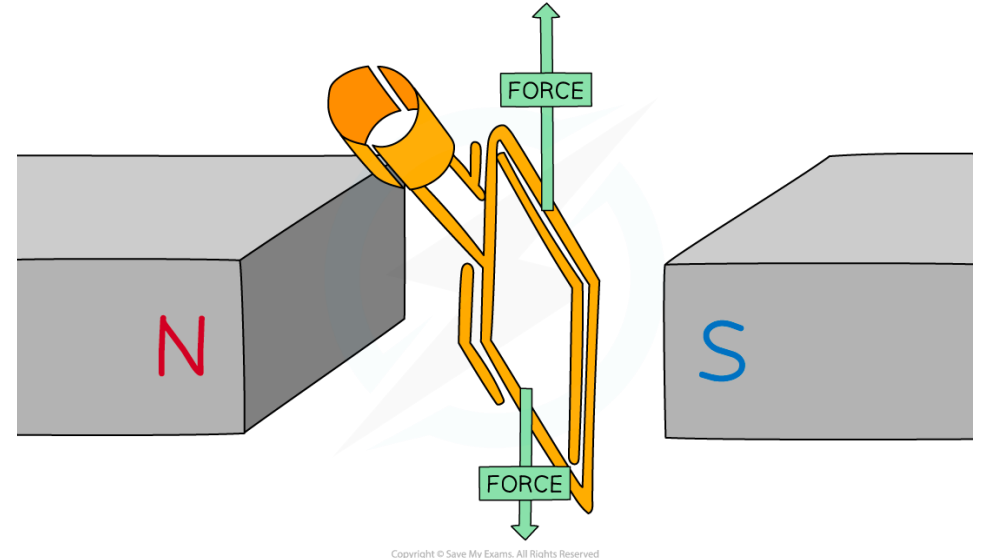
# 44. Wave properties

**Mechanical Waves** travel through a medium (substance).

The particles oscillate (vibrate) and transfer energy.

The particles do not travel along in the wave.

**Frequency (f)** - the number of complete waves that pass a

point every second.

1 wave per second has a frequency of 1Hz (hertz).

**Time period (T)** - the time for a complete cycle of a single wave.

**Frequency (Hz) = 1 ÷ time period (s)**

**F = 1 ÷ T**

Example: What is the frequency for a wave with a time period of 0.2s

```
E        f = 1 ÷ T
V        T = 0.2 s
E        f = 1 ÷ 0.2
R        5
Y        Hz
```

f = 5Hz

**Wavelength** - the distance between adjacent waves (i.e. from peak to peak or trough to trough)

**Amplitude** - the maximum displacement from the horizontal mid-line.

Peak

Trough
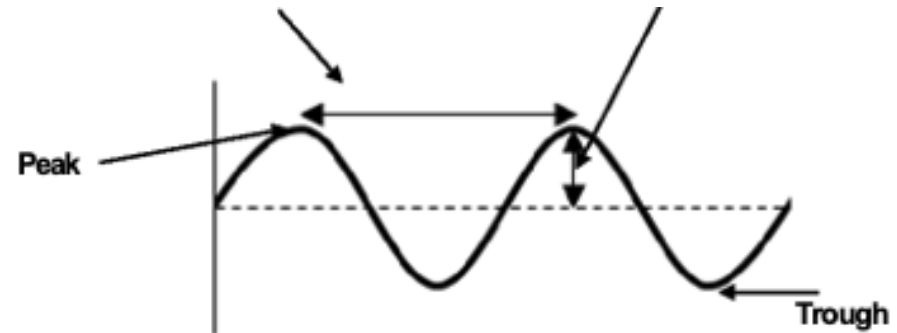
**Wave speed (m/s) = frequency (Hz) x wavelength (m)**

$$V = f \lambda$$

 Example: How fast is a wave travelling which has a 3m wavelength and a frequency of 20Hz?

```
E        V = f x λ
V        f = 20 Hz; λ = 3 m
E        V = 20 x 3
R        V = 60
Y        m/s
```

# 45. Transverse and Longitudinal waves

**Longitudinal Waves**

The **oscillations** (vibrations causing the wave are **parallel** to the direction of **energy transfer**.



Transfer of energy

Oscillations

Rarefaction        Compression

One wavelength
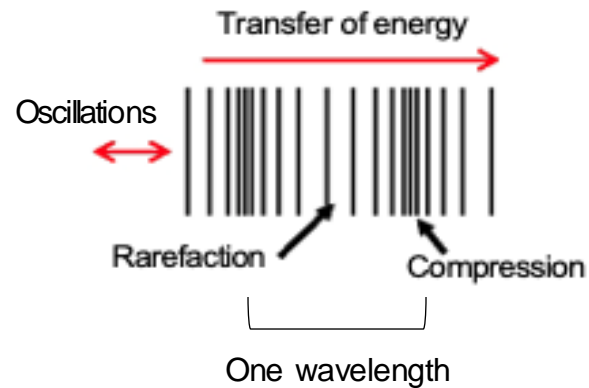
**Compression:** particles bunch up

**Rarefaction:** particles spread out

**Example:** Sound waves

**Transverse Waves**

The **oscillations** (vibrations causing the wave) are **perpendicular** (90°) to the direction of **energy transfer**.



Transfer of energy

Oscillations

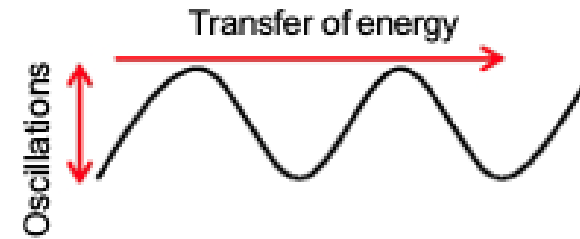**Example:** Light waves, X-rays and water waves (ripples)

All electromagnetic waves

# 46. Sound Waves and Speed of Sound experiment

**Sound waves** are **mechanical longitudinal waves**.

They need a medium to travel through.

The speed of sound can be calculated using:

**Speed (m/s) = distance (m) ÷ time (s)**

**Unit conversions:**

| | |
|---|---|
| km to m: | x 1000 |
| cm to m: | ÷ 100 |
| minutes to seconds: | x 60 |
| hours to seconds: | x 3600 |

**Speed of sound experiment**
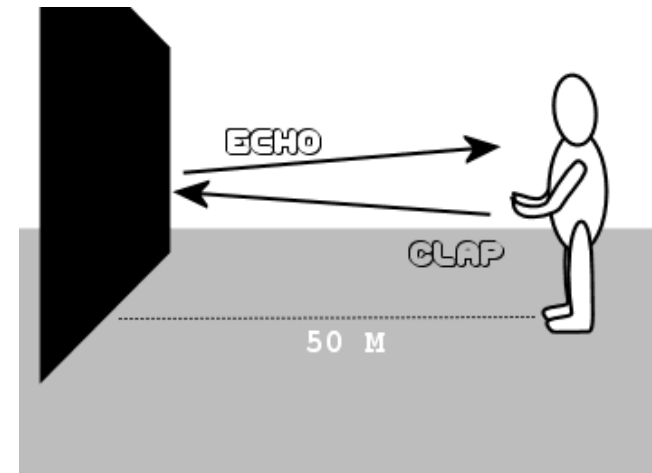
1. Measure the distance between the person and the wall using a metre ruler.
2. Double this distance.
3. Using a stop clock, measure the time taken from the clap being made to hearings it's echo.
4. Use the equation,

    speed = distance ÷ time.

