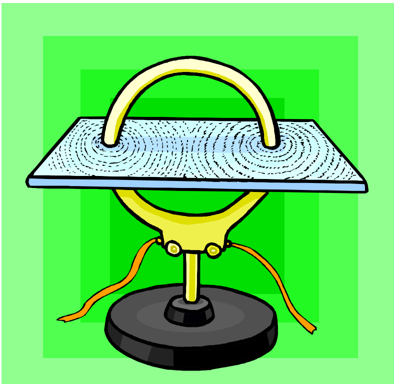
National 5 Physics

"ELECTRICITY"

Electric Charge Carriers and Electric Fields + Potential Difference (Voltage)



Name: ______________________________

This section of the "Electricity" unit initially introduces the two types of electric charge and explains how they interact with one another - it defines the term 'electric field' and shows how to represent an electric field using electric field lines. It explains some practical uses of electrostatics. It then moves on to define the terms 'current' and 'potential difference' ('voltage') before dealing with calculations involving quantity of charge, current and time. It ends by explaining the difference between 'direct current' (d.c.) and 'alternating current' (a.c.).

By the end of this section, you should be able to:

- ☐ state that there are two types of electric charge: positive and negative
- ☐ state that atoms consist of positively charged protons and neutral neutrons packed together in the centre (nucleus) which is surrounded by negatively charged electrons
- ☐ state that 'like electric charges repel' and 'opposite electric charges attract'
- ☐ state that an electric field is a region where an electrically-charged particle will experience a force that will make the particle move
- ☐ represent an electric field by drawing electric field lines between charged particles/objects
- ☐ state that electric current is the electric charge transferred per second
- ☐ state that the potential difference (voltage) of a power supply is a measure of the energy the supply gives to the charge carriers in an electric circuit
- ☐ use the formula $Q = It$ to solve problems involving the quantity of electric charge, current and time
- ☐ explain the difference between direct and alternating current

• ELECTRIC CHARGE - ELECTROSTATICS

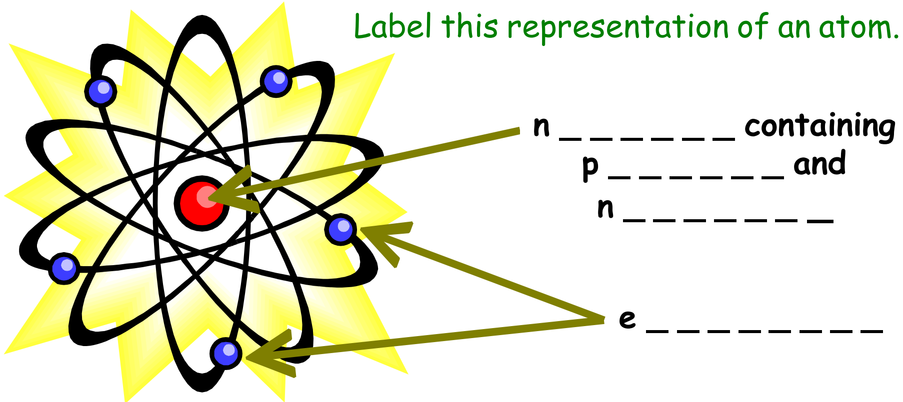
The Atom

Everything is made up of tiny particles called **a** _ _ _ _.

Each atom contains **p** _ _ _ _ _ _ and **n** _ _ _ _ _ _ _ that are tightly-packed together in a tiny centre called the **n** _ _ _ _ _ _.

Circling around the **n** _ _ _ _ _ _ are **e** _ _ _ _ _ _ _ _.

Label this representation of an atom.



There are two types of electric charge:
p _ _ _ _ _ _ _ _ (__) and **n** _ _ _ _ _ _ _ _ (__).
These are exact **o** _ _ _ _ _ _ _ _.

Protons have a **p** _ _ _ _ _ _ _ _ (__) electric charge.

Electrons have a **n** _ _ _ _ _ _ _ _ (__) electric charge.

Neutrons do not have an electric charge.

Atoms contain equal numbers of positively charged protons and negatively charged electrons, so the electric charges cancel out. Atoms therefore have no overall electric charge - atoms are said to be **electrically n** _ _ _ _ _ _.

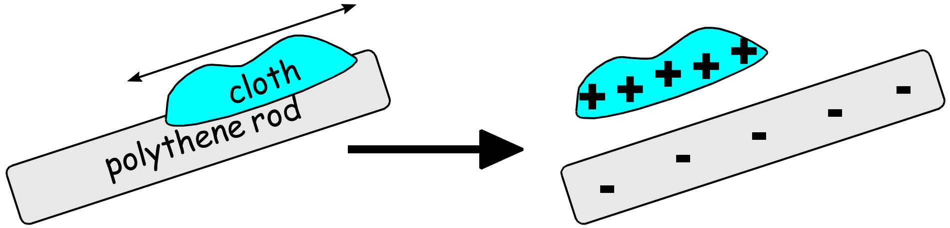
Because protons are positioned in the nucleus (centre) of atoms, they <u>can't</u> move out of the atoms. However, because electrons are positioned outside the nucleus, they <u>are</u> able to move out of and away from their atoms.

Charging Polythene and Nylon Rods

Objects become electrically-charged when *electrons* are added to them or taken away from them.

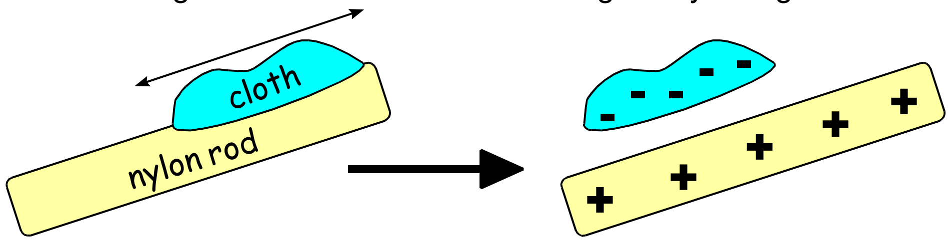
A polythene rod is neutral - its atoms contain equal numbers of positively charged protons and negatively charged electrons.

If we rub the rod with a neutral cloth, negatively charged electrons from the cloth are transferred to the rod. The rod now has more negatively charged electrons than positively charged protons, so is negatively charged. The cloth now has fewer negatively charged electrons than positively charged protons, so is positively charged.



A nylon rod is neutral - its atoms contain equal numbers of positively charged protons and negatively charged electrons.

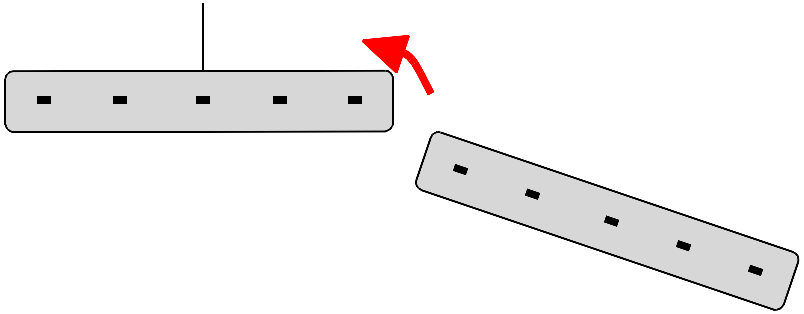
If we rub the nylon rod with a neutral cloth, the rod becomes positively charged and the cloth becomes negatively charged.



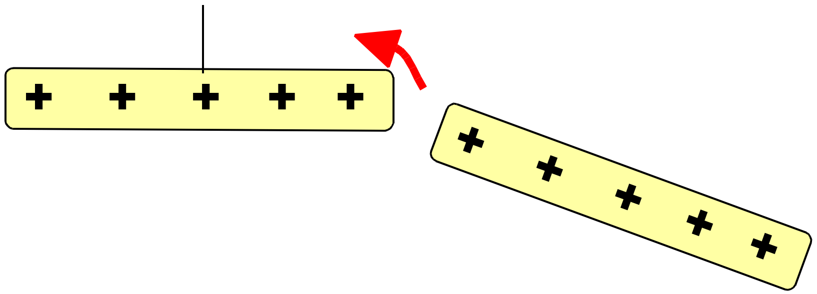
Explain what is happening in terms of **'electron transfer'**:

Attraction and Repulsion

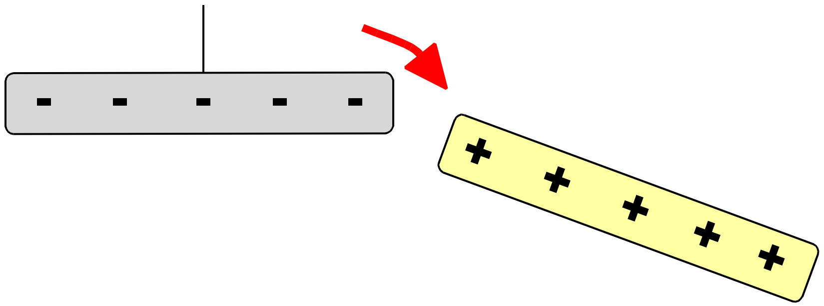
When a negatively charged polythene rod is brought close to another negatively charged polythene rod suspended on an insulating string, the suspended rod moves **a** _ _ _ - the rods **r** _ _ _ _.



When a positively charged nylon rod is brought close to another positively charged nylon rod suspended on an insulating string, the suspended rod moves **a** _ _ _ - the rods **r** _ _ _ _.

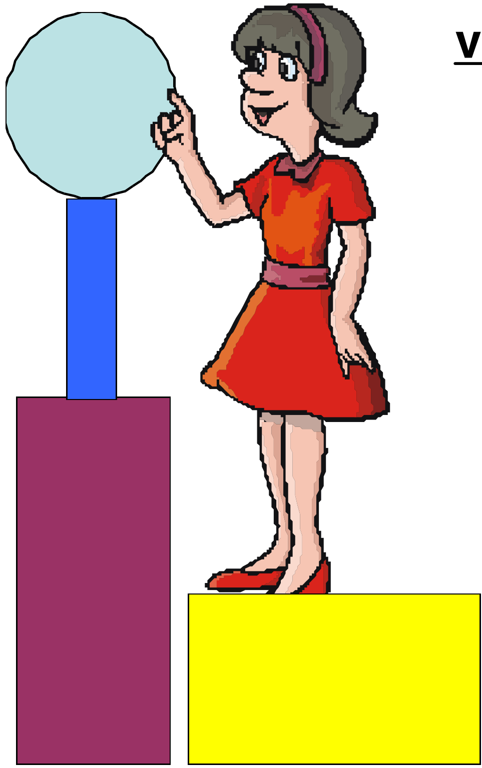


When a positively charged nylon rod is brought close to a negatively charged polythene rod suspended on an insulating string, the suspended rods move **t** _ _ _ _ _ _ one another - the rods **a** _ _ _ _ _ _.



It can be concluded that:

- **Like electrical charges r _ _ _ _**
- **Opposite electrical charges a _ _ _ _ _ _**



van de Graaff Generator

The girl touches the dome of the van de Graaff generator, which is then switched on.

- *What happens to the girl's hair?*

____

____

____

This is because the dome of the van de Graaff generator is positively charged.

As a result, **e** _ _ _ _ _ _ _ _ _ in the girl's body, including those in her hair, are **a** _ _ _ _ _ _ _ _ away from her body onto the positively charged dome.

This means all the strands of the girl's hair become **p** _ _ _ _ _ _ _ _ _ _ charged - the strands of hair therefore **r** _ _ _ _ one another because like charges **r** _ _ _ _.

Electric Fields

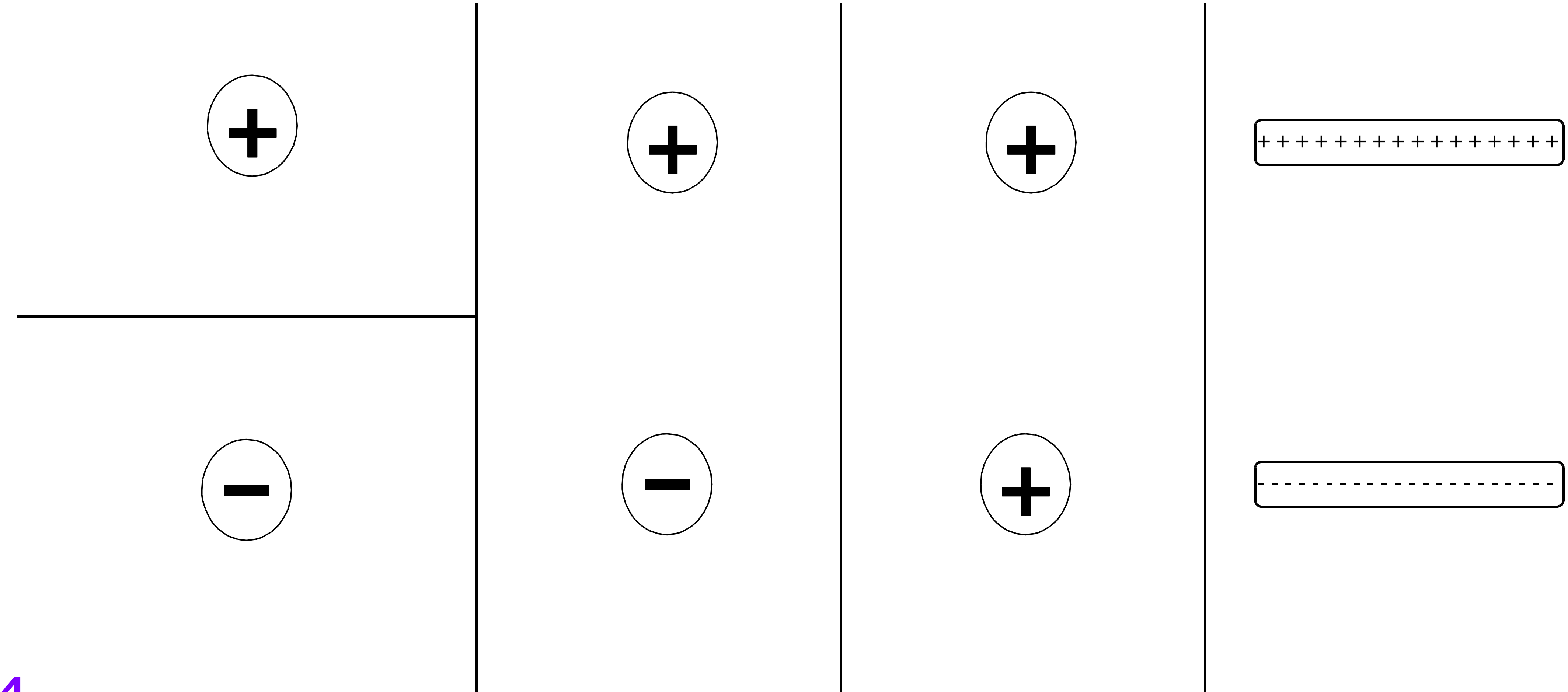
An **electric field** is a region where an electrically-charged particle will experience a force. This force will make the particle move.

Electric fields exist between electrically-charged particles and between electrically-charged objects.

To show where an electric field acts, we draw imaginary **electric field lines**. The arrow head on each electric field line shows the direction that a **positively charged particle** would move in, if that particle were placed in the electric field. A **negatively charged particle** would move in the opposite direction.

Electric field lines drawn close together indicate a strong electric field. Electric field lines drawn far apart indicate a weak electric field.

- You should draw electric field lines to show the 'shape' of the electric field in each case below. (Use textbooks or the internet to help you.)