**Sound waves**

Bigger the amplitude – taller the wave – louder the sound

Higher the frequency – more waves per second – higher pitch

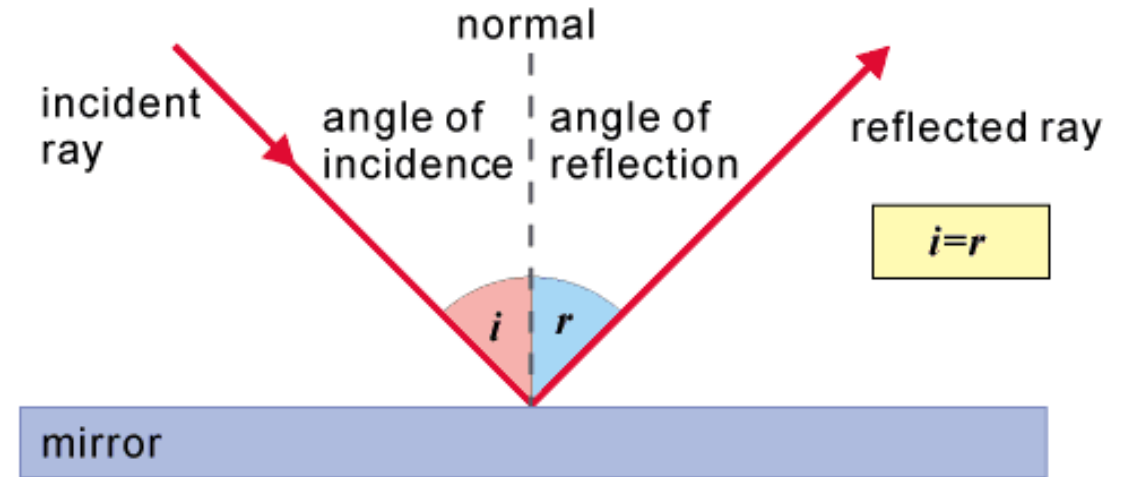# 47. Reflection, transmission and absorption of waves

**Reflection**

Angles are measured between the wave direction (ray) and a line at 90º to the mirror (boundary)

Normal = an imaginary line drawn at 90º to the surface

The angle of the wave approaching the boundary is called the angle of incidence (i)

The angle of the wave leaving the boundary is called the angle of reflection (r)

Angle of incidence (i) = Angle of reflection (r)

normal

incident ray

angle of incidence

angle of reflection

reflected ray

$i=r$

i    r

mirror

**Transmission**

Transmission occurs when a wave passes through a substance

The more transparent the material, the more light will pass through

For the process to count as transmission, the wave must pass through the material and emerge from the other side

When passing through a material, waves are usually partially absorbed

The transmitted wave may have a lower amplitude because of some absorption

For example, sound waves are quieter after they pass through a wall

**Absorption**

Occurs when energy is transferred from the wave into the particles of a substance

Sound waves are absorbed by brick or concrete in houses

Light will be absorbed if the frequency of light matches the energy levels of the electrons

If an object appears red, only red light has been reflected. All the other frequencies of visible light have been absorbed

# 48. Refraction of waves

**Refraction**

Waves change speed when they cross a **boundary** between two materials of different density or a boundary of different depths.
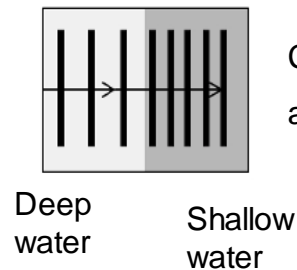
If the wave enters a medium of higher **density** at an **angle** the ray bends towards the normal (see diagram).

If it enters a medium **along the normal** then the wave does not change direction but the **wavelength** and **speed decrease**.

(waves closer together on diagram below but have not changed direction)

**Wave Front Diagrams**

The part of the wave front that enters the more dense medium first, slows down as the rest of the wave front continues at the same speed but has to travel further. The difference in distance and speed causes the wave to refract. A wave travelling from deep to shallow water also refracts.

**Refraction of Light ray**



Angle of incidence

Normal (always at $90^0$ to the boundary)

Incoming ray

Boundary

Angle of refraction

Refracted ray



Less dense   More dense



Deep water   Shallow water
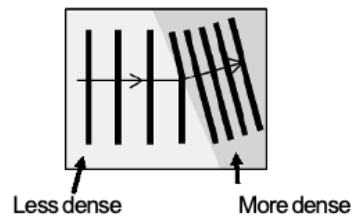
Change in speed but no change in direction as wave entered **along the normal**
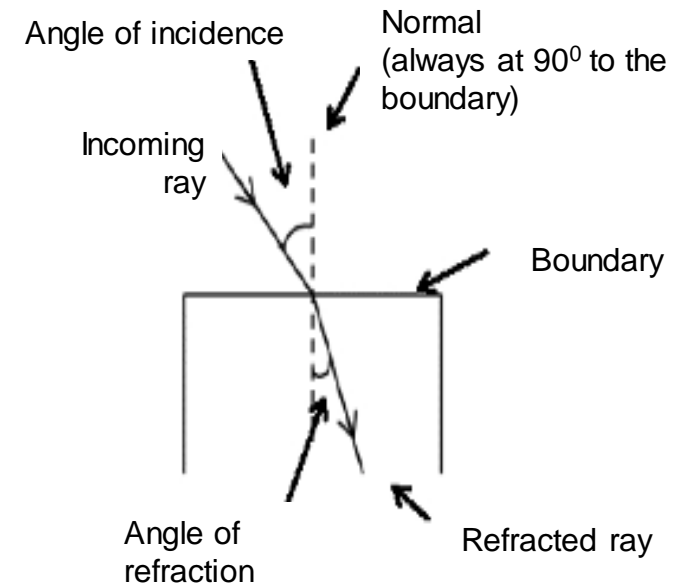
# 49. Electromagnetic Spectrum

All parts of the EM spectrum travel at the same speed.

They all travel at 300,000,000 m/s.

They are all transverse waves

All parts of the EM spectrum can travel through a vacuum (e.g. space)

Long wavelength ➝ Short wavelength

| Radio waves | Microwaves | Infrared | Visible light | Ultraviolet | X-rays | Gamma rays |

Low frequency ➝ High frequency

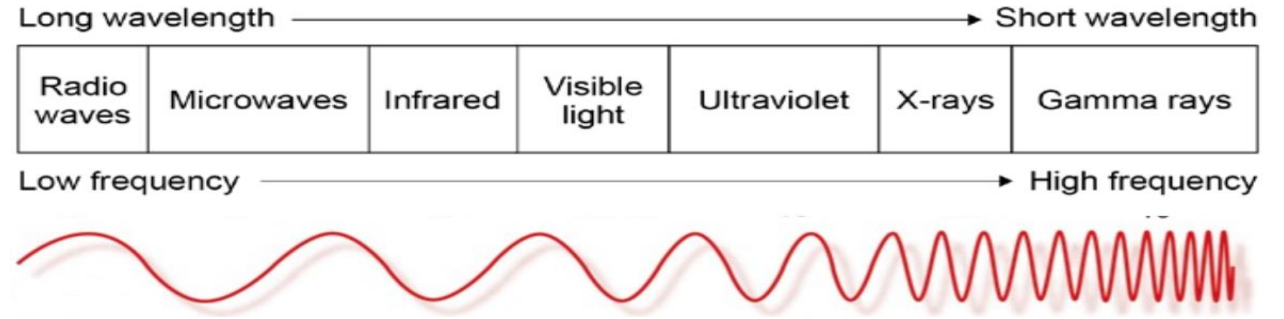| Radio Waves | Used for communication. Used for television and radios. Radio waves can be produced by oscillations in electrical circuits. When radio waves are absorbed they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves induce oscillations in an electrical circuit. |
|---|---|
| Microwaves | Used to communicate with satellites (T.V, mobile Phone) Cooking food. |
| Infra-red Radiation (IR) | Used for electrical heaters, cooking food, infrared cameras |
| Visible Light | Optical fibres transmit data using light over long distances |
| Ultra Violet Radiation (UV) | energy efficient lamps, sun tanning UV can damage surface cells, causing sunburn and increasing the risk of skin cancer. |
| X-Rays | X-Rays pass through flesh but are absorbed by the more dense bone. Ionising, so can cause mutations in DNA, destroy cells and cause cancer |
| Gamma Rays | Gamma rays can be used as a tracer. A gamma source is injected and its path through the body can be detected. Both are used to treat cancer as they kill cells. Ionising, so can cause mutations in DNA, destroy cells and cause cancer |

# 50. Forces

| Scalar | A quantity which has only magnitude | Speed, distance, time, mass… |
|---|---|---|
| Vector | A quantity which has both magnitude and direction | Force, velocity, momentum, acceleration.. |

| Contact Force | Involves 2 or more objects that must touch to act on each other | Friction, air resistance |
|---|---|---|
| Non contact force | Involves 2 or more objects that do not need to be touching for forces to act on each other | Gravitational force, electrostatic force, magnetic force |