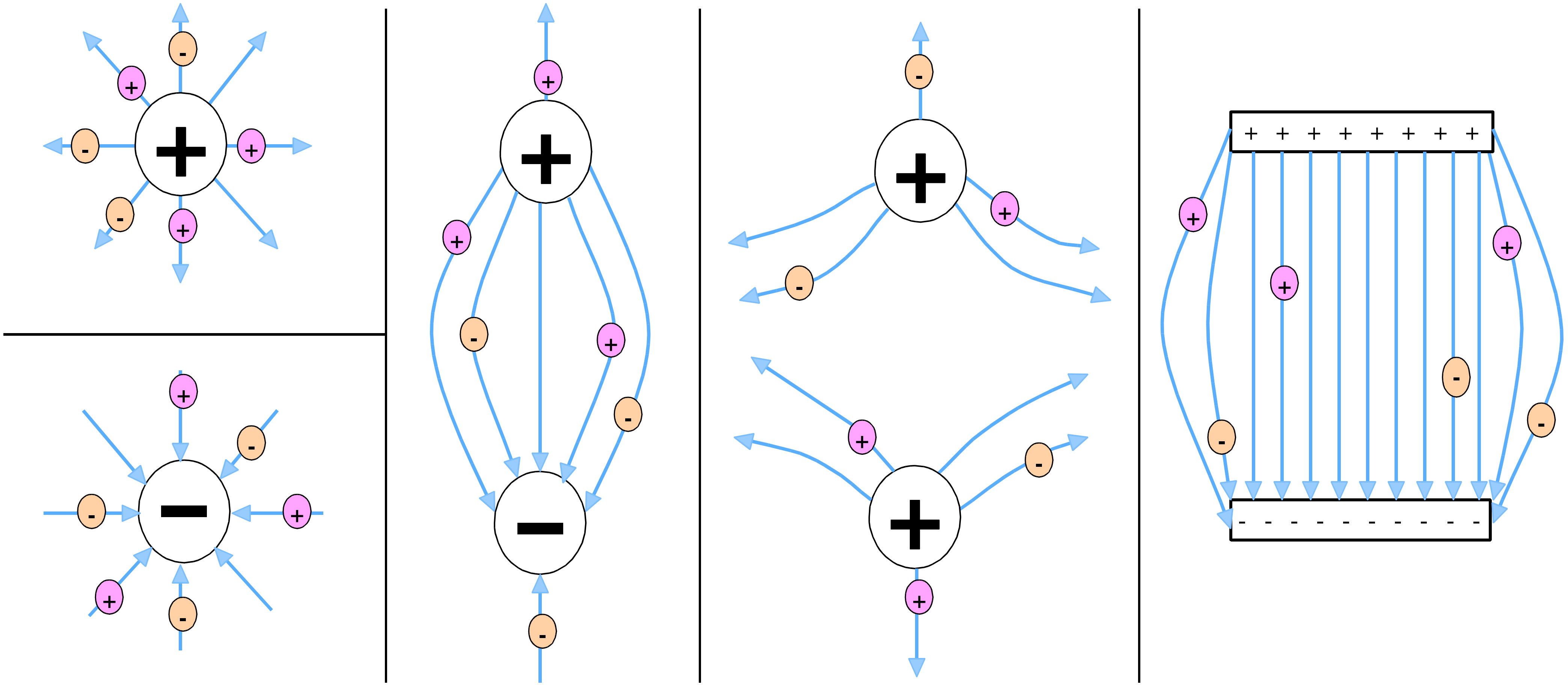
Electric Fields ..... continued

When an electrically-charged particle is placed in an electric field, the particle will follow the path of the electric field lines.

A positively-charged particle will travel ***in the direction*** of the arrow heads on the electric field lines.
A negatively-charged particle will travel ***in the opposite direction*** to the arrow heads.

Each diagram below uses electric field lines to show the shape of the electric field around/between electrically-charged particles/objects that are fixed in position - they can't move.
On each diagram, notice that 6 smaller electrically-charged particles have been placed on some of the electric field lines. These particles **are** free to move.

On each diagram, draw the path taken by each of the smaller electrically-charged particles as they move through the electric field. (Use an arrowhead to show the direction of movement.)



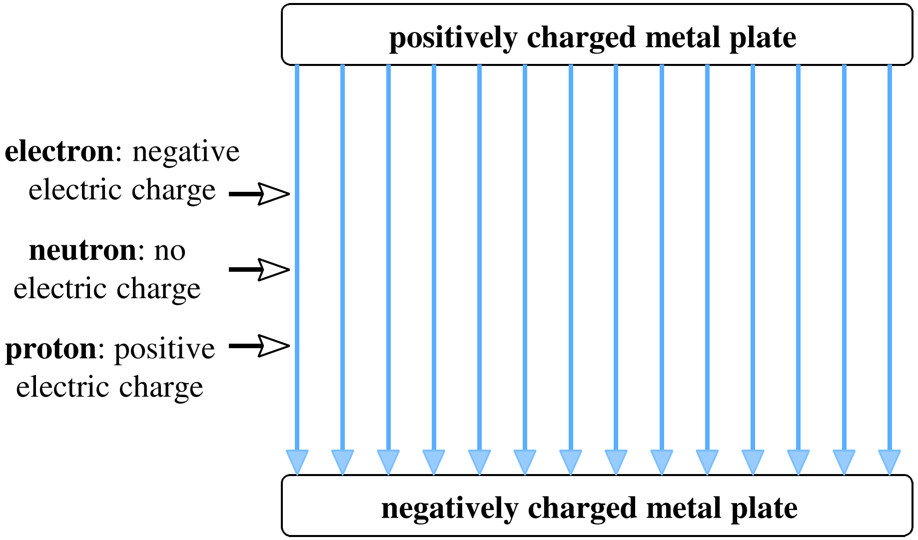
Electric Fields ..... continued

If an electrically-charged particle is fired into the electric field between two oppositely-charged parallel metal plates, at 90° (right-angles) to the electric field lines, the charged particle will experience an electrical force due to the electric field and will be deflected towards one parallel plate or the other as it travels between the plates
- the particle will follow a curved path.

A neutral particle (one with no electric charge) will not be deflected by the electric field - the neutral particle will travel through the plates in a horizontal straight line.

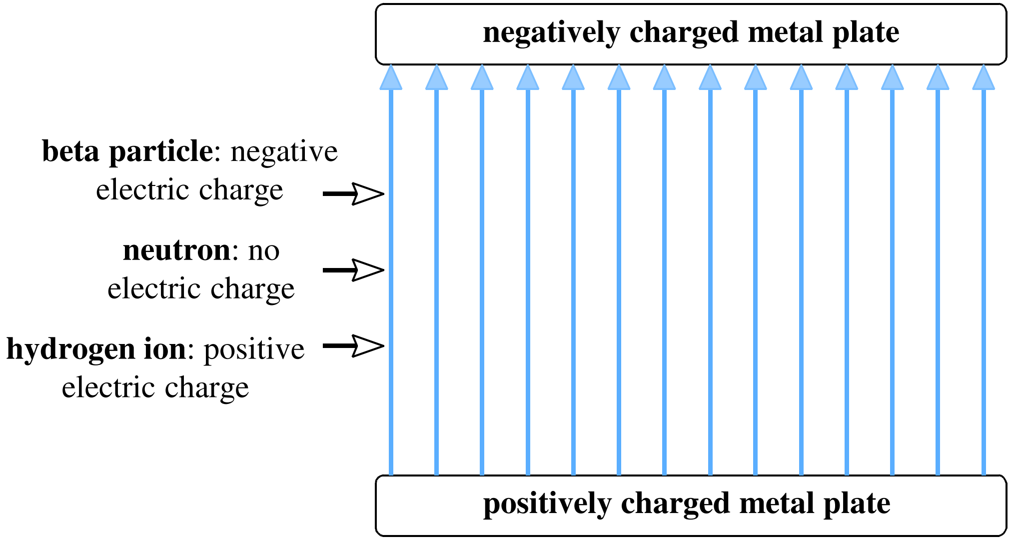
Draw the path taken by the electron, neutron and proton as they pass through the electric field shown in the diagram below.

HINT - an electron has far less mass than a proton (but the same size of electric charge), so will travel further through the parallel metal plates than the proton before coming into contact with one.



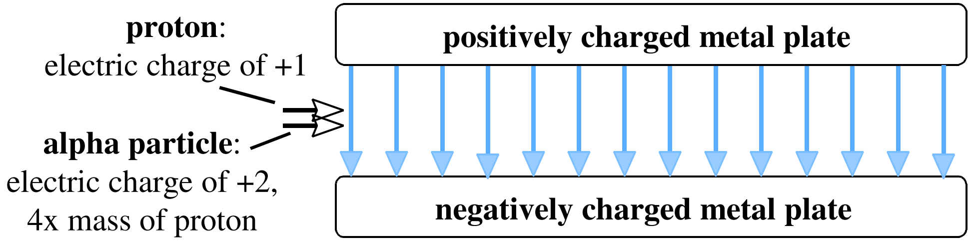
Draw the path taken by these particles as they pass through the electric field shown in the diagram below.

HINT - a beta particle has far less mass than a hydrogen ion (but the same size of electric charge), so will travel further through the parallel metal plates than the hydrogen ion before coming into contact with one.



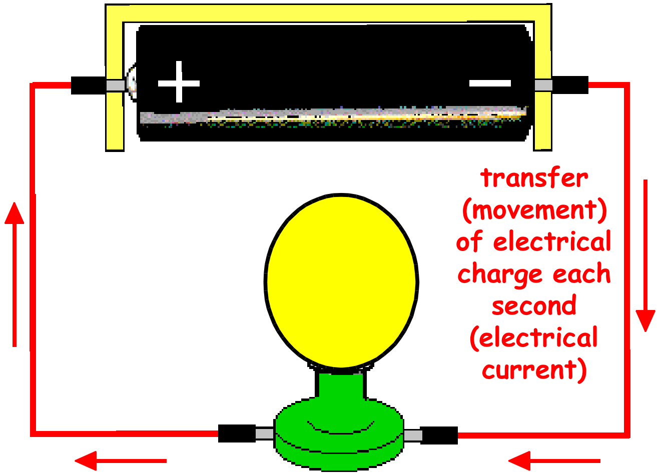
Draw the path taken by these particles as they pass through the electric field shown in the diagram below.

HINT - although an alpha particle has twice the positive charge of a proton, its mass is four times the mass of a proton, so it should travel less far through the parallel metal plates than the proton before coming into contact with one.



Notes

• ELECTRIC CURRENT and POTENTIAL DIFFERENCE



Tiny, negatively-charged particles called **e** _ _ _ _ _ _ _ _ _ travel around an electric circuit.

E _ _ _ _ _ _ _ _ _ can only travel through substances called **c** _ _ _ _ _ _ _ _ _ _ (e.g., **m** _ _ _ _ _ _) but not through substances called **i** _ _ _ _ _ _ _ _ _ _ (e.g., most **non - m** _ _ _ _ _ _, like **p** _ _ _ _ _ _ _ and **r** _ _ _ _ _ _ .)

When negatively-charged electrons travel around electric circuits, electric charge is transferred (moved) around the circuit.

"ELECTRIC CURRENT IS THE QUANTITY OF ELECTRIC CHARGE TRANSFERRED (MOVED) EACH SECOND."

Electric current is measured in units called amperes.
Unit symbol: A.

In this electrical circuit, the battery gives the electrons **energy** (**e** _ _ _ _ _ _ _ _ _ _ **energy**) to travel around the circuit from its **n** _ _ _ _ _ _ _ _ (**-**) terminal to its **p** _ _ _ _ _ _ _ _ (**+**) terminal. The **p** _ _ _ _ _ _ _ _ _ _ **d** _ _ _ _ _ _ _ _ _ _ _ (or **v** _ _ _ _ _ _ _) of the battery indicated how much **e** _ _ _ _ _ _ _ _ _ _ **energy** it gives the electrons.
The higher the **potential difference** (**v** _ _ _ _ _ _ _), the higher the **e** _ _ _ _ _ _ _ _ _ _ **energy**.

The potential difference (or voltage) of a battery (or other power supply) is a measure of the electrical energy it gives to the electrons (electric charge carriers) in an electric circuit.

Potential difference (or voltage) is measured in units called volts.
Unit symbol: V.

The electrons lose their **e** _ _ _ _ _ _ _ _ _ _ **energy** as they travel around an electrical circuit.
In this circuit, the lamp converts their **e** _ _ _ _ _ _ _ _ _ _ **energy** into **l** _ _ _ _ and **h** _ _ _ energy.

The potential difference (or voltage) "across" an electric circuit component (such as the lamp) is a measure of the electrical energy the component converts into other forms of energy as electric charges travel through it.

1) (a) Name the particles that travel around an electric circuit, transferring (moving) electric charge.

(b) What type of electric charge do these particles transfer? (positive or negative)

2) (a) Define the term 'electric current':

(b) State the unit and unit symbol for 'electric current':

3) (a) Define the term 'potential difference' ('voltage') for a battery/power supply:

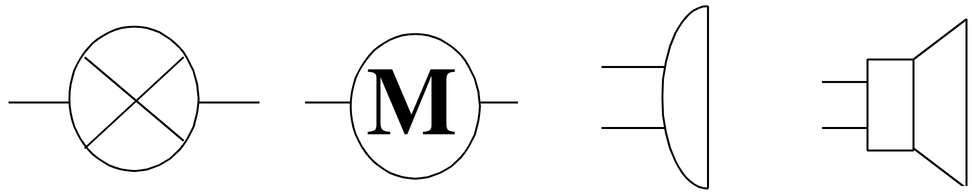
(b) State the unit and unit symbol for 'potential difference' ('voltage'):

4) (a) What happens to the electrical energy of electrons (electric charge carriers) as they travel through an electric circuit component?

(b) What does the electric circuit component do to the electrical energy "lost" by the electrons (electric charge carriers) as they travel through it?

5) Define the term 'potential difference' ('voltage') for an electric circuit component:

6) For each of these electric circuit components, state the energy conversion(s) that take place when electrons (electric charge carriers) travel through them:



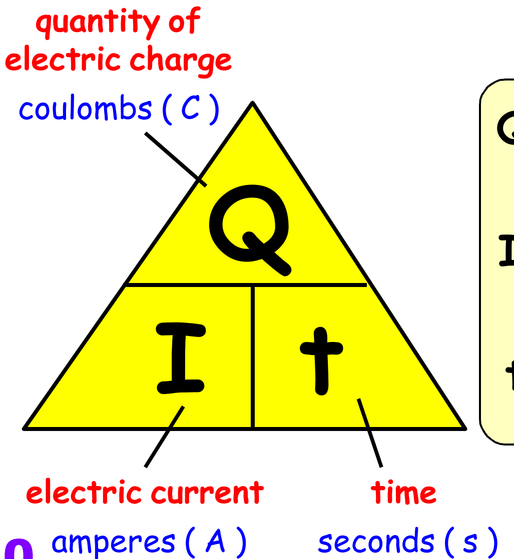
lamp electric motor buzzer loudspeaker

• ELECTRIC CURRENT, ELECTRIC CHARGE and TIME

"ELECTRIC CURRENT IS THE QUANTITY OF ELECTRIC CHARGE TRANSFERRED (MOVED) EACH SECOND."

$$\text{ELECTRIC CURRENT (I)} = \frac{\text{QUANTITY of ELECTRIC CHARGE (Q)}}{\text{TIME (t)}}$$

The unit for electrical charge is the coulomb (C).



Q =

I =

t =

7) Calculate the electric current through an electric circuit component when:

- 20 C of electric charge is transferred for 10 s.
- 0.5 C of electric charge is transferred for 5 s.
- 240 C of electric charge is transferred for 60 s.

8) What quantity of electric charge will have flowed through a metal wire when:

- an electric current of 10 A passes for 20 s?
- an electric current of 15 A passes for 3 s?
- an electric current of 20 A passes for 60 s?

9) The electric current through a lamp is 2 A. What time must the lamp be switched on for to allow:

- 50 C of electric charge to pass through it?
- 75 C of electric charge to pass through it?
- 100 C of electric charge to pass through it?

10) Calculate the current through an electrical circuit component if 200 C of charge flow through the component in a time of 50 s.

13) Calculate the charge that flowed through a copper wire if the current through the wire was 0.12 A for a time of 400 s.

16) Calculate the time a radio is switched on for if 144 C of charge flow through the radio when the current through it is 0.15 A.

19) An electrical conductor allows 570 C of charge to flow through it in a time of 1 minute. Calculate the current through the electrical conductor.

11) If 900 C of charge flow through an electric motor in a time of 150 s, calculate the current through the motor.

14) If the current through a an electrical appliance is 4.5 A for a time of 600 s, calculate the charge flowing through the appliance.

17) If 1170 C of charge flow through a games console when the current through the console is 1.3 A, for what time is the console switched on?

20) When the current through a food mixer is 1.8 A for a time of 3 minutes, what charge flows through the food mixer?

12) The charge flowing through an electric buzzer is 1.25 C for 50 s. Calculate the current through the buzzer.

15) What charge flows through a lamp if the current through the lamp is 0.25 A for a time of 900 s.

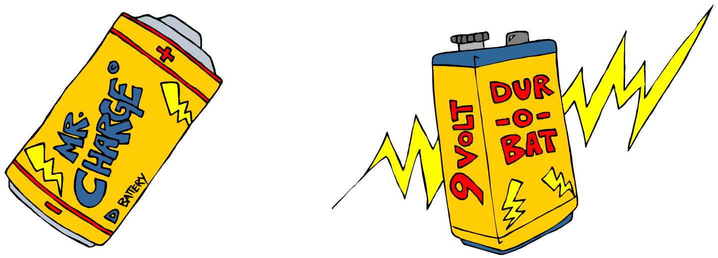
18) What time does it take 7.2 C of charge to flow through an electric toothbrush if the current through the toothbrush is 0.09 A?