**Mass:** Amount of matter in an object

Measured using a balance

Measured in kg

**Weight:** A force depending on the object's mass and force of gravity

Measured using a Newton meter

Measured in N

**Centre of mass:** The point through which the weight of an object acts.
- The **wider** base an object has, the **lower** its centre of mass and it is more **stable**
- The **narrower** base an object has, the **higher** its centre of mass and the object is more likely to topple over if pushed

**Weight (N) = mass (kg) x gravitational field strength (N/kg)**

**W = mg**
e.g. What is the weight of a 2kg mass on earth

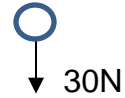| | |
|---|---|
| E | W=m x g |
| V | m = 2kg and g = 9.8N/kg |
| E | W = 2 x 9.8 |
| R | W = 19.6 |
| Y | N |

# 51. Resultant Forces

Found by adding together any forces acting along the same line (direction) and subtracting any that act in the opposite direction:

Drag (50N)
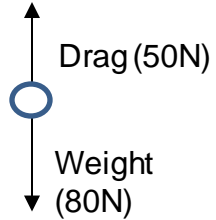
The resultant force is 30N (80-50) downwards.

Weight (80N)

The resultant force is a single force which is equivalent to the 2 forces acting together

30N

When a **force** moves an object through a **distance**, **energy is transferred** and **work is done**.

To make something move a force must be applied, which requires energy.

The force does work to move the object and energy is transferred between stores.

**Calculating Resultant Forces using a diagram**

A scooter is pushed with 4N north and is blown 3N east by the wind. Find the magnitude and direction of the resultant force.

1. Draw a scale diagram.

2. Join the ends of the two forces (dotted arrow)

3.Measure the length of this line and use the scale to work out the size (magnitude) of the force.

4. Measure the bearing (angle) with a protractor.

Scale:
1cm = 1N

3cm

$37^O$ to vertical

4cm

Resultant force
= 5cm = 5N

Measure the angle to give a bearing.
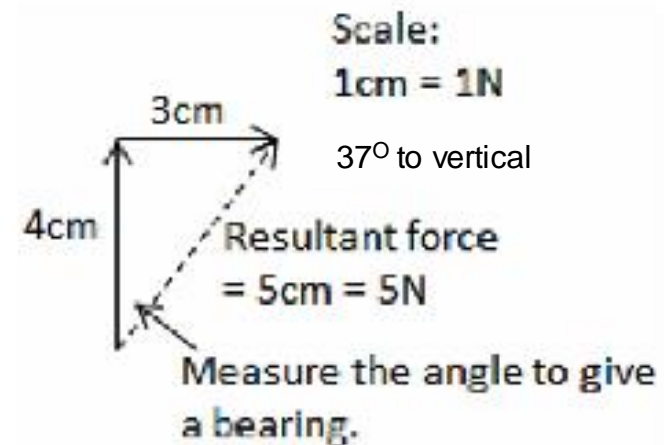
# 52. Resolving Forces—Parallelogram of forces 1

You will be given this vector diagram
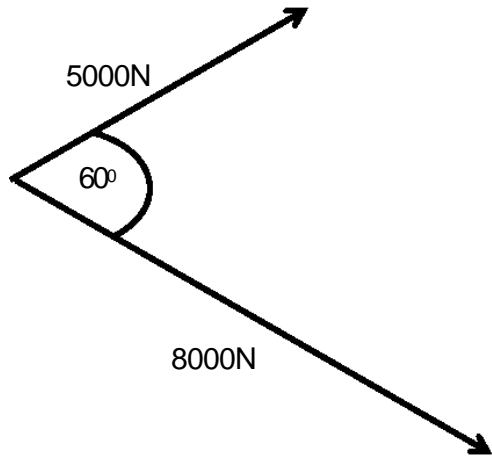
**1**. Draw the missing side of the parallelogram from the highlighted force

5000N

8000N

$60^0$

5000N

8000N

$60^0$

Co interior angles add up to $180^0$

$120^0$

5000N
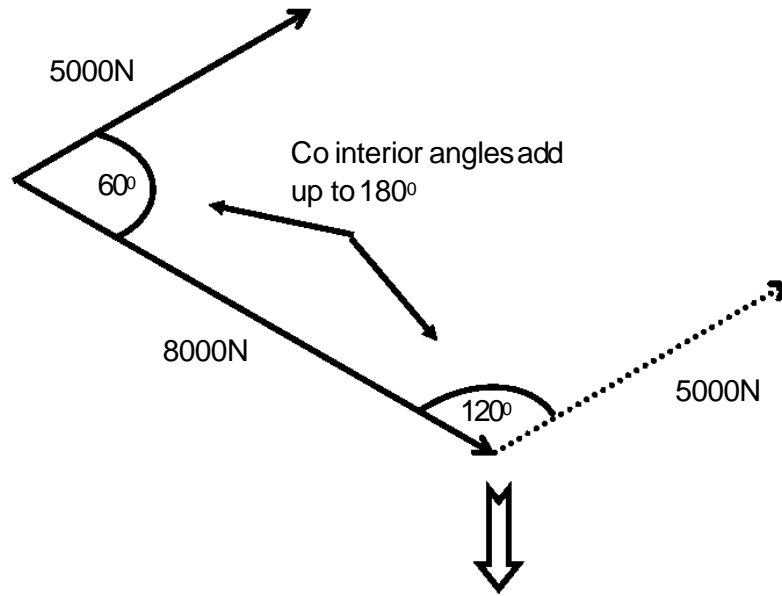
**3.** Draw the resultant force and measure with a ruler

5000N

8000N

$60^0$

8000N

11.3 cm

5000N

$120^0$
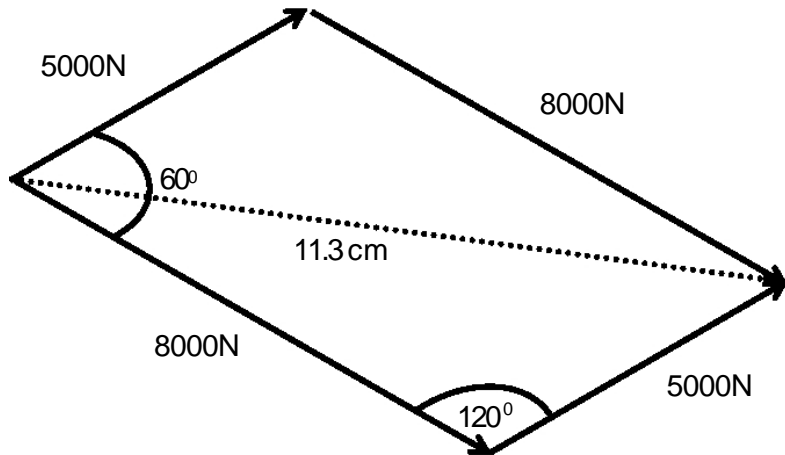
**2.** Draw in the last side of the parallelogram

5000N

8000N

$60^0$

8000N

5000N

$120^0$
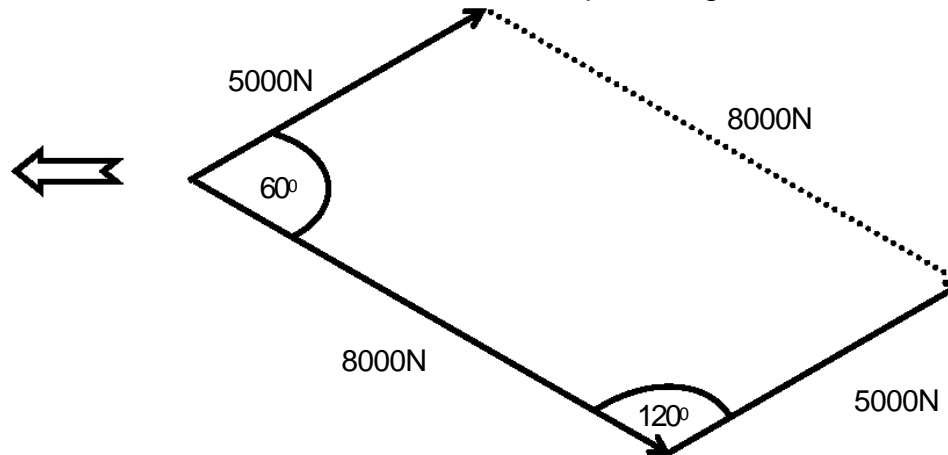
# 53. Resolving Forces—Parallelogram of forces 2