21) If 33.6 C of charge flow through a torch bulb when the current through the bulb is 0.08 A, for what time is the bulb lit?

• DIRECT CURRENT (d.c.) and ALTERNATING CURRENT (a.c.)

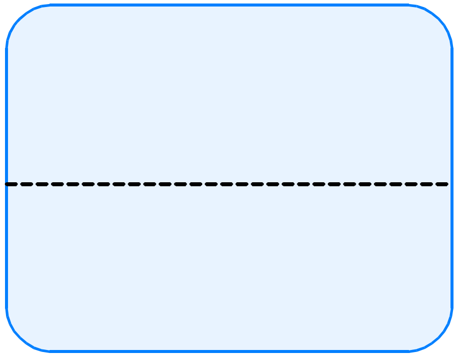
Electricity (electrical energy) can be supplied in one of two forms
- either **d _ _ _ _ _ current (d.c.)** or **a _ _ _ _ _ _ _ _ _ _ current (a.c.)**

direct current (d.c.)



Direct current (d.c.) is supplied by b _ _ _ _ _ _ _ _ _.

A battery connected to the Y-input terminals of an oscilloscope produces this trace on the screen:

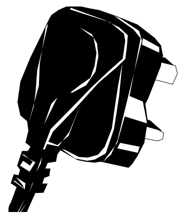


This shows that the current supplied from a battery has a constant value - such a current is known as
____________ _________ (____).

Direct current (d.c.) passes through an electric circuit in only _______ direction.

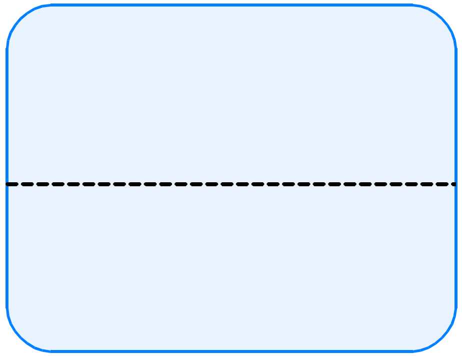
- **How could you make the current flow in the opposite direction?** _______________________________________
____

alternating current (a.c.)



Alternating current (a.c.) is supplied from the m _ _ _ _ s _ _ _ _ _ _.

The mains supply connected to the Y-input terminals of an oscilloscope produces this trace on the screen:



This shows that the current supplied from the mains supply has a value that changes (alternates) with time - such a current is known as _______________ _________ (___).

An electron in a circuit connected to the mains supply keeps reversing its direction - it keeps travelling backwards and forwards over the same path _____ times every second.

We say that the mains supply has a frequency of _____ hertz (Hz).

• EXTRA NOTES ON CURRENT AND POTENTIAL DIFFERENCE (VOLTAGE)

Current

We learned earlier that .....

Electric current is the quantity of **e** _ _ _ _ _ _ _ _ **c** _ _ _ _ _ transferred (moved) each **s** _ _ _ _ _.

$$\text{ELECTRIC CURRENT (I)} = \frac{\text{QUANTITY of ELECTRIC CHARGE (Q)}}{\text{TIME (t)}} \qquad \boxed{I = \frac{Q}{t}}$$

ELECTRIC CURRENT (I) unit: amperes (A)

QUANTITY of ELECTRIC CHARGE (Q) unit: coulombs (C)

TIME (t) unit: seconds (s)

The unit for **electric current** is the **a** _ _ _ _ _ (_).

Because **electric current** is equal to the quantity of **e** _ _ _ _ _ _ _ _ **c** _ _ _ _ _ (measured in **c** _ _ _ _ _ _ _ _) divided by **t** _ _ _ (measured in **s** _ _ _ _ _ _), we can say that:

1 a _ _ _ _ _ _ = 1 c _ _ _ _ _ _ _ per s _ _ _ _ _ _

$$(1\ A = 1\ C\ s^{-1})$$

Potential Difference (Voltage)

We learned earlier that .....

The **potential difference** (**voltage**) of a battery/power supply is a measure of the **e** _ _ _ _ _ _ _ _ _ _ **e** _ _ _ _ _ _ it gives to the **e** _ _ _ _ _ _ _ _ _ (**e** _ _ _ _ _ _ _ _ _ **c** _ _ _ _ _ _ **c** _ _ _ _ _ _ _ _) in an electric circuit.

To be exact .....

The **potential difference** (**voltage**) of a battery/power supply is a measure of the **e** _ _ _ _ _ _ _ _ _ _ **e** _ _ _ _ _ _ it gives to each **c** _ _ _ _ _ _ _ of **e** _ _ _ _ _ _ _ _ **c** _ _ _ _ _ _ that passes through it.

$$\text{POTENTIAL DIFFERENCE [VOLTAGE] (V)} = \frac{\text{ELECTRICAL ENERGY (E)}}{\text{QUANTITY of ELECTRIC CHARGE (Q)}} \qquad \boxed{V = \frac{E}{Q}}$$

POTENTIAL DIFFERENCE [VOLTAGE] (V) unit: volts (V)

ELECTRICAL ENERGY (E) unit: joules (J)

QUANTITY of ELECTRIC CHARGE (Q) unit: coulombs (C)

You will not find this equation on the SQA formula sheet.

The unit for **potential difference** (**voltage**) is the **v** _ _ _ (_).

Because **potential difference** (**voltage**) is equal to the **e** _ _ _ _ _ _ _ _ _ _ **e** _ _ _ _ _ _ (measured in **j** _ _ _ _ _) divided by the quantity of **e** _ _ _ _ _ _ _ _ **c** _ _ _ _ _ _ (measured in **c** _ _ _ _ _ _ _ _), we can say that:

1 v _ _ _ = 1 j _ _ _ _ _ per c _ _ _ _ _ _ _

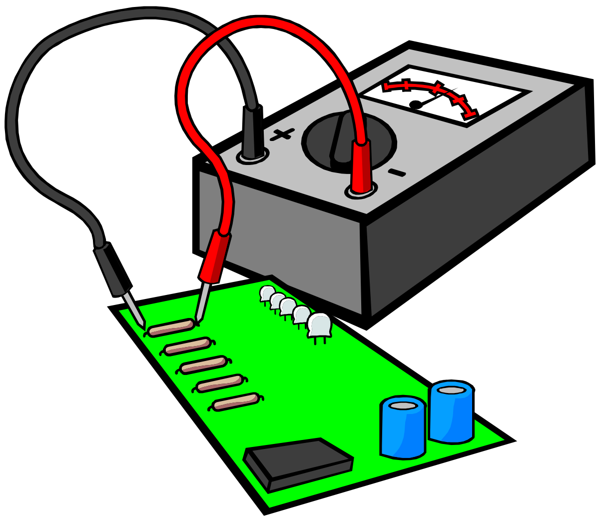
$$(1\ V = 1\ J\ C^{-1})$$

Notes

National 5 Physics

"ELECTRICITY"

Resistance and Ohm's Law



Name: ______________________________

This section of the "Electricity" unit introduces the term 'resistance' - the opposition to the flow of electric current. It explains that, due to resistance, when electric current flows through a circuit component, some electrical energy is changed into heat energy. It explains the purpose of fixed and variable 'resistors' in an electric circuit and how to measure the resistance of a circuit component using an ohmmeter. It then shows how to connect ammeters and voltmeters in an electric circuit in order to measure electric current and potential difference (voltage). It goes on to explain Ohm's Law (including the Ohm's Law relationship V = IR) and the fact that, in general, as the temperature of an electric conductor increases, its resistance also increases. The section ends with a description of 'non-ohmic' conductors - electric conductors that do not obey Ohm's Law.

By the end of this section, you should be able to:

☐ explain the meaning of the term 'resistance'

☐ state that, due to resistance, when an electric current flows through a circuit component, some electrical energy is changed into heat energy

☐ state that the unit for resistance is the 'ohm' (Ω)

☐ explain the purpose of fixed and variable 'resistors' in an electric circuit and recognise the circuit symbol for each

☐ describe how to measure the resistance of a circuit component using an ohmmeter

☐ describe how to connect 'ammeters' and 'voltmeters' in an electric circuit in order to measure 'electric current' and 'potential difference' ('voltage')

☐ understand the 'Ohm's Law' graph of 'potential difference (voltage) against current' plus the relationship 'V = IR' and use it to solve problems involving resistance, potential difference (voltage) and current

☐ state that, in general, as the temperature of an electric conductor increases, its resistance also increases

☐ understand what is meant by the term 'non-ohmic' conductor

• RESISTANCE

In an electric circuit, electrons travel through metal wires and electric circuit components.

Every electric circuit component opposes the flow of electrons to some extent.
This opposition to the flow of electrons is called **r** _ _ _ _ _ _ _ _ _ _.

- The **l** _ _ _ _ _ the resistance, the **s** _ _ _ _ _ _ the current.
- The **s** _ _ _ _ _ _ the resistance, the **l** _ _ _ _ _ the current.

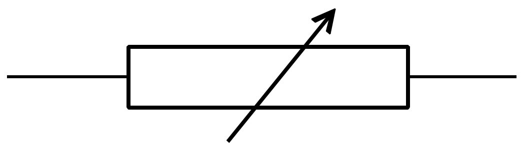
Due to resistance, when current travels through an electric circuit component, some **electrical energy** is converted into **heat energy** by the component. (This is made use of in the metal heating coils/elements of **electric fires**, **k** _ _ _ _ _ _ and **t** _ _ _ _ _ _ _.)

Some electric circuit components are deliberately included in electric circuits to oppose the flow of electrons, i.e., they control the size of the electric current in the circuit. These components are called **r** _ _ _ _ _ _ _ _.

• FIXED RESISTORS

Each fixed resistor has only one value of resistance.

• VARIABLE RESISTORS

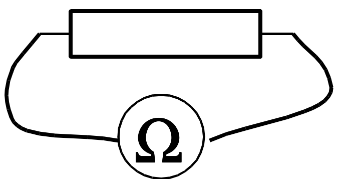


You can change the resistance of a variable resistor. (To change the resistance of a simple variable resistor, you turn a dial or move a slider on the resistor.)

The unit for resistance is the o _ _ (_)

The simplest way to measure the **resistance** of a resistor (or any other electric circuit component) is to connect an **ohmmeter** across its ends. The resistor should be separate - not connected in an electric circuit.

The ohmmeter displays the resistance value.

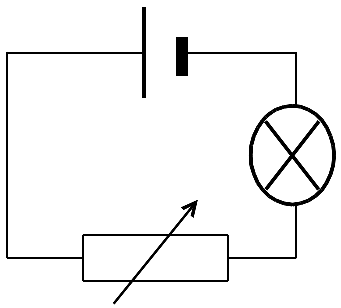


ohmmeter

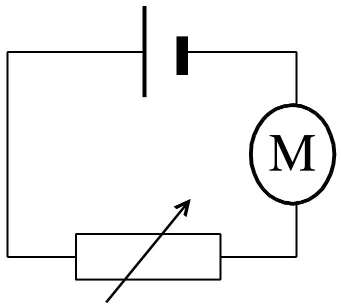
Label each **circuit component** below.

State the purpose of the **variable resistor** in each circuit?

____
____
____
____
____



____
____
____
____
____

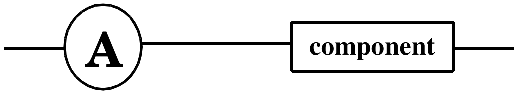


Ammeters and Voltmeters

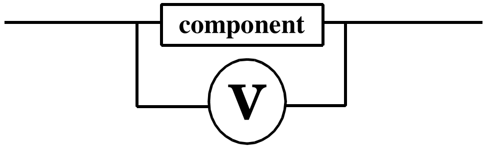
When we want to measure **electric current** and **potential difference (voltage)** values in an electric circuit, we use **ammeters** and **voltmeters**.

Connecting ammeters and voltmeters

Ammeters measure the **c** _ _ _ _ _ _ _ **t** _ _ _ _ _ _ _ an electric circuit component and must be connected **in line with** (**in series with**) the component:



Voltmeters measure the **p** _ _ _ _ _ _ _ _ **d** _ _ _ _ _ _ _ _ _ (**v** _ _ _ _ _ _) **a** _ _ _ _ _ an electric circuit component and must be connected **across** (**in parallel with**) the component:



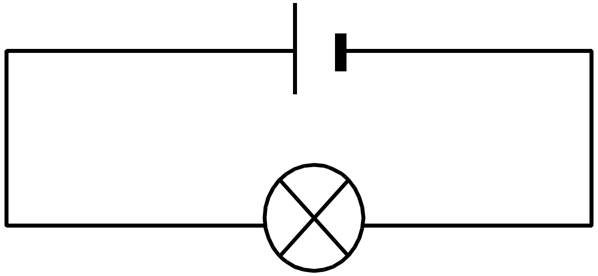
When we take readings from an **ammeter** connected to an electric circuit component, we 'talk about' the **current t** _ _ _ _ _ _ the component.

When we take readings from a **voltmeter** connected to an electric circuit component, we 'talk about' the **potential difference (voltage) a** _ _ _ _ _ the component.

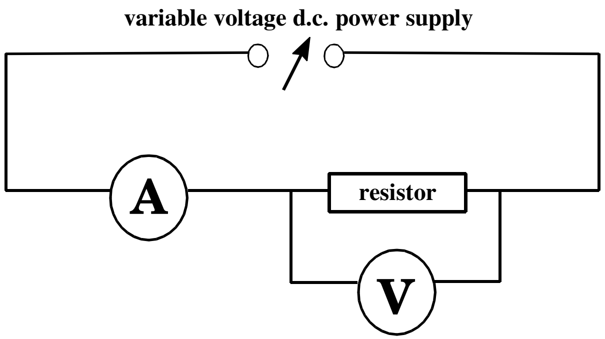
1) Which device would you use to measure the **current through** a lamp? ______________

2) Which device would you use to measure the **potential difference (voltage) across** a lamp? ______________

3) Show this by drawing these devices in the correct place on this electric circuit diagram:



Resistance and Ohm's Law



Using the electric circuit shown, every time you change the 'voltage setting' on the variable voltage d.c. power supply, the values for the **potential difference (voltage) across the resistor** and **current through the resistor** will change.

WE ASSUME THAT THE TEMPERATURE OF THE RESISTOR DOES NOT CHANGE (REMAINS CONSTANT).

If you change the 'potential difference (voltage) setting' 6 times, 6 different pairs of potential difference (voltage) and current values will be obtained:

Typical pairs of values are shown in this table:

potential difference (voltage) across resistor (V)/ V	**2.0**	**4.0**	**6.0**	**8.0**	**10**	**12**
current through resistor (I)/ A	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
$\dfrac{\textbf{voltage}}{\textbf{current}}$						

No matter which pair of potential difference (voltage) and current values you take, when you divide potential difference [voltage] (V) by current (I), you will always get the same answer - *see this for yourself by completing the last row of the table.*

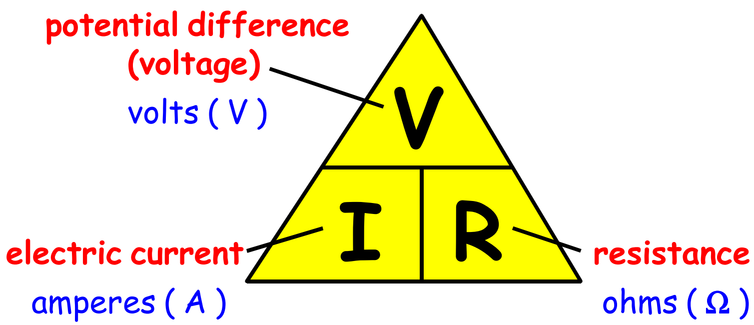
$$\frac{V}{I} = \text{constant value.}$$

This **constant value** is called the **resistance** (**R**) of the resistor.

$$\textbf{resistance (R)} = \frac{\textbf{voltage (V)}}{\textbf{current (I)}}$$

This relationship, discovered in 1827 by a teacher in Germany called Georg Simon Ohm, is known as "Ohm's law".

THIS RELATIONSHIP ONLY HOLDS IF THE TEMPERATURE OF THE RESISTOR DOES NOT CHANGE (REMAINS CONSTANT).

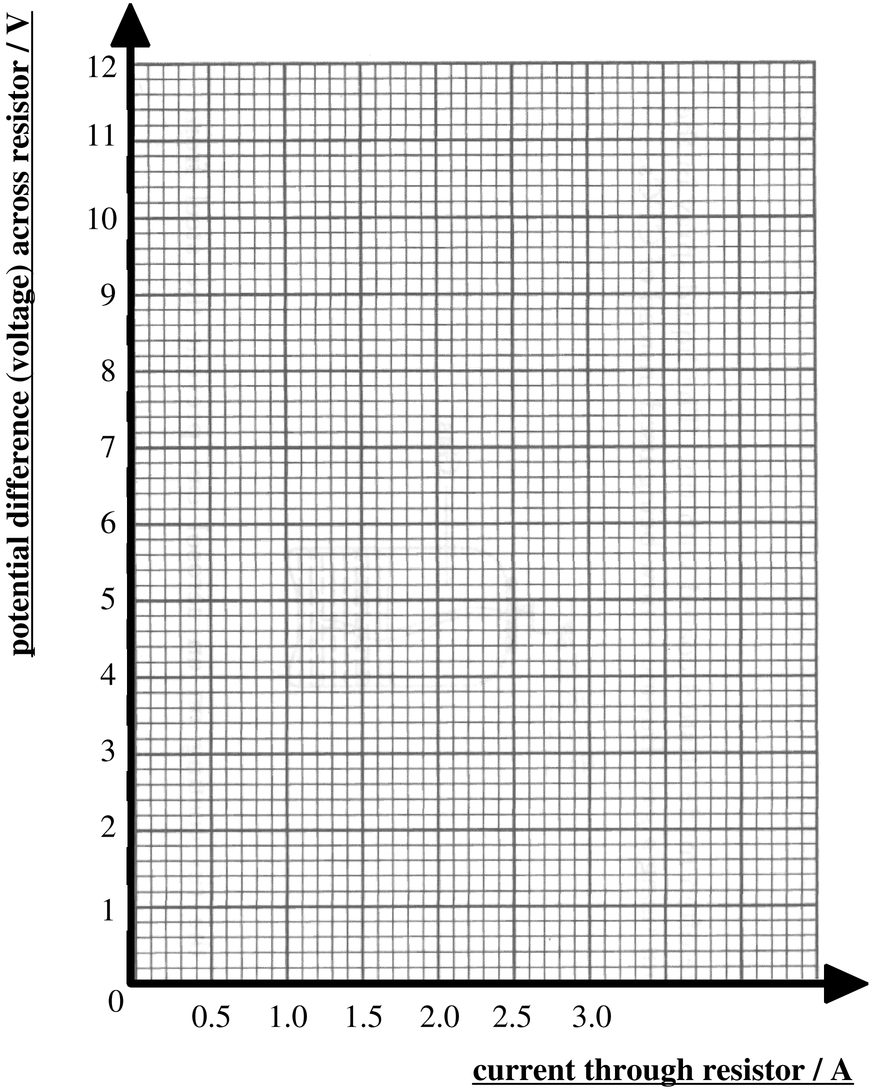


V =

I =

R =

Plot a line graph of **potential difference (voltage) across resistor** against **current through resistor**, using the values given on the previous page.



The line graph of **potential difference (voltage) across resistor** against **current through resistor** will give a **straight line passing through the origin**.

In mathematical terms, we can say that **the potential difference (voltage) across the resistor is directly proportional to the current through the resistor** - this means that if the potential difference (voltage) doubles or trebles, the current will also double or treble.

Calculate the **gradient** of the straight line passing through the origin.

The gradient of the straight line passing through the origin is equal to the resistance of the resistor.

SUMMARY

Ohm's Law states that the potential difference (voltage) across a resistor is directly proportional to the current through the resistor, provided the temperature of the resistor remains constant.

Electric circuit components (such as resistors) that obey Ohm's Law are known as "ohmic conductors" - a line graph of potential difference (voltage) across the component against current through component will give a straight line passing through the origin. The gradient of the straight line will be equal to the resistance of the circuit component.

4) You should now attempt the following **"Ohm's law"** problems:

Calculate the **potential difference (voltage)** across:

- a 5 Ω resistor carrying a current of 3 A;
- a 10 Ω resistor carrying a current of 8 A;
- a 100 Ω resistor carrying a current of 0.2 A.

Calculate the **current** through:

- a 100 Ω resistor with 200 V across it;
- a 5 Ω resistor with 30 V across it;
- a 2.5 Ω resistor with 25 V across it.

Calculate the **resistance** of:

- a light bulb marked "6 V, 0.05 A";
- a resistor with 30 V across it and a current of 5 A through it;
- the heating coil of an electric fire that has 230 V across it and carries a current of 2.3 A through it.

5) Calculate the resistance of a resistor that has a potential difference (voltage) of 9 V across it when the current through it is 1.5 A.

6) A circuit component obeys Ohm's Law. If the current through the circuit component is 0.05 A when the potential difference (voltage) across it is 2 V, calculate the resistance of the circuit component.

7) The current through an electric motor is 0.25 A when the potential difference (voltage) across the motor is 1.25 V. Calculate the resistance of the motor.

8) Calculate the potential difference (voltage) across a 500 Ω resistor if the current through the resistor is 0.01 A.

9) A resistor has a resistance of 1 000 Ω. If the current through the resistor is 0.04 A, calculate the potential difference (voltage) across the resistor.

10) A 100 Ω resistor carries a current of 0.75 A. Calculate the potential difference (voltage) across the resistor.

11) The potential difference (voltage) across a 200 Ω resistor is 50 V. Calculate the current through the resistor.

12) A 2 000 Ω resistor has a potential difference (voltage) of 40 V across it. Calculate the current through the resistor.

13) A Calculate the current through a 2.5 Ω electric buzzer when the potential difference across the buzzer is 12.5 V.

14) An 'ohmic conductor' has a current of 0.36 A through it due to a potential difference (voltage) of 7.2 V across it. What is the resistance of the 'ohmic conductor'?

15) What is the potential difference (voltage) across an 'ohmic conductor' of resistance 420 Ω when the current through it is 0.06 A?

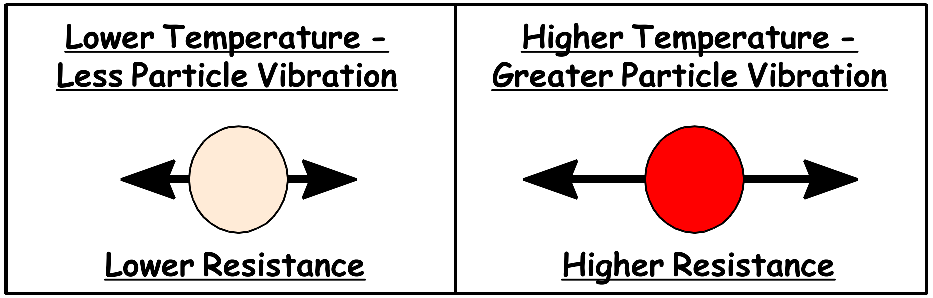
16) What is the current through an 'ohmic conductor' of resistance 0.9 Ω if the potential difference (voltage) across it is 8.1 V?

Resistance and Temperature Change

In general, as the temperature of an electric conductor (such as a copper wire) increases, the atoms in the conductor vibrate more
- the higher the temperature, the greater the vibration.

The 'extra vibration' of the atoms makes it more difficult for electrons to travel through the conductor
- so the resistance of the conductor increases.

In general, as the temperature of an electric conductor increases, its resistance increases.



17) (a) In general, what happens to the resistance of an electric conductor as its temperature increases?

____

(b) Explain why.

____

____

____

____

____

____

Resistance and Ohm's Law (Continued) ..... Non-Ohmic Conductors (1)

Not all electric conductors obey Ohm's Law - their resistance changes as the current through them changes. Such electrical conductors are known as **non-ohmic conductors**.

For **non-ohmic conductors**, the line graph of **potential difference (voltage) across the component** against **current through the component** is not a straight line passing through the origin.

This means that the resistance of the conductor can't be determined by calculating the gradient of its 'potential difference (voltage) against current line graph'. However, the resistance of the component for any pair of potential difference (voltage) and current values taken from the line graph can still be calculated using the Ohm's Law equation:

$$R = \frac{V}{I}$$

18) (a) Do all electric conductors obey Ohm's Law? ____

(b) As the current through them changes, what happens to their resistance? __________________________

(c) What do we call such electric conductors?

____

(d) Describe the potential difference (voltage) against current line graph for such electric conductors.

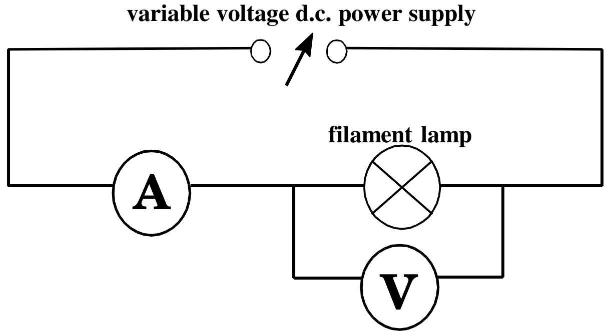
____

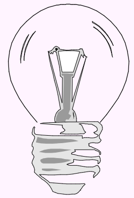
(e) How can we calculate the resistance of the electric conductor for any pair of voltage and current values taken from its voltage against current line graph?

____

Resistance and Ohm's Law (Continued) ..... Non-Ohmic Conductors (2)

This electric circuit was used to obtain pairs of values for the potential difference (voltage) across an electric filament lamp (from a ray-box) and the current through the lamp.





A filament lamp contains a thin piece of metal wire (the 'filament'). This turns electrical energy into heat and light energy when there is an electric current through it.

As the potential difference (voltage) across the lamp increased, its brightness increased. The lamp did not reach its 'full working brightness'.

The readings taken are given in the table below:

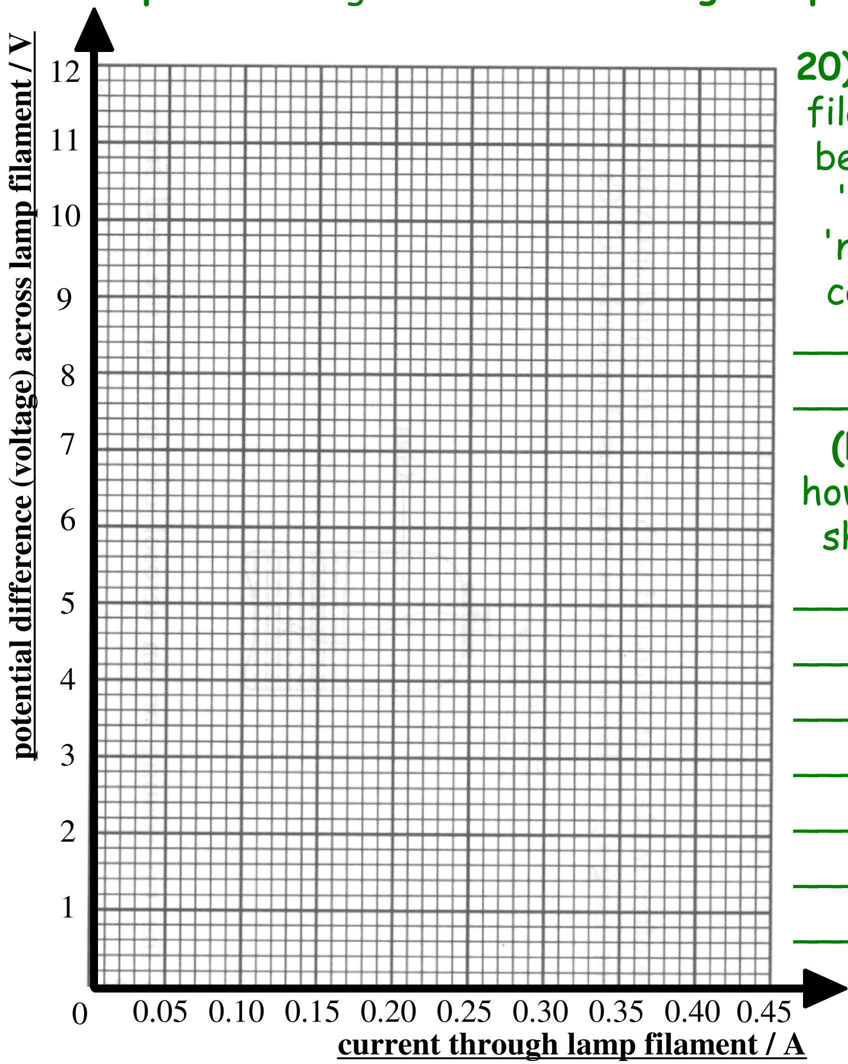
increased lamp brightness

potential difference (voltage) across lamp filament (V)/ V	current through lamp filament (I)/ A	resistance of lamp filament (R)/ Ω = V/I
0.20	0.05	
0.60	0.10	
1.4	0.15	
2.2	0.20	
3.2	0.25	
4.6	0.30	
6.0	0.35	
8.6	0.40	
11.8	0.45	

Complete the last column of the table to show the resistance of the lamp filament for each pair of potential difference (voltage) and current values.
(GIVE EACH ANSWER TO 1 DECIMAL PLACE.)

19) What happened to the resistance of the lamp filament as the lamp brightness increased? ____________________

Plot a line graph of **potential difference (voltage) across lamp filament** against **current through lamp filament**.



20) (a) Did the filament lamp behave as an 'ohmic' or 'non-ohmic' conductor?

____

____

(b) Explain how the graph shows this:

____

____

____

____

____

____

____

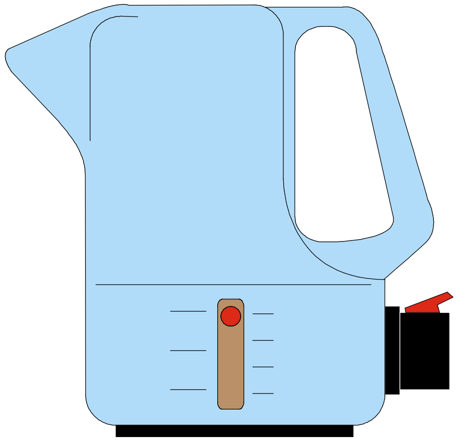
21) What do you think happened to the temperature of the lamp filament as the brightness of the lamp increased? ______________________________

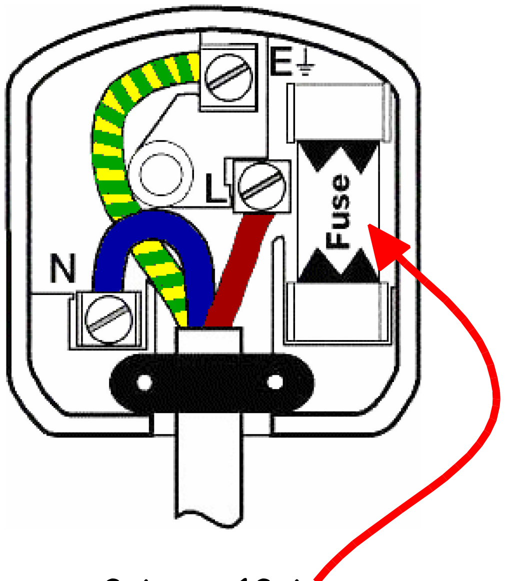
Notes

National 5 Physics

"ELECTRICITY"

Electrical Power





Name: ______________________________

This section of the "Electricity" unit initially describes household electrical appliances as 'energy changers that change (transform) electrical energy into other types of energy.

It then describes the 'power rating' of an electrical appliance as the quantity of electrical energy it changes (transforms) into other types of energy every second.

The purpose of the fuse in the three-pin electric plug connecting an electrical appliance to the mains supply is then explained and the general rule for selecting the correct 'fuse rating' (3 A or 13 A) for the plug is linked to the 'power rating' of the electrical appliance.

The section ends with a series of calculations involving 'electrical power', 'electrical energy', 'time', 'electric current', 'voltage' ('potential difference') and 'resistance'.

By the end of this section, you should be able to:

☐ state that household electrical appliances are 'energy changers' and give examples of the energy change that occurs in different appliances

☐ state that the 'power rating' of a household electrical appliance is the quantity of electrical energy it changes (transforms) into other types of energy every second

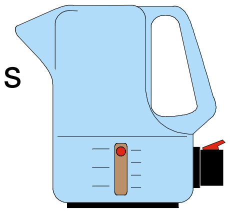
☐ state the purpose of the fuse in a three-pin electric plug connecting a household electrical appliance to the mains supply and select the correct 'fuse rating' (3 A or 13 A) for the plug, depending upon the 'power rating' of the electrical appliance

☐ carry out calculations involving 'electrical power', 'electrical energy', 'time', 'electric current', 'voltage' ('potential difference') and 'resistance' using the formulas $E = Pt$, $P = IV$, $P = I^2R$ and $V^2 = PR$

HOUSEHOLD ELECTRICAL APPLIANCES - Energy Changers

Household electrical appliances (such as cookers, radios, etc) are **energy changers** - they change (transform) **electrical energy** into **other types of energy**.