**4.** Use your scale to calculate the size of the resultant force
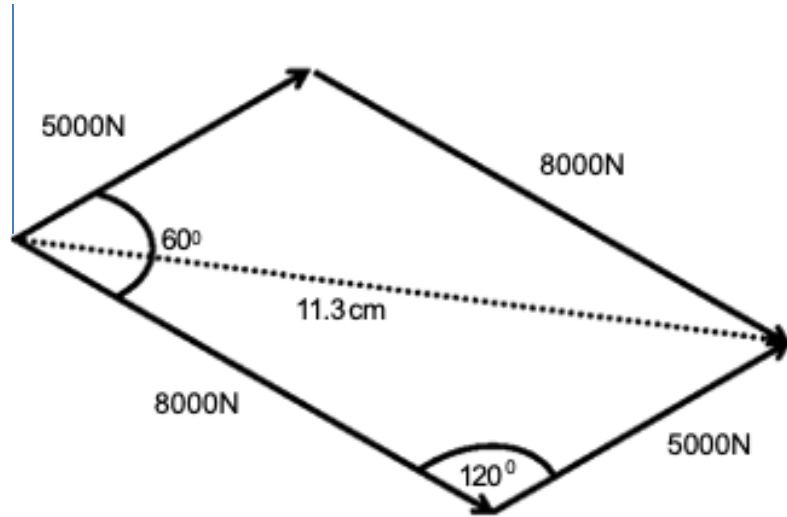
Measure angle to give vector angle e.g $110^0$ from vertical
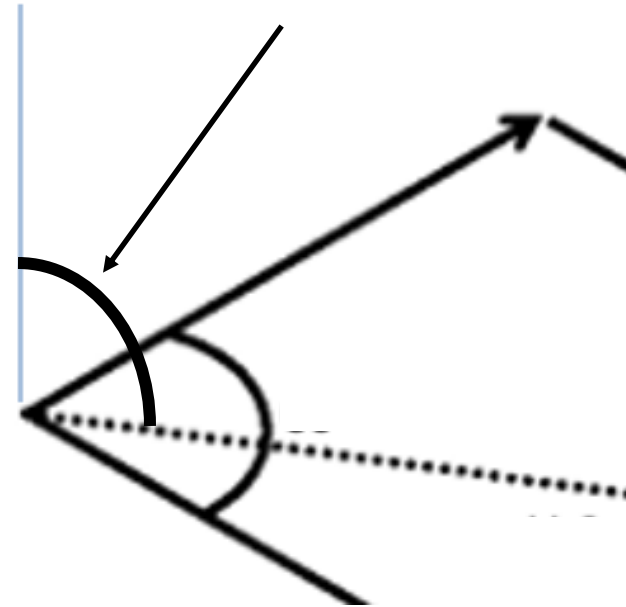


Resultant force length = 11.3 cm

Scale = 1 cm = 1000 N

11.3 x 1000 = 11300 N  Resultant force = 11300 N

Measure angle resultant force acts at from vertical because vector requires magnitude and direction.

Resultant force = 11.3 kN at $110^0$ to vertical

# 54. Resolving Forces – On an inclined plane 1

A box is resting on a 30° incline. Resolve the force into a parallel & perpendicular components. The box has a weight of 50N.
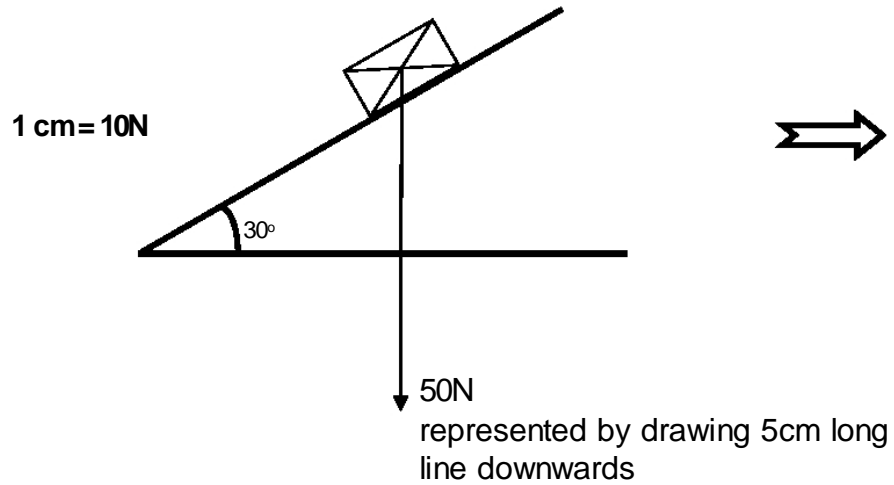
**1**. Draw a line parallel to the slope

**1 cm = 10N**

30°

50N
represented by drawing 5cm long line downwards

50N

**3.** Draw a second line parallel to the slope at the end of the 50N line

30°

50N

**2.** Draw a line perpendicular to this and through the centre of the object

30°

50N
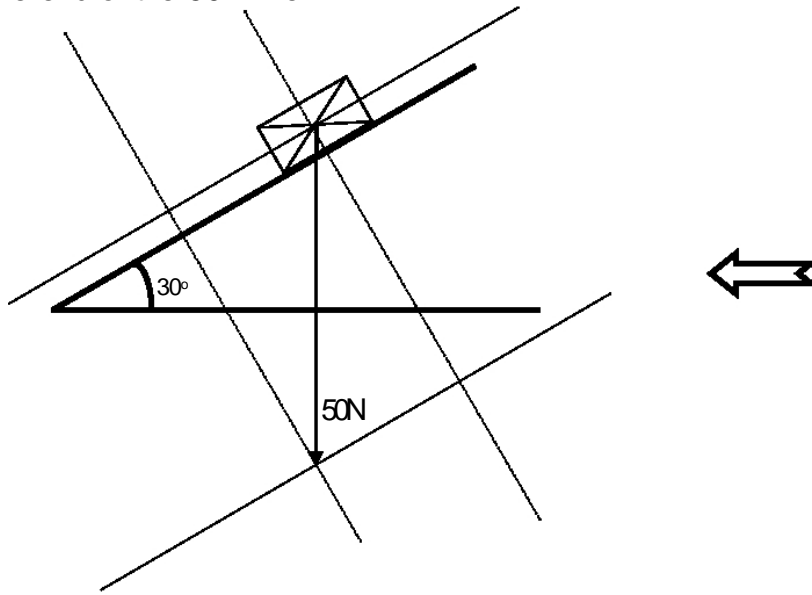
# 55. Resolving Forces – On an inclined plane 2

**4.** Measure the length of the perpendicular and parallel

8.8 cm

30°

50N
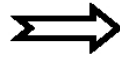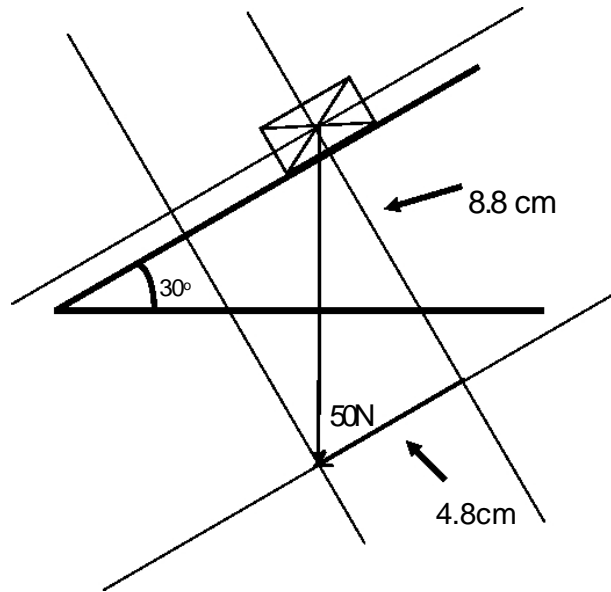
4.8cm

**5.** Calculate your parallel and perpendicular component lines as below

**1 cm = 10 N**

Parallel Component = 4.8 cm

4.8 X 10 = 48 N

Perpendicular Component = 8.8 cm

8.8 X 10 = 88 N

# 56. Elasticity

To stretch, compress or bend an object more than one force must act on it.