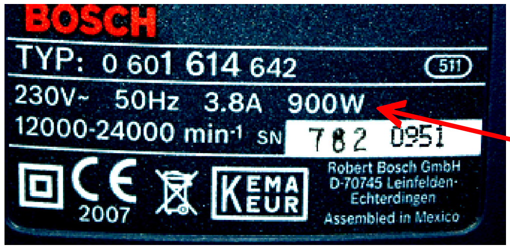
For example, an electric kettle changes (transforms) **electrical energy** into **heat energy**:



electrical ⟶ **heat**

POWER RATING OF HOUSEHOLD ELECTRICAL APPLIANCES

On every household electrical appliance, you will find a small **information** or **rating plate** that tells you important details about the appliance.



a typical rating plate for a household electrical appliance

power rating

One important detail is the **p** _ _ _ _ **r** _ _ _ _ _ _ of the appliance - a number that tells you how much **e** _ _ _ _ _ _ _ _ _ _ **e** _ _ _ _ _ _ the appliance changes (transforms) into other types of energy every second. (The **h** _ _ _ _ _ _ the power rating, the **h** _ _ _ _ _ _ the electrical energy changed/transformed every second - and the **h** _ _ _ _ _ _ the **c** _ _ _!)

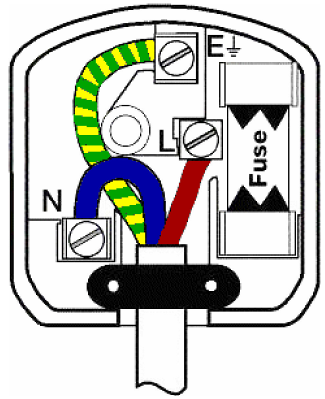
Power ratings have units of **watts (W)** or **kilowatts (kW)**.

1 000 W = 1 kW.

FUSE RATING FOR HOUSEHOLD ELECTRICAL APPLIANCES

Most household electrical appliances can be connected to the **m** _ _ _ _ **s** _ _ _ _ _ _ (the electricity sockets located in almost every room of our homes.)

This connection is made through a **"three-pin electric plug"** that is fitted to an **"electric flex"** (a flexible cable attached to the appliance.)



Every three-pin electric plug must be fitted with a **f** _ _ _ - a thin piece of **m** _ _ _ _ **w** _ _ _ enclosed in a cylinder.

Electric current flows from the mains supply to an appliance through the **m** _ _ _ _ **w** _ _ _ of the **f** _ _ _.

If the current becomes too high, the **m** _ _ _ _ **w** _ _ _ melts (blows). This stops the current flowing through the flex and appliance, thus preventing damage due to overheating.

It is important to fit the correct value of fuse to the three-pin electric plug of an appliance. The fuse value chosen should be slightly **l** _ _ _ _ _ _ than the maximum value of current used by the appliance.

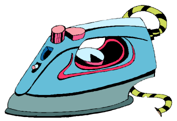
If a fuse with too **low** a value is chosen, it will **b** _ _ _ at the instant the appliance is switched on.

If a fuse with too **high** a value is chosen, it may not **b** _ _ _ if the current passing through the metal wires of the flex becomes too large - this could be a **f** _ _ _ hazard.

It is now recommended that 2 standard values of fuse should be fitted in 3-pin electric plugs. The fuse value depends on the power rating of the appliance for which it will be used:

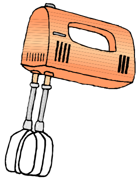
- **Most appliances up to power rating 720 W ...... fit a 3 A fuse**
- **Appliances of power rating over 720 W ..... fit a 13 A fuse**

(a) For each of the household electrical appliances shown below, state the energy change that it carries out.
(b) Use textbooks, information leaflets, shopping catalogues or the internet to find a typical 'power rating' for the appliance.
(c) Select the appropriate 'fuse rating' for the fuse that must be fitted in the three-pin electric plug of the appliance: **3 A** or **13 A**.



iron

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

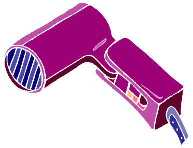


food mixer

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

lamp

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

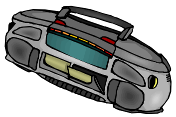


hair dryer

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

television

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

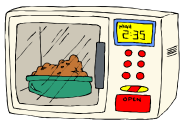


radio/CD player

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

washing machine

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

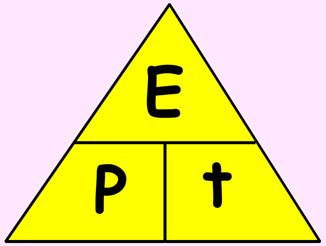


microwave oven

- Energy change: ______________________
- Typical power rating : ______________
- Fuse rating: __________

• ELECTRICAL ENERGY and POWER

The ELECTRICAL POWER (or POWER RATING) of a household electrical appliance is the amount of ELECTRICAL ENERGY it changes (transforms) into other types of energy every second.



Energy (E) = Power (P) x time (t)

unit: joules (J) — unit: watts (W) — unit: seconds (s)

E =

P =

t =

Calculate the **power rating** of:

- an electric drill that changes 5 000 J of electrical energy into kinetic energy every 2 s

- an electric shaver that changes (transforms) 2 000 J of electrical energy every 50 s

- a television set that transforms 600 J of electrical energy every 12 s

Calculate the **electrical energy** changed (transformed) by:

- a 100 W electric light bulb in 60 s

- a 3 000 W electric kettle in 15 s

- a 500 W electric hedge trimmer in 90 s

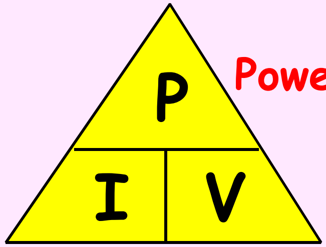
Calculate the **time taken** for:

- an 800 W electric blanket to change 160 000 J of electrical energy into heat energy

- a 2 000 W electric heater to change (transform) 900 000 J of electrical energy into heat energy

- a 750 W electric power drill to transform 26 250 J of electrical energy

The **electrical power (or power rating)** of a household electrical appliance can be calculated if we know the **current through the appliance** and the **voltage (potential difference) across the appliance**.



Power (P) = Current (I) × Voltage [potential difference] (V)

unit: watts (W) — unit: amperes (A) — unit: volts (V)

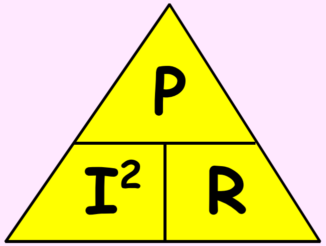
P =

I =

V =

Calculate the **power rating** of:	Calculate the **voltage (potential difference)** across:	Calculate the **current** through:
• a 230 V electric soldering iron that requires a current of 0.1 A	• a 9 W electric toy requiring a current of 0.75 A	• a 230 V, 115 W food mixer
• a 12 V car headlamp that requires a current of 0.75 A	• a 690 W electric power drill requiring a current of 3 A	• a 230 V, 4 600 W electric cooker
• a 230 V electric kettle that requires a current of 12.5 A	• a 1 150 W electric vacuum cleaner requiring a current of 5 A	• a 12 V, 9 W electric motor for a toy car

The **electrical power (or power rating)** of a household electrical appliance can also be calculated if we know the **current through the appliance** and the **resistance of the appliance**.



Power (P) = Current^2 (I^2) x Resistance (R)

unit: watts (W) | unit: amperes (A) | unit: ohms (Ω)

P =

I^2 =

R =

Calculate the **power rating** of:

- a 5 Ω resistor carrying a current of 2 A
- an electric cable of resistance 2 Ω carrying a current of 3 A.
- a 10 Ω resistor carrying 5 A of current.

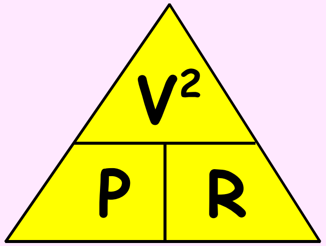
Calculate the **current** through:

- a 2 Ω resistor that has a power rating of 0.5 W.
- an electric lamp that has a resistance of 32 Ω and a power rating of 2 W.
- the heating coil of an electric heater that has a resistance of 24 Ω and a power rating of 240 W.

Calculate the **resistance** of:

- a 40 W resistor carrying 2 A of current.
- a 250 W electric motor that has a current of 0.5 A through it.
- a 50 W circuit component that has a current of 0.25 A through it.

The **electrical power (or power rating)** of a household electrical appliance can also be calculated if we know the **voltage (potential difference) across the appliance** and the **resistance of the appliance**.



Voltage^2 (V^2) = Power (P) x Resistance (R)

unit: volts (V) — unit: watts (W) — unit: ohms (Ω)

V^2 =

P =

R =

Calculate the **power rating** of:

- a 5 Ω resistor with a voltage (potential difference) of 15 V across it
- an electric toy of resistance 2 Ω with a voltage (potential difference) of 6 V across it
- a household appliance of resistance 460 Ω with a voltage (potential difference) of 230 V across it

Calculate the **voltage (potential difference)** across:

- a 200 Ω resistor that has a power rating of 72 W.
- an electric circuit component that has a resistance of 25 Ω and a power rating of 225 W.
- an electric power tool that has a resistance of 52.9 Ω and a power rating of 1 000 W.

Calculate the **resistance** of:

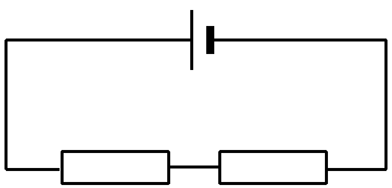
- a 30 W car headlamp with a voltage (potential difference) of 12 V across it
- a 6 W electric motor with a voltage (potential difference) of 9 V across it
- a 5 W circuit component that has a voltage (potential difference) of 230 V across it

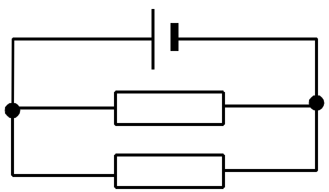
Notes

National 5 Physics

"ELECTRICITY"

'Series and Parallel Circuits' and 'Resistors Connected in Series and Parallel'





Name: ______________________________

This section of the "Electricity" unit initially revises how to measure electric current, potential difference (voltage) and resistance. It then introduces 'series' and 'parallel' electric circuits and explains the 'rules' that apply to electric current and potential difference (voltage) in each type of circuit: problems to illustrate these 'rules' are included. Next, 'car wiring', a practical example of 'parallel' circuits, is explained. The section goes on to explain the calculation of the total resistance of a number of resistors/circuit components connected in 'series' then in 'parallel' - this is extended to the calculation of the total resistance of complex electric circuits containing a combination of resistors/circuit components connected in 'series' and 'parallel': problems to illustrate the use of these calculations are included.

By the end of this section, you should be able to:

☐ describe how to connect 'ammeters', 'voltmeters' and 'ohmmeters' in order to measure 'electric current', 'potential difference' ('voltage') and 'resistance'

☐ state current and potential difference (voltage) rules for components in series and parallel electric circuits

☐ apply these rules to solve problems involving series and parallel electric circuits

☐ calculate the total resistance of a number of resistors/circuit components connected in series, in parallel and in series/parallel

☐ apply these calculation to solve problems involving series, parallel and combined series-parallel electric circuits

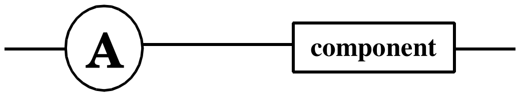
• MEASURING CURRENT, POTENTIAL DIFFERENCE (VOLTAGE) and RESISTANCE

In the "Ohm's Law" section of this unit, we found out how to measure **current**, **potential difference** (**voltage**) and **resistance** values using appropriate meters.

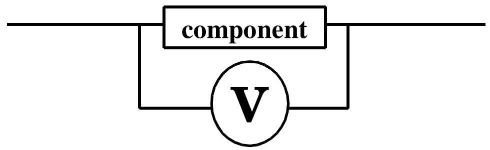
Complete the following summary:

Ammeters, Voltmeters and Ohmmeters

Ammeters measure the **c** _ _ _ _ _ _ _ **t** _ _ _ _ _ _ _ an electric circuit component and must be connected **in line with** (**in** **series** **with**) the component:



Voltmeters measure the **p** _ _ _ _ _ _ _ _ _ **d** _ _ _ _ _ _ _ _ _ _ (**v** _ _ _ _ _ _ _) **a** _ _ _ _ _ _ an electric circuit component and must be connected **across** (**in** **parallel** **with**) the component:



If we wanted to determine the **resistance** of the electric circuit component, we could divide the **p** _ _ _ _ _ _ _ _ _ **d** _ _ _ _ _ _ _ _ _ _ (**v** _ _ _ _ _ _ _ _ _) reading [unit: _ _ _ _ _ (_)] by the **a** _ _ _ _ _ _ _ reading [unit: a _ _ _ _ _ _ _ (_)] to obtain the resistance [unit: o _ _ _ (_).]

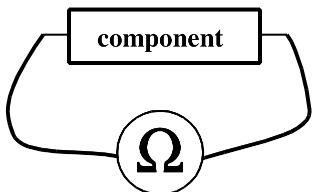
By doing so, we are using the Ohm's Law equation

$$R = \frac{V}{I}$$

______________________ → R = V/I ← ______________________

____

The simplest way to measure the **resistance** of the electric circuit component is to connect an **o** _ _ _ _ _ _ _ _ across its ends.
The circuit component should be separate - not connected in an electric circuit.
The **o** _ _ _ _ _ _ _ _ displays the resistance value.

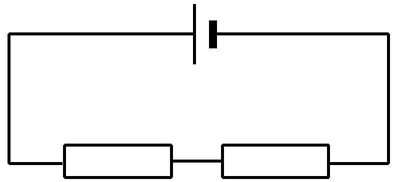


ohmmeter

CURRENT AND VOLTAGE RULES FOR SERIES AND PARALLEL CIRCUITS

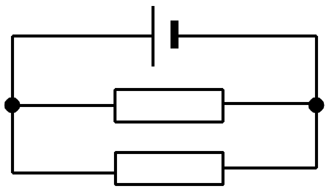
Circuit components can be connected to a **battery/power supply** in two different ways:

(1) in a **series circuit**



The battery/power supply and circuit components are connected in a **continuous loop**.

(2) in a **parallel circuit**



The circuit components are connected in **separate branches** across the battery/power supply.

Current and Potential Difference (Voltage) Rules for Components in Series and Parallel Circuits

Current in a Series Circuit

The supply current has only one route to travel.

The current is the s _ _ _ at all points in the circuit.

Voltages in a Series Circuit

The supply potential difference (voltage) is shared between the circuit components.

The potential differences (voltages) across the circuit components add up to the s _ _ _ _ _ potential difference (voltage.)

Currents in a Parallel Circuit

The supply current splits up (or joins together) every time it meets a branch (join) in the circuit.

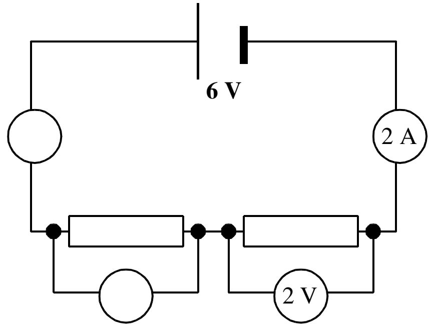
The currents through the parallel branches add up to the s _ _ _ _ _ current.

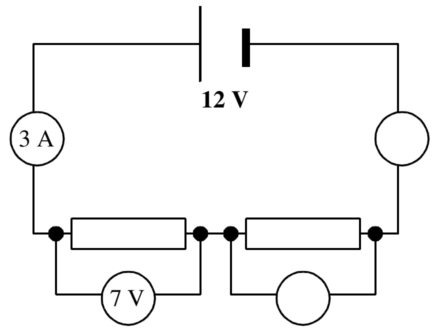
Voltage in a Parallel Circuit

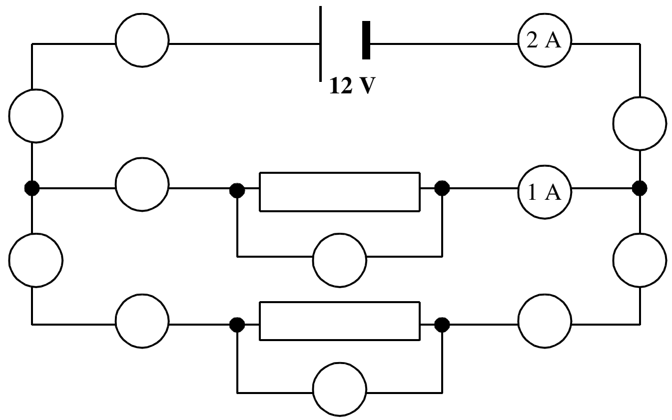
Each branch of the circuit has the same potential difference (voltage) across it.