Extension is directly proportional to force:

**Force (N) = spring constant (N/m) x extension (m)**
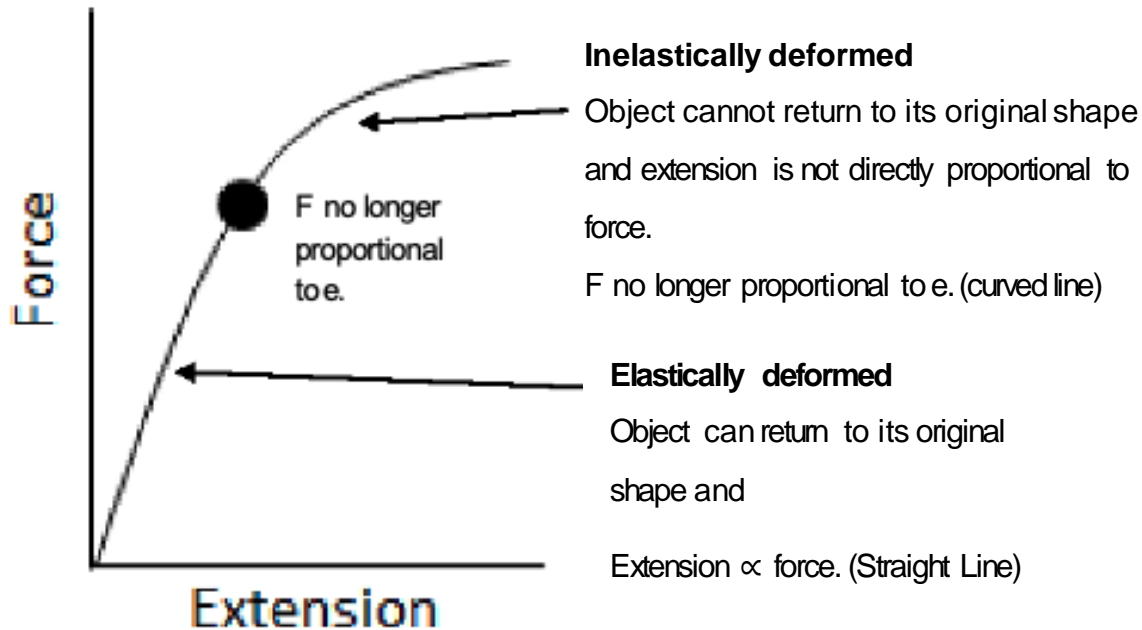
**F = ke**



**Inelastically deformed**

Object cannot return to its original shape and extension is not directly proportional to force.

F no longer proportional to e. (curved line)

**Elastically deformed**

Object can return to its original shape and

Extension ∝ force. (Straight Line)

F no longer proportional to e.

**Elastic Potential Energy**

A force acting on an object may cause the shape of an object to change.

Elastic objects can store elastic potential energy if they are stretched or squashed. For example, this happens when a catapult is used or a spring is stretched.

Objects can also store elastic potential energy when they are squashed.

**Elastic potential energy (J) = 0.5 x spring constant (N/m) x extension$^2$ (m)**

**Unit conversions:**
kJ to J:      x 1000
cm to m:    ÷ 100

# 57. Newton's laws of motion

| | | |
|---|---|---|
| First Law | A body at rest will remain at rest, and a body in motion will remain in motion, unless it is acted upon by an unbalanced force.<br><br>Inertia is the tendency of a body to remain in the same state of motion | |
| Second Law<br><br><br>. | The amount a body accelerates is directly proportional to the force applied to it and inversely proportional to the mass of the body.<br>F = ma<br><br>e.g. An aeroplane accelerates from a low speed to a high speed with the engines at maximum power<br>At maximum power the forward force of the engines is constant as it accelerates the air resistance increases<br>resultant force = force from engines – air resistance<br>Therefore resultant force decreases acceleration is directly proportional to resultant force | **Inertial mass** is the property of an object which describes how difficult it is to change its velocity<br>Inertial mass = force ÷ acceleration<br>Inertial mass is defined as the ratio of force to acceleration<br>Inertial mass is inversely proportional to acceleration<br>(mass = 1 ÷ acceleration)<br>Larger inertial masses will experience small accelerations<br>Smaller inertial masses will experience large accelerations |
| Third Law | When two objects interact, the forces they exert on each other are **equal** and **opposite**.<br>This is an **equilibrium** situation - neither object moves because the forces are balanced. | |

# 58. Momentum

A vector quantity (has size and direction).

**Momentum (kg m/s) = mass (kg) x velocity (m/s)**

**P = mv**

Conserved momentum:

total momentum before = total momentum

afterwards

e.g. A 2 kg object (A) moving at 3m/s crashes into a

4 kg stationary object (B) causing both objects to

move away locked together.

What velocity do they move away at?

Total momentum before = $(m_A \times v_A) + (m_B \times v_B)$

= (2 x 3) + (4 x 0) = 6kgm/s

Total momentum after = 6kgm/s = $(m_A + m_B) \times v_{new}$

$V_{new} = 6 / (2+4) = 1$m/s

Momentum is a vector therefore the direction is the same

because it is a positive answer. A negative sign would show

the opposite direction.

$$\text{Force} = \frac{\text{change in momentum}}{\text{change in time}}$$

**Change in momentum safety features**

**Seat belts**

Seat belts stop you tumbling around inside the car if there is a collision. However,

they are designed to stretch a bit in a collision.

This increases the time taken for the body's momentum to reach zero, and so

reduces the forces on it.

**Air bags**

Air bags increase the time taken for the head's momentum to reach zero, and so

reduce the forces on it.

They also act a soft cushion and prevent cuts.

**Crumple zones**

Crumple zones are areas of a vehicle that are designed to crush in a controlled way

in a collision.

They increase the time taken to change the momentum of the driver and passengers

in a crash, which reduces the force involved.

# 59. Speed, velocity and acceleration

| Typical Speed Walking | 1.5 m/s |
|---|---|
| Running | 3 m/s |
| Cycling | 6 m/s |
| Car | 25 m/s |
| Train | 55 m/s |
| Plane | 250 m/s |

| Speed | How fast something is going without reference to a direction. It is a scalar quantity. |
|---|---|
| Velocity | A speed in a given direction |
| Acceleration | How quickly something is speeding up, or its rate of change of velocity. Deceleration is how quickly something is slowing down or negative acceleration. |

**Terminal Velocity**

The maximum speed an object will fall at through a fluid (liquid or gas).

As the speed of a falling object increases so does the frictional force (drag) opposing the objects weight (which doesn't change).

The resultant force is therefore reducing until the drag is equal to the weight. Acceleration is reduced to zero and the terminal velocity is reached.

**Uniform Acceleration**

This can happen due to gravity acting on an object in free fall.

$$v^2 - u^2 = 2\,a\,s$$

v = final velocity (m/s)
u = initial velocity (m/s)
a = acceleration (m/s$^2$)
s = distance (m)



$F_{drag}$

$F_{weight}$

**Velocity and circular motion**

When an object travels along a circular path, its velocity is always changing

The **speed** of the object moving in a circle is constant (travelling the same distance every second)

The **direction** of travel is always changing as the object moves along the circular path

This means that an object moving in circular motion travels at a **constant speed** but has a **changing velocity**
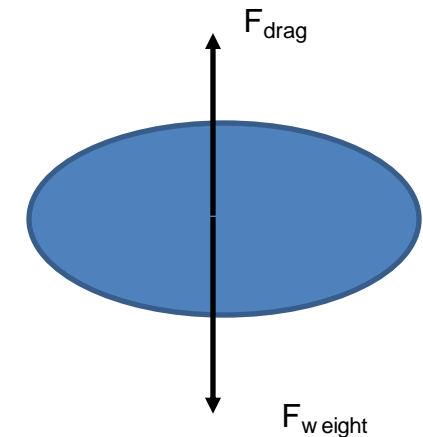
# 60. Graphs of Motion

**Distance – time graph**
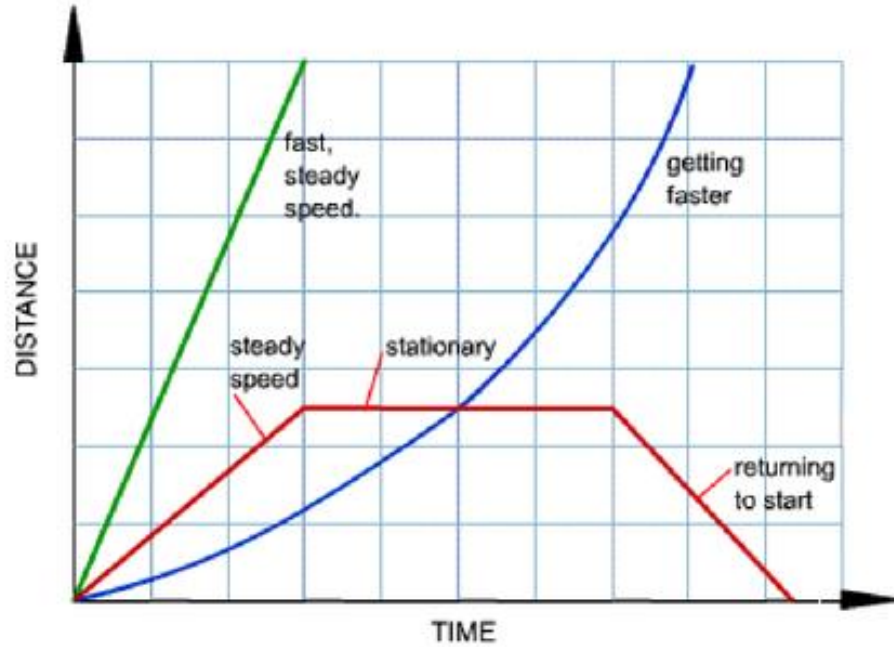


Gradient = speed of object

Gradient = change in y
          change in x

**Velocity – time graph**



Gradient = acceleration of object

Distance travelled = area under the line

Average velocity = $(v + u) / 2$

# 61. Thinking, Braking and Stopping Distances

Typical **reaction time** for a person is 0.2-0.9s

**Thinking distance** – the distance travelled during the reaction time. The distance between the driver seeing the danger and taking action to avoid it.
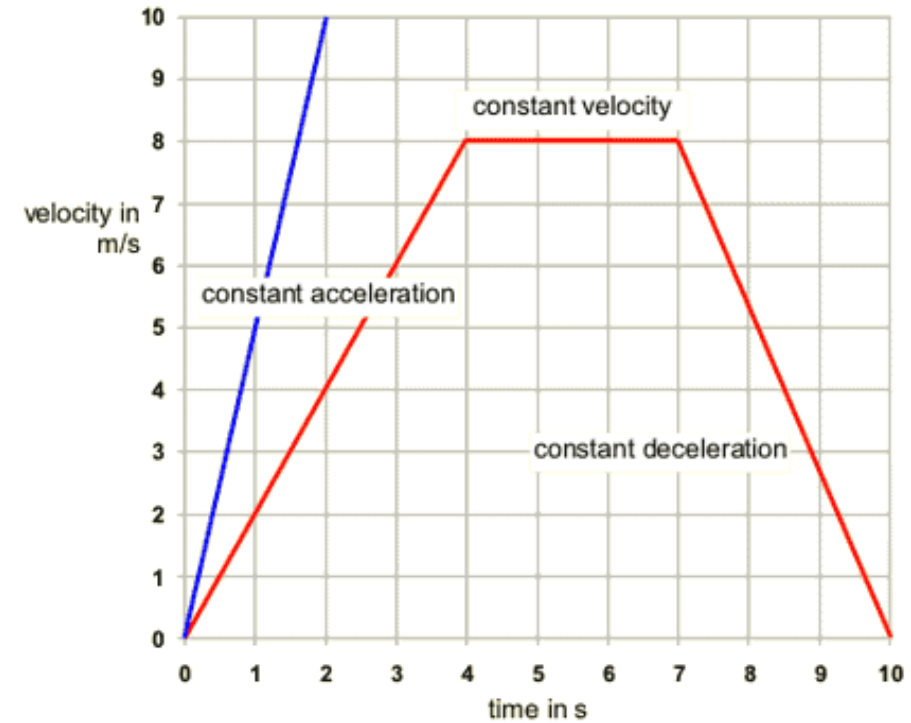
**Braking distance** – distance travelled before a car stops after the brakes have been applied. It increases as the speed of the car increases.

**Stopping distance**= thinking distance + braking distance

**Reaction time** – the time taken for the driver to react to the stimulus

**Thinking distance** is affected by:

- Speed

- Your reaction time which is affected by:

I. Alcohol

II. Drugs

III. Sleep deprivation

IV. Distractions

**Reaction time** experiment:

Ruler drop test

Computer based experiments

**Braking distance** is affected by:

- Speed

- Weather and the road surface e.g. icy

- Condition of tyres e.g. bald tyres cannot get rid of the water in wet conditions leading to skidding

- Quality of brakes

# 62. Required Practical 6: Force and extension



**Force and Extension**

The extension of a spring is directly proportional to the force applied, provided its limit of proportionality is not exceeded
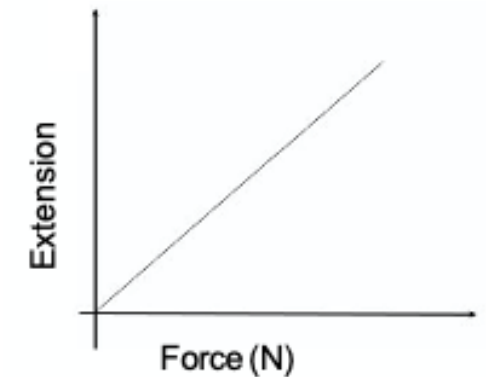
**Independent variable -** Force applied (N)

**Dependent variable -** Extension of spring (m)

**Control variable -** same spring, keep ruler in the same position.

**Method**

1. Hang the spring on the end of the clamp and gently clamp it to secure it.

2. Measure the original length of the spring and record this length.

3. Add a 100 g (1 Newton) mass holder to the end of the spring.

4. Measure the new length and calculate the extension.

5. Add 100 g masses, one at a time, measuring the length and calculating (and recording) the extension of the spring each time.

6. Stop when you have added a total of 500 g. Be careful not to overstretch the spring.
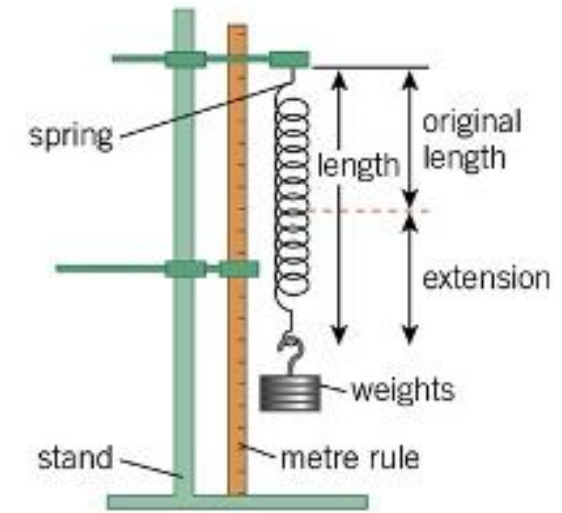


Spring constant (N/m) = Force (N) ÷ extension (m)
Spring constant = gradient of the line

# 63. Required Practical 7: The effect of force on acceleration

**Independent variable** – Force (N)   (weight due to mass W=mg)

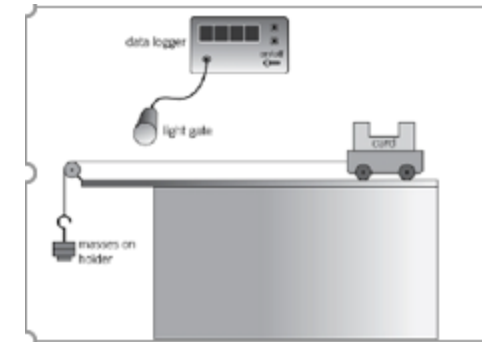**Dependent variable** – acceleration (m/s$^2$)

**Control variables** – mass of trolley, same trolley starts from same position each time

## Method

1. Measure the length of each card segment and make a note of this.

2. Set up the apparatus as shown in the diagram below. When the trolley is as close to the pulley as it can get, the bottom of the mass holder should be between 0.5 cm and 1 cm above the floor.