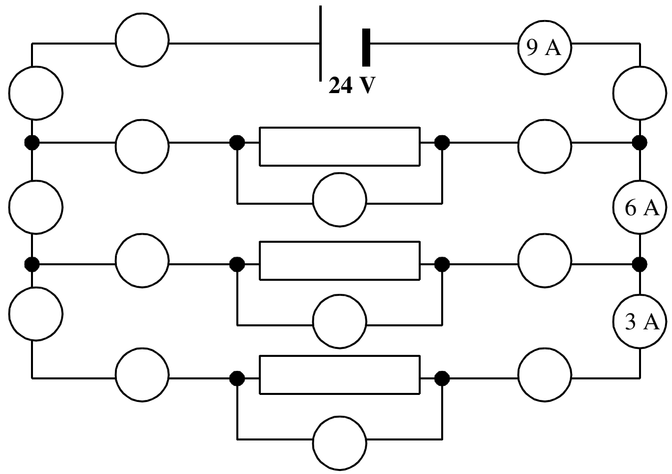
The potential difference (voltage) across the parallel branches is the s _ _ _ and equal to the s _ _ _ _ _ potential difference (voltage.)

1) For each **electric circuit** shown below, write the correct **current** and **potential difference** (**voltage**) values on the **meters**:



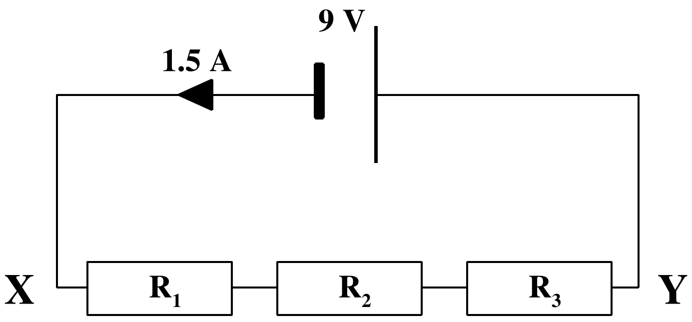






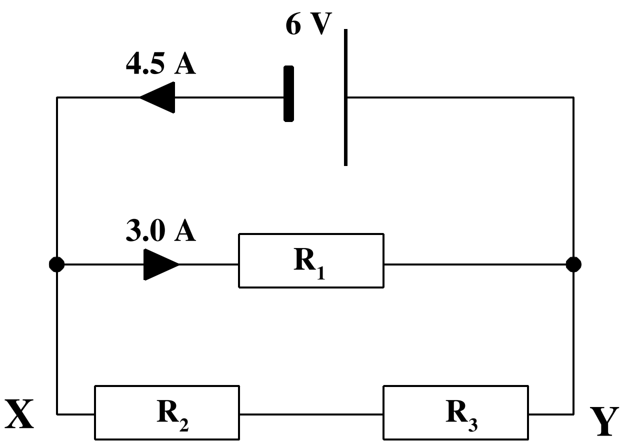
2) In each of these three circuits, all the resistors are identical - they have the same resistance.
For each circuit, complete the table to show the current and potential difference (voltage) values requested:

Because the resistors in this series circuit are identical, the supply potential difference (voltage) will be shared equally between the three resistors.



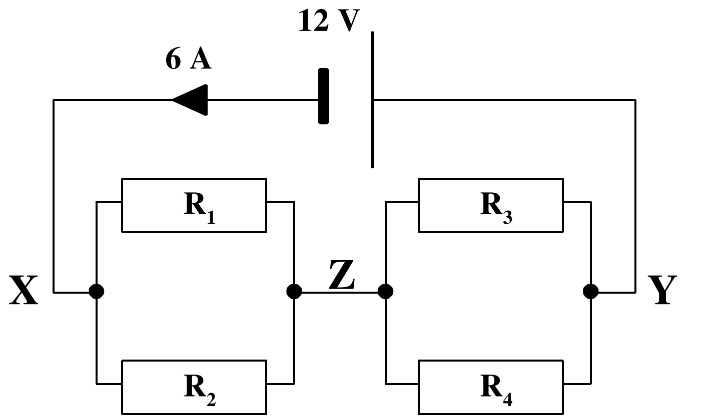
part of circuit/ resistor	current through / A	potential difference (voltage) across / V
XY		
R_1		
R_2		
R_3		

The potential difference (voltage) across every branch in a parallel circuit is equal to the supply potential difference (voltage). In this parallel circuit, because the resistors are identical, the supply voltage across branch XY will be shared (divided) equally between the two resistors in the branch.



part of circuit/ resistor	current through / A	potential difference (voltage) across / V
R_1		
XY		
R_2		
R_3		

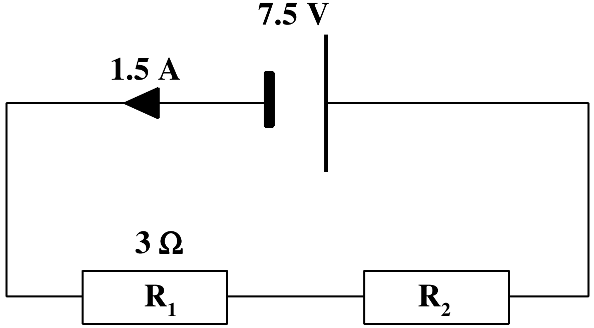
In this combined series-parallel circuit, because the resistors are identical, the current will split up equally when it reaches each pair of parallel resistors. Also, the supply potential difference (voltage) across XY will be shared (divided) equally between XZ and ZY. Each resistor in a parallel pair will have the same potential difference (voltage) across it.



part of circuit /resistor	current through / A	potential difference (voltage) across / V
XY		
XZ		
ZY		
R_1		
R_2		
R_3		
R_4		

For the following problems, each circuit contains resistors with different resistance values. To solve the problems, you will have to apply the rules for current and voltage in series/parallel circuits and use the Ohm's Law equation "V = IR". This equation can be applied to individual circuit components, and also to the whole circuit.

3) For this series circuit:



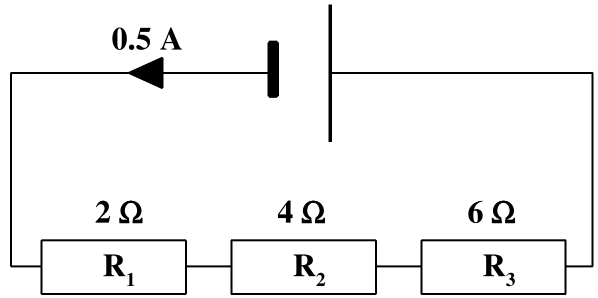
(a) Calculate the potential difference (voltage) across resistor R_1.

(b) Determine the potential difference (voltage) across resistor R_2.

(c) State the current through resistor R_2.

(d) Calculate the resistance of resistor R_2.

4) For this series circuit:



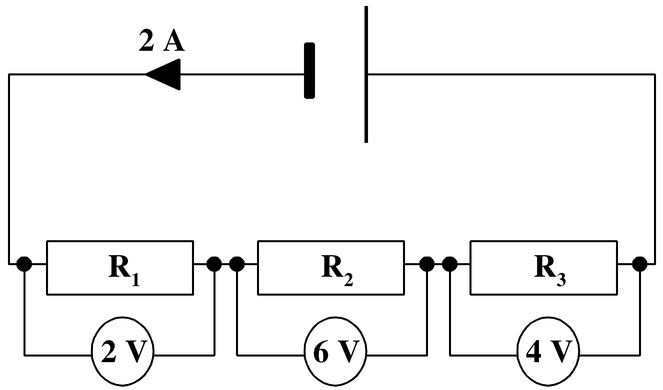
(a) Calculate the potential difference (voltage) across resistor R_1.

(b) Calculate the potential difference (voltage) across resistor R_2.

(c) Calculate the potential difference (voltage) across resistor R_3.

(d) Determine the potential difference (voltage) of the battery.

5) For this series circuit:



(a) Calculate the potential difference (voltage) of the battery.

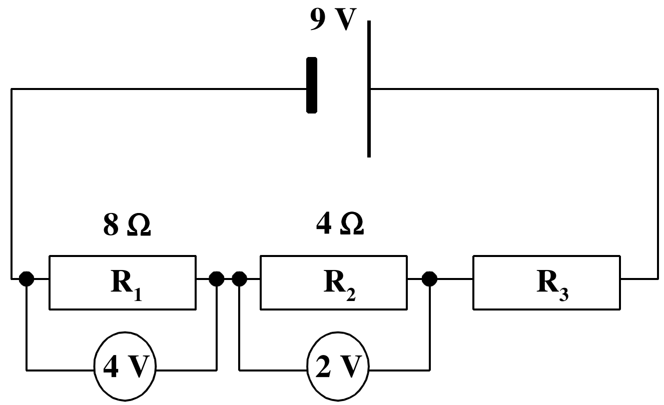
(b) Calculate the total resistance of the circuit.

(c) Calculate the resistance of resistor R_1.

(d) Calculate the resistance of resistor R_2.

(e) Calculate the resistance of resistor R_3.

6) For this series circuit:



(a) Calculate the current through resistor R_1.

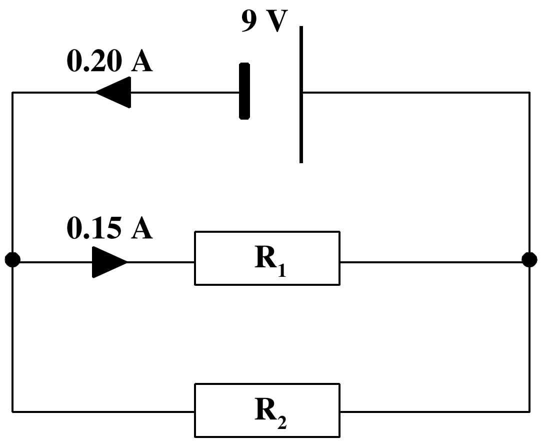
(b) Calculate the current through resistor R_2.

(c) State the current through resistor R_3.

(d) Calculate the resistance of resistor R_3.

(e) Calculate the potential difference (voltage) across resistor R_3.

7) For this parallel circuit:



(a) State the potential difference (voltage) across resistor R_1.

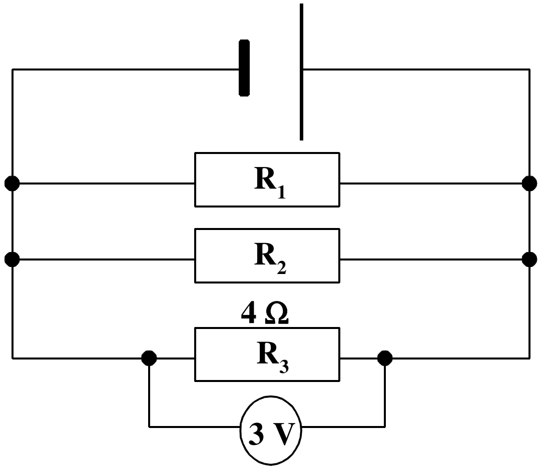
(b) State the potential difference (voltage) across resistor R_2.

(c) Determine the current through resistor R_2.

(d) Calculate the resistance of resistor R_1.

(e) Calculate the resistance of resistor R_2.

8) For this parallel circuit:



(a) State the potential difference (voltage) across resistor R_1.

(b) State the potential difference (voltage) across resistor R_2.

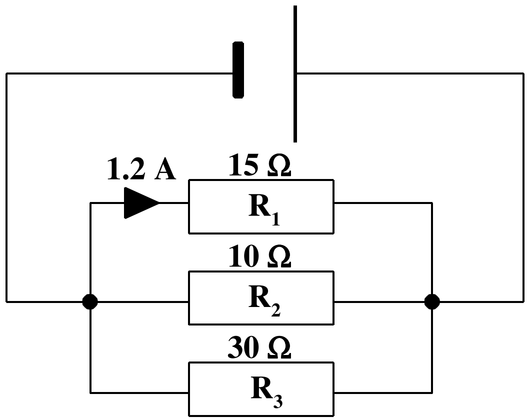
(c) State the potential difference (voltage) of the battery.

(d) Calculate the current through resistor R_3.

(e) Resistors R_1 and R_2 both have the same resistance (8 Ω). What must be the current through each resistor?

(f) Determine the current supplied by the battery.

9) For this parallel circuit:



NOTICE THIS ALTERNATIVE WAY OF REPRESENTING A PARALLEL CIRCUIT.

(a) Calculate the potential difference (voltage) across resistor R_1.

(b) State the potential difference (voltage) of the battery.

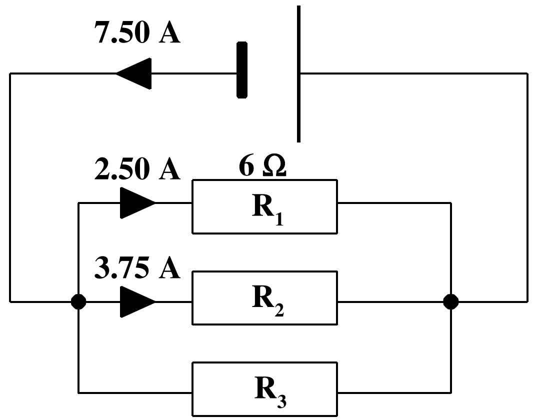
(c) What must be the potential difference (voltage) across resistors R_2 and R_3.

(d) Calculate the current through resistor R_2.

(e) Calculate the current through resistor R_3.

(f) Determine the current supplied by the battery.

10) For this parallel circuit:



NOTICE THIS ALTERNATIVE WAY OF REPRESENTING A PARALLEL CIRCUIT.

(a) Calculate the potential difference (voltage) across resistor R_1.

(b) State the potential difference (voltage) of the battery.

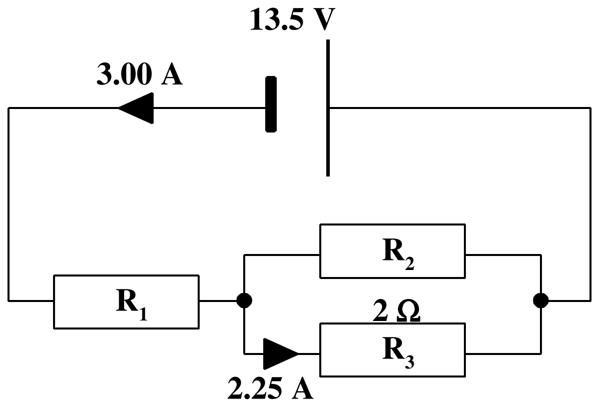
(c) What must be the potential difference (voltage) across resistors R_2 and R_3.

(d) Calculate the resistance of resistor R_2.

(e) Calculate the current through resistor R_3.

(f) Calculate the resistance of resistor R_3.

11) For this combined series-parallel circuit:



(a) Calculate the potential difference (voltage) across resistor R_3.

(b) State the potential difference (voltage) across resistor R_2.

(c) Determine the current through resistor R_2.

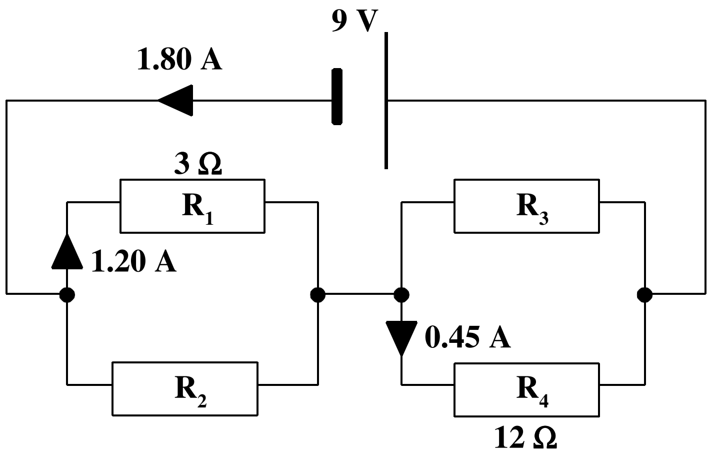
(d) Calculate the resistance of resistor R_2.

(e) Determine the potential difference (voltage) across resistor R_1.

(f) State the current through resistor R_1.

(g) Calculate the resistance of resistor R_1.

12) For this combined series-parallel circuit:



(a) Calculate the potential difference (voltage) across resistor R_1.

(b) State the potential difference (voltage) across resistor R_2.

(c) Determine the current through resistor R_2.

(d) Calculate the resistance of resistor R_2.

(e) Determine the potential difference (voltage) across resistor R_4.