3. During this experiment the trolley will travel towards the pulley.

4. Set up the data logger. You will use its measurements to find the trolley's acceleration.

5. Add mass to the mass holder so that the total mass, including the holder, is 250 g.

6. Pull back the trolley, set the data logger to record, and then let the trolley run to the pulley. Collect the necessary measurements from the data logger.

7. Take 50 g off the mass holder and place it onto the trolley. You may need to use a small amount of tape or sticky tack to hold the mass securely in place. Repeat step 6.

8. Repeat steps 6-7 until there is 200 g on the trolley - this will be the fifth and final run.

## How to reduce random errors
Repeat the measurements/investigation

Ignore anomalies and calculate the mean



The acceleration of an object is **proportional** to the result- ant force acting on the object.

The acceleration of an object is proportional to the resultant force acting upon it. F = ma  or a = F/m

m is the mass of the trolley and not the weight being attached to the string

# 64. Required Practical 8: The effect of mass on acceleration

**Independent variable** – mass of the trolley (N)

**Dependent variable** – acceleration (m/s²)

**Control variables** – Force being applied, trolley starts from same position each time
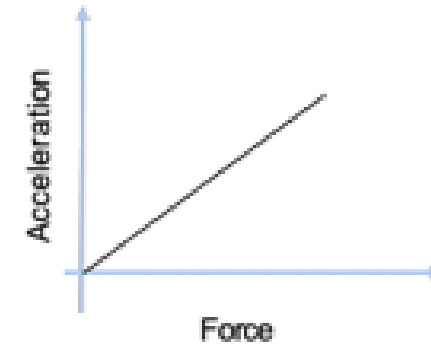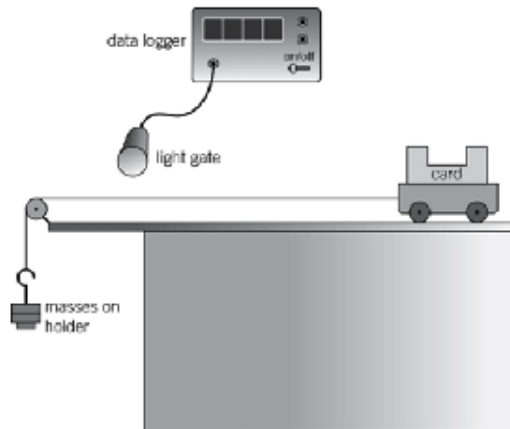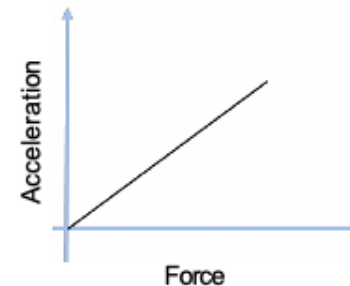
**Method**

1. Measure the length of each card segment and make a note of this.

2. Set up the apparatus as shown in the diagram below. When the trolley is as close to the pulley as it can get, the bottom of the mass holder should be between 0.5 cm and 1 cm above the floor.

3. During this experiment the trolley will travel towards the pulley. If you need to, place a lump of modelling clay or a block in front of the pulley to protect it from being hit by the trolley.

4. Set up the data logger. You will use its measurements to find the trolley's acceleration. There are different ways of doing this, depend- ing on the data logger and the method your teacher asks you to use.

5. You will be changing the mass (by stacking extra trolleys under the first one) but keeping the applied force the same (by keeping the same number of masses on the mass holder). First, measure the mass of one trolley. (You can assume all trolleys have the same mass.)

6. Each time you change the number of stacked trolleys, measure the acceleration. You may need to change the height of the light gate so that the card still passes through it.
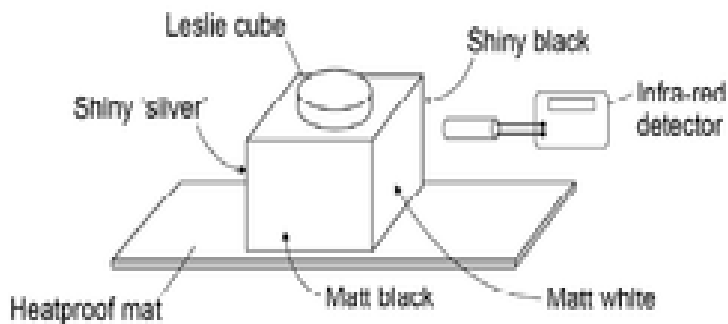
The acceleration of an object is **inversely proportional** to the mass of the object.

$a = F/m$

# 65. Required practical 9: Infra red radiation

**Demonstration**



**Method:**

1. Set up equipment as shown in diagram
2. Fill cube with hot water and put on lid
3. Use the detector to measure the amount of radiation from each surface

**IV:** surface

**DV:** Amount of IR absorbed or radiated

**CV:** Distance between surface and IR detector

**Advantages of using this cube:**

- All surfaces are at the same temperature
- More surfaces are tested
- Volume and temperature of the water does not need to be measured

All bodies (objects) emit and absorb **infrared radiation**.

An object that is good at absorbing radiation is also a good **emitter**, so a perfect black body would be the best possible emitter of radiation.

**White and shiny silvery surfaces are the worst absorbers**, as they reflect all visible light wavelengths. Poor absorbers are also poor emitters, and do not emit radiation as quickly as darker colours. Radiators in homes are usually painted white so that the infrared radiation is emitted gradually.

**Class practical**

1. Fill a matt black boiling tube and a shiny boiling tube with equal volumes of hot water.
2. Record temperature of water inside boiling tubes every 30 seconds.
3. Plot results on a graph

**IV:** surface of boiling tube

**DV:** temperature of hot water

**CV:** volume of hot water, time intervals recording the temperature

Matt black boiling tube: Temperature drops the most and it is the best at it is the best at emitting heat.

# 66. Required practical 10: Speed of water waves

1. Set up the ripple tank as shown in the diagram.
2. Make sure that there is a large sheet of white card or paper on the floor under the tank.
3. Pour water to a depth of about 5 mm into the tank.
4. Adjust the height of the wooden rod so that it just touches the surface of the water.
5. Switch on the overhead lamp and the electric motor.
6. Adjust the speed of the motor to produce low frequency water waves.
7. Adjust the height of the lamp so that the pattern of the waves can be clearly seen on the white card.
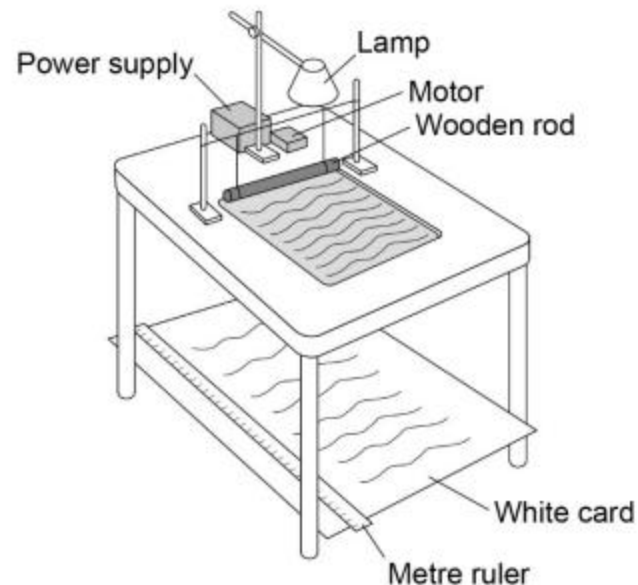


**How to find the frequency of a wave using a ripple tank:** count the number of ripples that pass a point in 10 seconds. Divide the number of waves by 10.

**How to measure the wavelength:** measure the distance across 10 gaps between the shadow lines. Divide this distance by 10.

**How to calculate the speed of the wave**

Wave speed (m/s) = frequency (Hz) x wavelength (m)

**How to improve the method of calculating the wavelength:**
Take a photo of the shadows and the ruler.
Benefit is that the waves are not being disturbed.

**Reasons for using a:**
Lamp: create shadows of the ripples
Metre ruler: measure the distance between 10 waves.
Signal generator: The vibration generator can have a built in signal generator so that you can directly set the frequency of paddle oscillation i.e. frequency of the ripple waves.

**Deeper water** means longer wavelength because velocity increases and frequency is constant

# 67. Maths in Science 1

| | |
|---|---|
| **Anomalous result** | A number that does not fit the pattern |
| **Mean** | Adding up a list of numbers and dividing by how many numbers are in the list. Exclude the anomalous result. |
| **Median** | The middle value when a list of numbers is put in order from smallest to largest |
| **Mode** | The most common value in a list of numbers. If two values are tied then there are two modes. If more than two values are tied then there is no mode. |
| **Range** | The largest number take away the smallest value in a set of data or written as X-Y. |
| **Uncertainty** | range ÷ 2 |
| **Surface area of a cube** | (area of 1 side) x 6 sides |
| **Volume of a cube** | Width x height x depth |
| **Area of a circle** | $\prod$ x (radius)$^2$ |

**Prefixes**

1 kJ = 1 x 10$^3$ J = 1000 J

1 pm = 1 x 10$^{-12}$ m

1 mm = 1 x 10$^{-3}$ m= 0.001 m

| | |
|---|---|
| kilo | 10 $^3$ |
| centi | 10 $^{-2}$ |
| milli | 10 $^{-3}$ |
| micro | 10 $^{-6}$ |
| nano | 10 $^{-9}$ |
| pico | 10 $^{-12}$ |

**5607.376**

**Standard form:** 5.607 x 10$^3$

**2 decimal places:** 5607.38

**3 significant figures:** 5610

**0.03581**

**Standard form**: 3.581 x 10$^{-2}$

**2 decimal places:** 0.04

**3 significant figures**: 0.0358

# 68. Maths in Science 2

**Calculating percentage:** (part ÷ whole) x 100

e.g. Out of 90 insects, 40 of them were ladybirds. What is the % of ladybirds?

(40 ÷ 90) x 100 = 44 %

**Calculating percentage change:**

(difference ÷ starting value) x 100

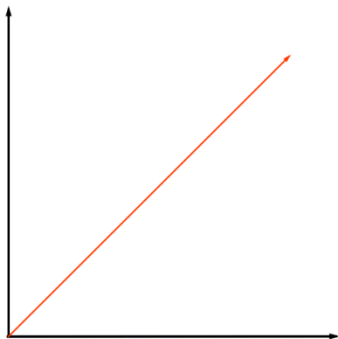(0.59 ÷ 2.22) x 100 = 26.6 %

| Conc of Sucrose (M) | Mass of potato at start (g) | Mass of potato at end (g) | Change in mass (g) |
|---|---|---|---|
| 0 | 2.22 | 2.81 | 0.59 |

**Graphs**

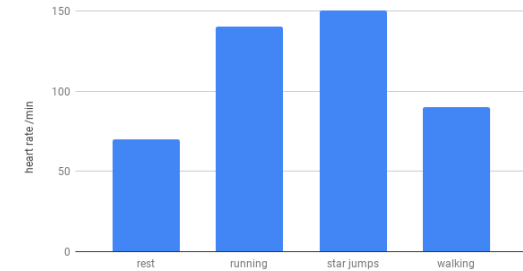**Proportional (α)**
When the line passes through the origin

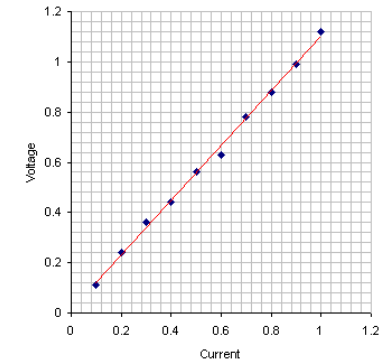x axis = independent variable = left hand column of results table

y axis = dependent variable = right hand column of results table

**Categoric data**: data put into groups e.g. colour of eyes
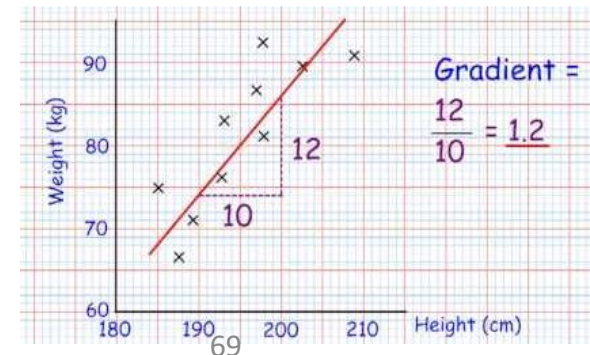Draw a bar chart

The effect of exercise on heart rate

**Continuous data**: data that can take any value e.g. current
Draw a line graph

**Gradient and Graphs**

Gradient = $\frac{\text{Change in y}}{\text{Change in x}}$

Gradient = $\frac{12}{10}$ = 1.2

| | |
|---|---|
| kinetic energy = 0.5 × mass × (speed)² | $E_k = \frac{1}{2}mv^2$ |
| elastic potential energy = 0.5 × spring constant × (extension)² | $E_e = \frac{1}{2}ke^2$ |
| gravitational potential energy = mass × gravitational field strength × height | $E_p = mgh$ |
| change in thermal energy = mass × specific heat capacity × temperature change | $\Delta E = mc\Delta\theta$ |
| power = $\dfrac{\text{energy transferred}}{\text{time}}$ | $P = \dfrac{E}{t}$ |
| power = $\dfrac{\text{work done}}{\text{time}}$ | $P = \dfrac{W}{t}$ |
| efficiency = $\dfrac{\text{useful output energy transfer}}{\text{total input energy transfer}}$ | |
| efficiency = $\dfrac{\text{useful power output}}{\text{total power input}}$ | |
| charge flow = current × time | $Q = It$ |
| potential difference = current × resistance | $V = IR$ |
| power = potential difference × current | $P = VI$ |
| power = (current)² × resistance | $P = I^2R$ |
| energy transferred = power × time | $E = Pt$ |

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| | | |
|---|---|---|
| | energy transferred = charge flow × potential difference | $E = Q V$ |
| HT | potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil | $V_p I_p = V_s I_s$ |
| | density = $\dfrac{\text{mass}}{\text{volume}}$ | $\rho = \dfrac{m}{V}$ |
| | thermal energy for a change of state = mass × specific latent heat | $E = m L$ |
| | weight = mass × gravitational field strength | $W = m g$ |
| | work done = force × distance (along the line of action of the force) | $W = F s$ |
| | force = spring constant × extension | $F = k e$ |
| | distance travelled = speed × time | $s = v t$ |
| | acceleration = $\dfrac{\text{change in velocity}}{\text{time taken}}$ | $a = \dfrac{\Delta v}{t}$ |
| | (final velocity)² – (initial velocity)² = 2 × acceleration × distance | $v^2 - u^2 = 2 a s$ |
| | resultant force = mass × acceleration | $F = m a$ |
| HT | momentum = mass × velocity | $p = m v$ |
| | period = $\dfrac{1}{\text{frequency}}$ | $T = \dfrac{1}{f}$ |
| | wave speed = frequency × wavelength | $v = f \lambda$ |
| HT | force on a conductor (at right angles to a magnetic field) carrying a current = magnetic flux density × current × length | $F = B I l$ |

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