(f) State the potential difference (voltage) across resistor R_3.

(g) Determine the current through resistor R_3.

(h) Calculate the resistance of resistor R_3.

• CAR WIRING

Car wiring is an interesting practical use of electric circuits.

A typical **car wiring diagram** for the **sidelights** and **headlights** is shown below.

The purpose of a switch connected beside (in series with) a circuit component is to connect or disconnect that component from the battery/power supply.

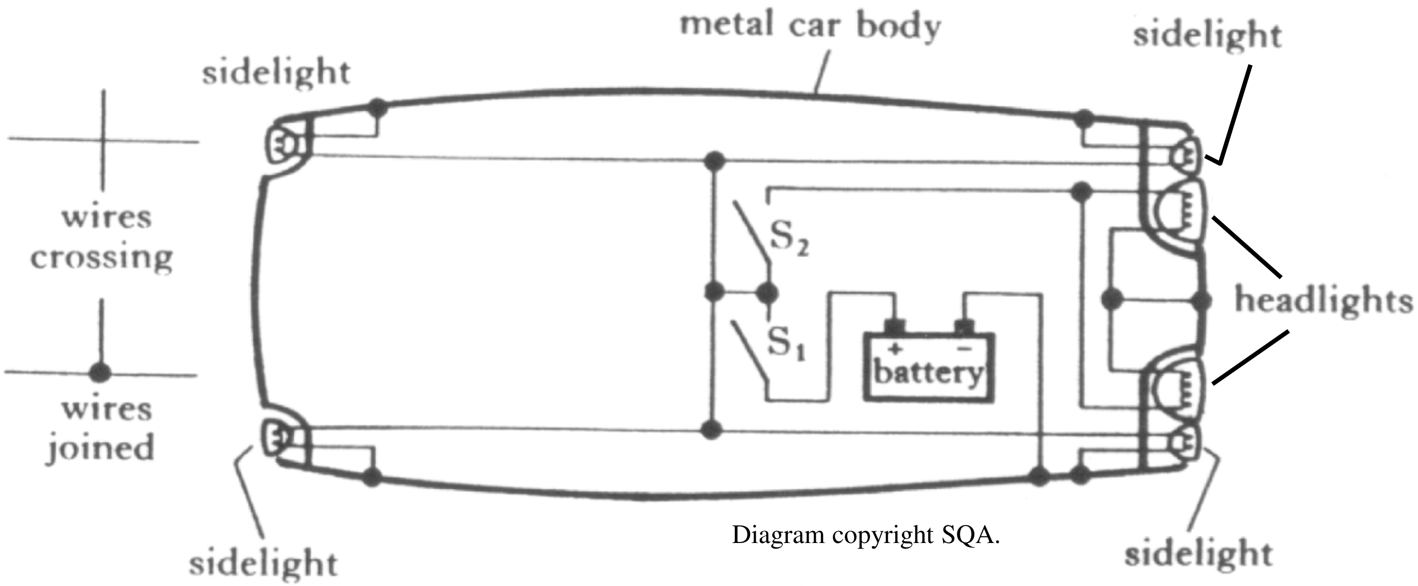


Diagram copyright SQA.

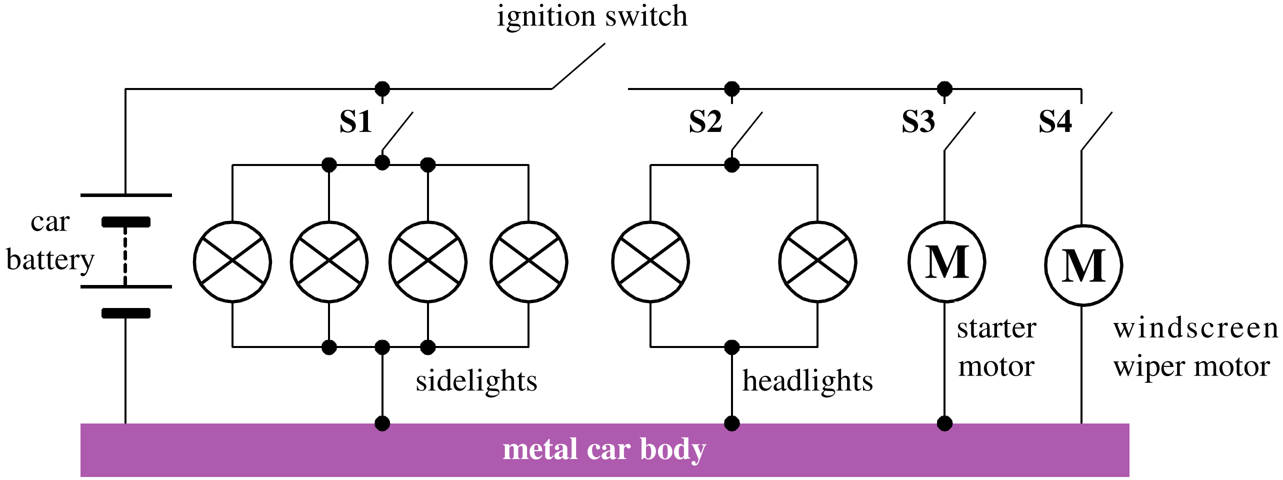
The car lights operate using electric current from the car **b** _ _ _ _ _ _.

The **n** _ _ _ _ _ _ _ terminal of the car battery is connected to the metal car body, as are connections from each light. Electric current can flow from the car battery, through the metal car body, to each light - this reduces the length of connecting **w** _ _ _ required.

The **sidelights** are switched on by closing switch ___. The **headlights** are switched on by closing switches _________.

The car lights are connected in **p** _ _ _ _ _ _ _ - if one lamp goes out, the other lamps will remain **l** _ _.

13) The **wiring diagram** for a typical **car** is shown:



(a) What supplies **electrical energy** (**electricity**) to the various components? ________________________________

(b) Are the components connected in **series** or **parallel**? ____________

(c) Assuming all the **lamps** are switched **on**, explain what will happen to the remaining lamps if one lamp "blows" (breaks): ____________________

____

____

(d) State one **advantage** of connecting all the components to the **car body**: ________________________________

____

(e) Which **switch** (or **switches**) must be **closed** to operate the:

(i) sidelights: ________________________________

(ii) headlights ________________________________

(iii) starter motor: ____________________________

(iv) windscreen wiper motor: ____________________

(f) Describe the **path** of the **electric current** flowing in the circuit when only **switch S1** is closed: ____________________________________

____

____

14) In a typical **4 door car**, a **lamp** lights inside the passenger compartment when **__either__** of the 4 doors is **__opened__**.

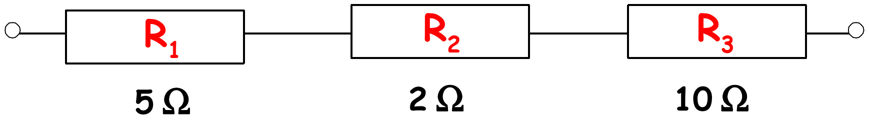
With the aid of a **circuit diagram**, explain how car designers make this possible:

• RESISTORS IN SERIES

For resistors connected in **series**, the **total series resistance** (R_T) can be calculated using the formula:

$$R_T = R_1 + R_2 (+ R_3 + \ldots)$$

For example, for the resistors connected below:



$$R_T = R_1 + R_2 + R_3$$

$$R_T = 5 + 2 + 10$$

$$R_T = \underline{\underline{17\ \Omega}}$$

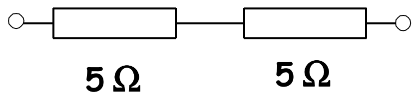
When resistors are connected in series, the total resistance is always larger than the resistance of the highest value resistor in the series combination.

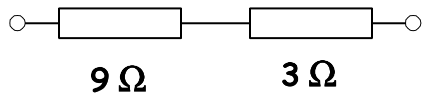
You should always check the resistance unit of all the resistors connected together in any electric circuit.

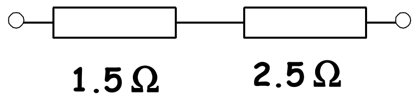
If all the units are all the same (e.g., Ω, mΩ, kΩ, MΩ), simply perform the appropriate calculation, then write that unit beside the final answer.

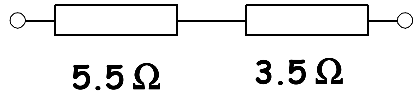
If the units are different (e.g.,Ω and kΩ), you must convert all the resistor values so they have the same resistance unit before carrying out the calculation.

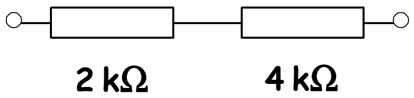
15) Calculate the **total series resistance** of each resistor combination:

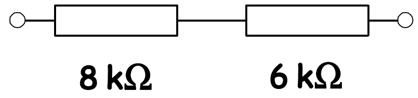


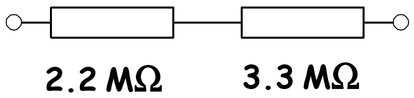


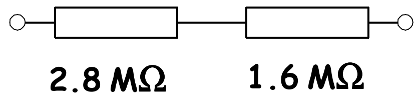




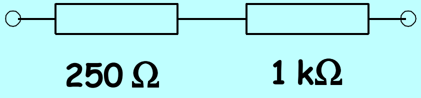


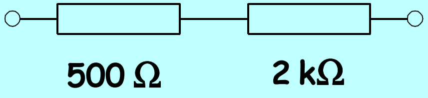


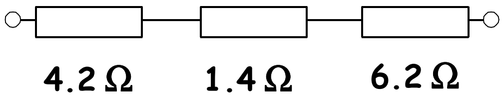


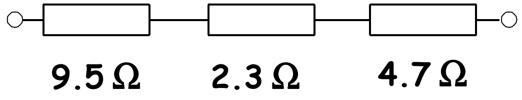


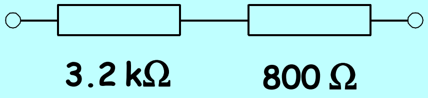
IMPORTANT NOTE: 1 kΩ = 1 000 Ω

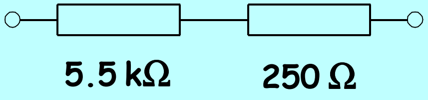


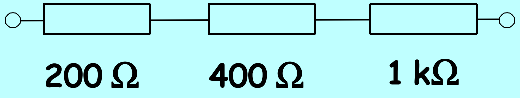


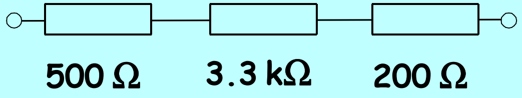


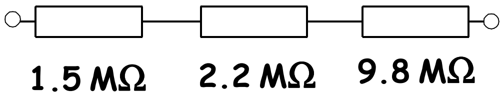


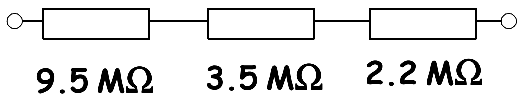


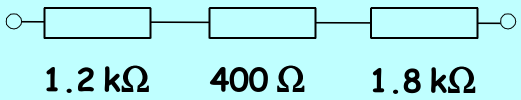


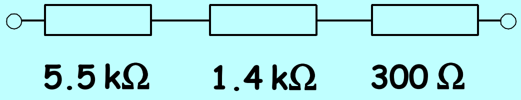










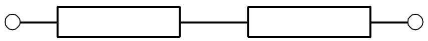


• RESISTORS IN SERIES (continued)

In some problems involving resistors connected in series, you may be given the total resistance (R_T) of the resistor combination. You would then be asked to calculate the resistance of one of the resistors in the combination.

For example:

The total resistance (R_T) of this series combination of resistors is 12 Ω. Calculate the resistance of resistor R_1.



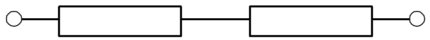
$R_T = R_1 + R_2$

$12 = R_1 + 5$

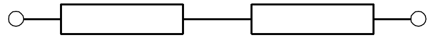
$R_1 = 12 - 5$

$R_1 = \underline{\underline{7\ \Omega}}$

16) Calculate the **resistance** of the unknown resistor in each of these series resistor combinations:

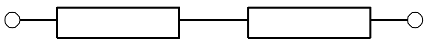


$R_T = 15\ \Omega$

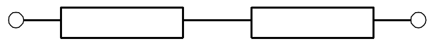


$R_T = 12.5\ \Omega$

$R_T = 100\ \Omega$

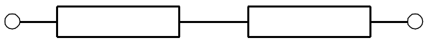


$R_T = 12\ \Omega$

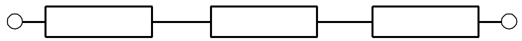


$R_T = 8.6\ M\Omega$

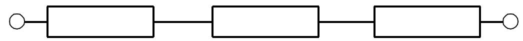
$R_T = 15\ M\Omega$



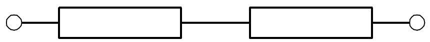
$R_T = 35\ k\Omega$



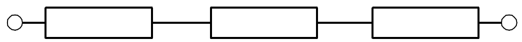
$R_T = 18\ \Omega$



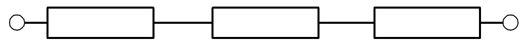
$R_T = 30\ \Omega$



$R_T = 20\ \Omega$



$R_T = 4.5\ k\Omega$



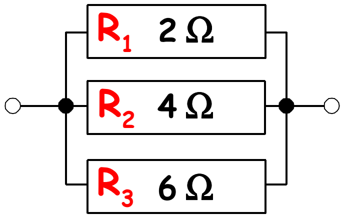
$R_T = 25\ k\Omega$

• RESISTORS IN PARALLEL

For resistors connected in **parallel**, the **total parallel resistance** (R_T) can be calculated using the formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \left(+ \frac{1}{R_3} + \ldots \right)$$

For example, for the resistors connected below:



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$$

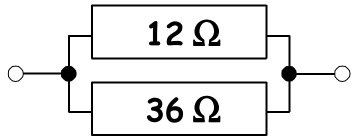
$$= \frac{11}{12}$$

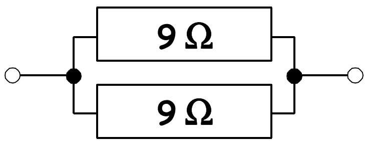
$$\therefore R_T = \frac{12}{11} = \underline{\underline{1.1\ \Omega}}$$

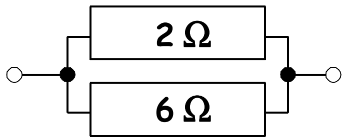
When resistors are connected in parallel, the total resistance is always less than the resistance of the lowest value resistor in the parallel combination.

The "fraction key" or "reciprocal key" on your calculator will be very helpful for solving parallel resistor problems.

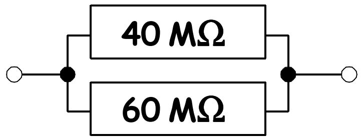
17) Calculate the **total parallel resistance** of each resistor combination:

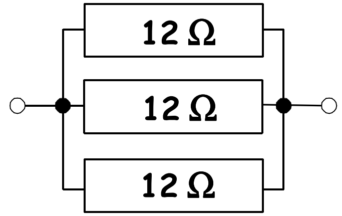


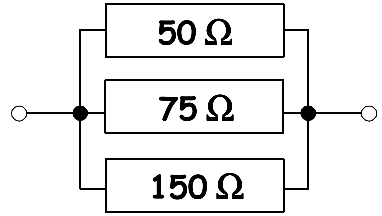


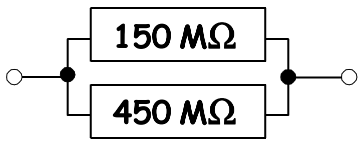


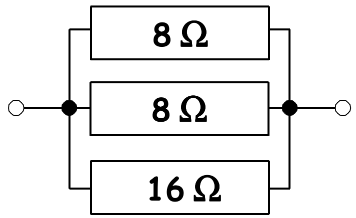
17) Continued

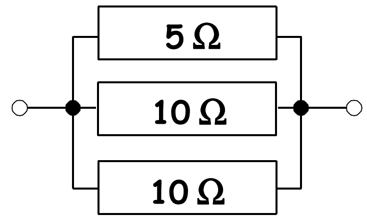




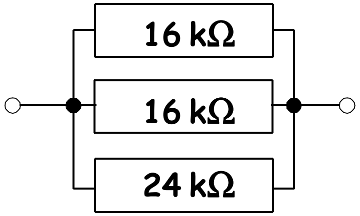


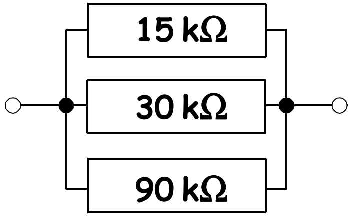


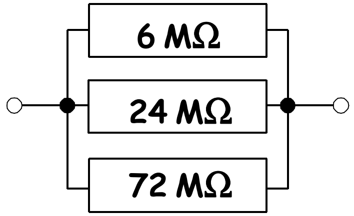


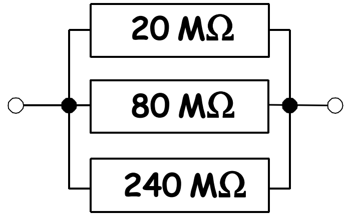


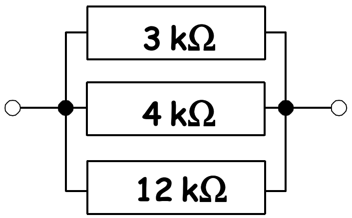
17) Continued

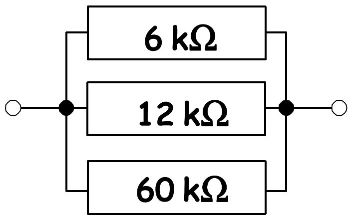


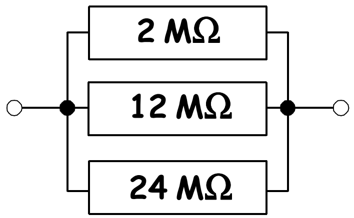


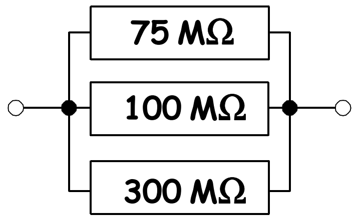










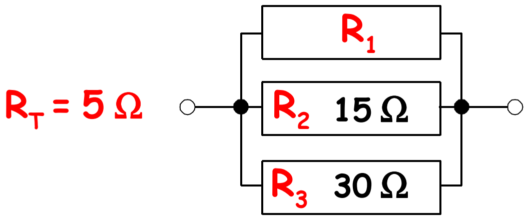


• RESISTORS IN PARALLEL (continued)

In some problems involving resistors connected in parallel, you may be given the total resistance (R_T) of the resistor combination. You would then be asked to calculate the resistance of one of the resistors in the combination.

For example:

The total resistance (R_T) of this parallel combination of resistors is 5 Ω. Calculate the resistance of resistor R_1.



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

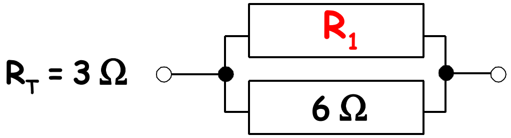
$$\frac{1}{5} = \frac{1}{R_1} + \frac{1}{15} + \frac{1}{30}$$

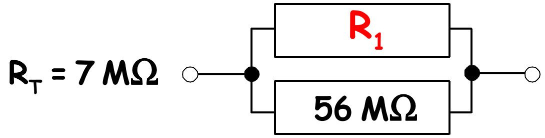
$$\frac{1}{R_1} = \frac{1}{5} - \frac{1}{15} - \frac{1}{30}$$

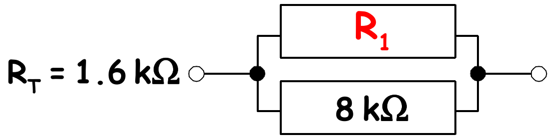
$$\frac{1}{R_1} = \frac{1}{10}$$

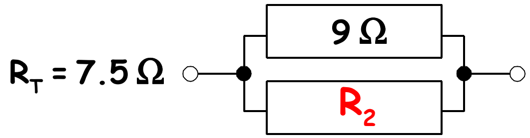
$$\therefore R_1 = \frac{10}{1} = \underline{\underline{10\ \Omega}}$$

18) Calculate the **resistance** of each 'unknown' resistor in these parallel resistor combinations:



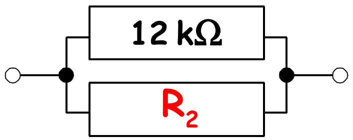




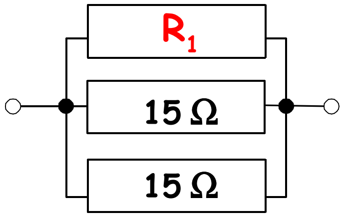


18) Continued

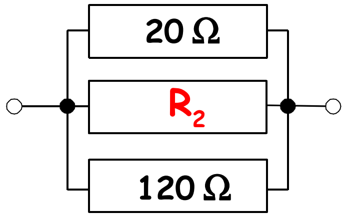
R_T = 10 kΩ



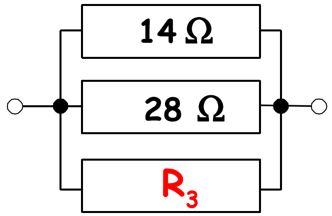
R_T = 5 Ω



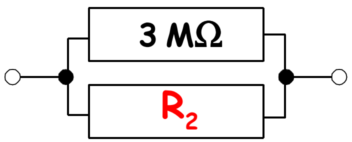
R_T = 12 Ω



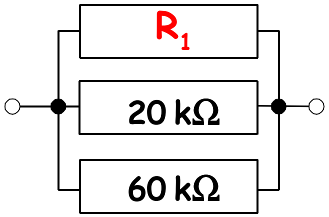
R_T = 8 Ω



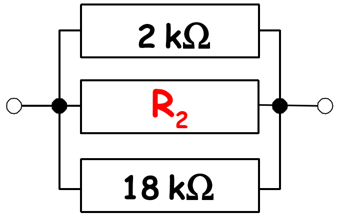
R_T = 2.4 M Ω



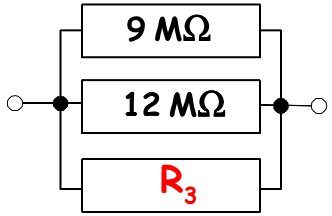
R_T = 3.75 kΩ



R_T = 1.5 kΩ



R_T = 4.5 MΩ

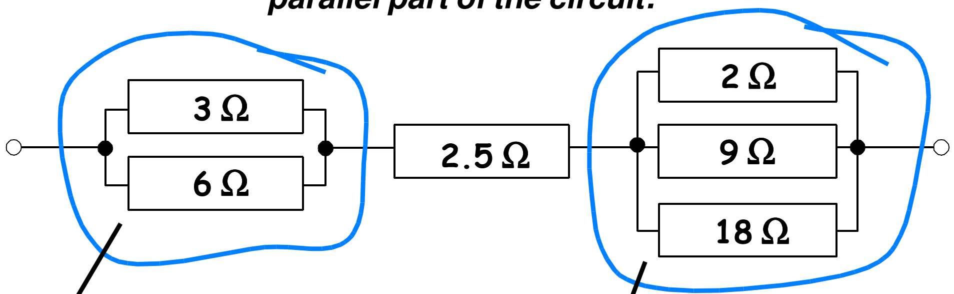


• RESISTORS IN SERIES AND PARALLEL

In a complex electric circuit, resistors (or other circuit components) can be connected together in series and in parallel, as shown below.

To calculate the total resistance of the resistors, the following steps must be taken:

1) Calculate the total resistance (R_T) of each parallel part of the circuit:



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \qquad\qquad \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{3} + \frac{1}{6} \qquad\qquad = \frac{1}{2} + \frac{1}{9} + \frac{1}{18}$$

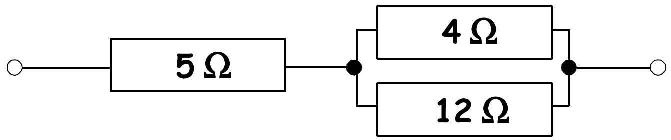
$$= \frac{1}{2} \qquad\qquad = \frac{2}{3}$$

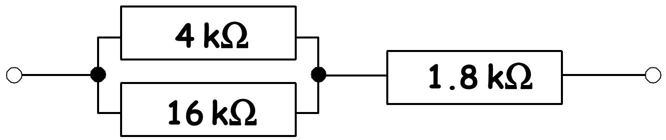
$$\therefore R_T = \frac{2}{1} = \underline{2\,\Omega} \qquad\qquad \therefore R_T = \frac{3}{2} = \underline{1.5\,\Omega}$$

2) Since the parallel parts of the circuit are in series with each other, and with individual (non-parallel) resistors, add together the resistance of each individual resistor and the total resistance of each parallel part:

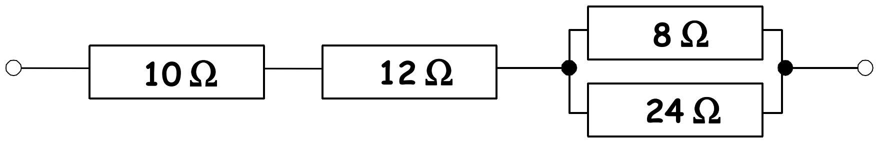
$$R_T = 2 + 2.5 + 1.5 = \underline{6\,\Omega}$$

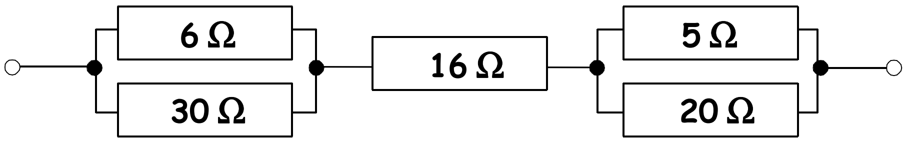
19) Calculate the **total resistance** of each resistor combination:

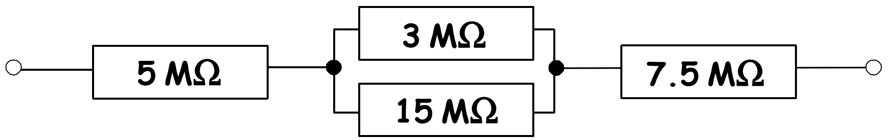


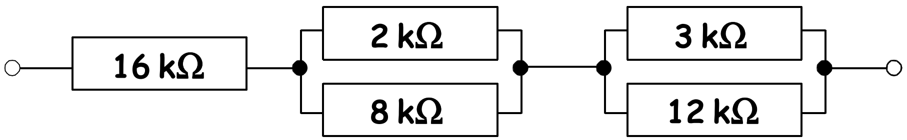


19) continued

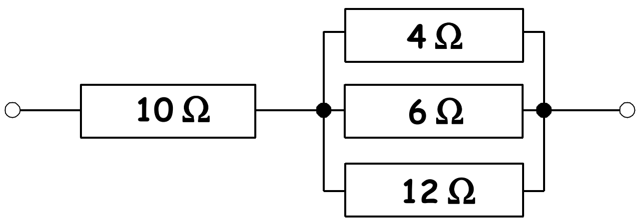


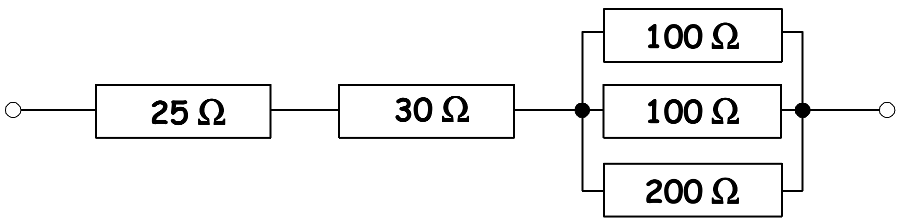


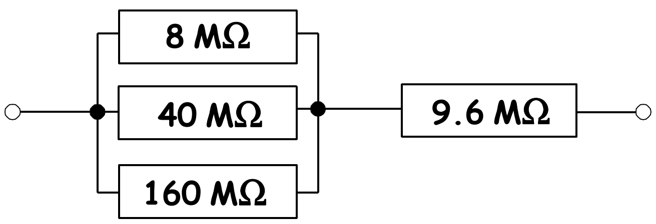


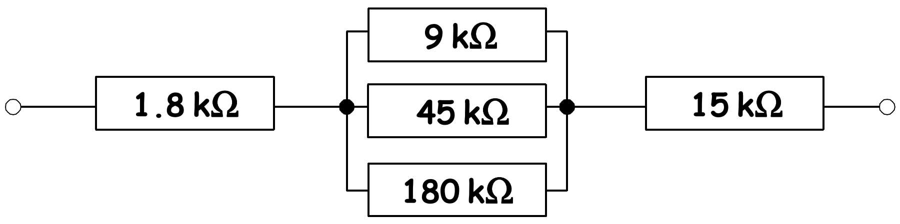


19) continued

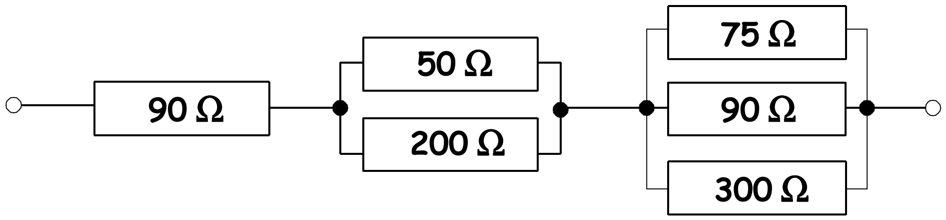


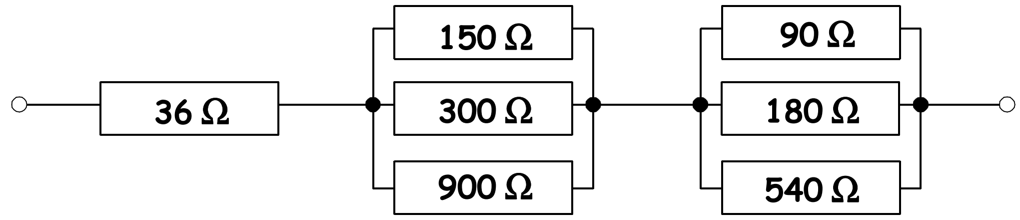


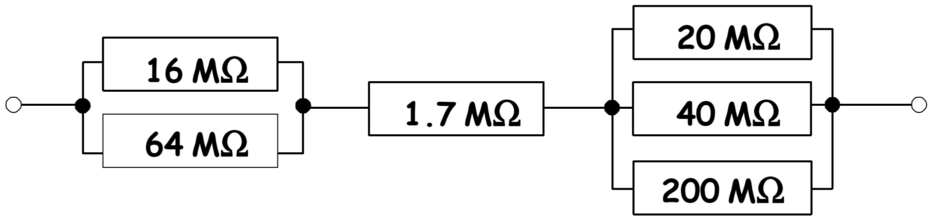


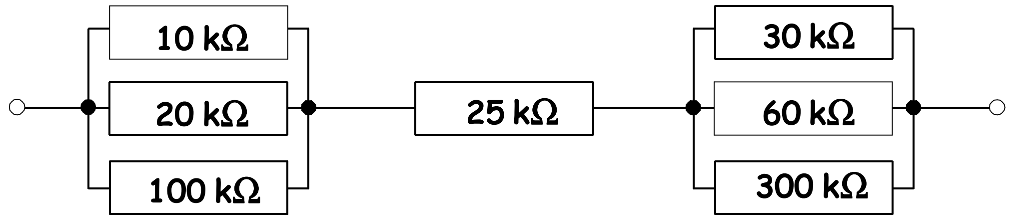


19) continued





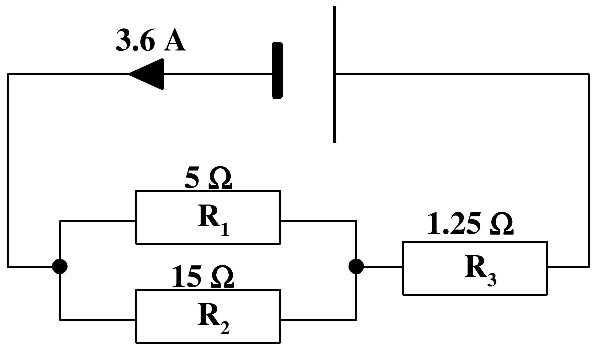




For the following problems, each circuit contains resistors connected together in series and in parallel. To solve the problems, you will have to apply the equation for the total resistance of resistors connected in series, the equation for the total resistance of resistors connected in parallel, the rules for current and voltage in series/parallel circuits and use the Ohm's Law equation "V = IR". This equation can be applied to individual circuit components, and also to the whole circuit.

YOU MAY WISH TO LOOK OVER THE PROBLEMS YOU ATTEMPTED ON PAGES 5 - 9

20) For this combined series-parallel circuit:



(a) Calculate the total resistance of the three resistors.

(b) Calculate the potential difference (voltage) of the battery.

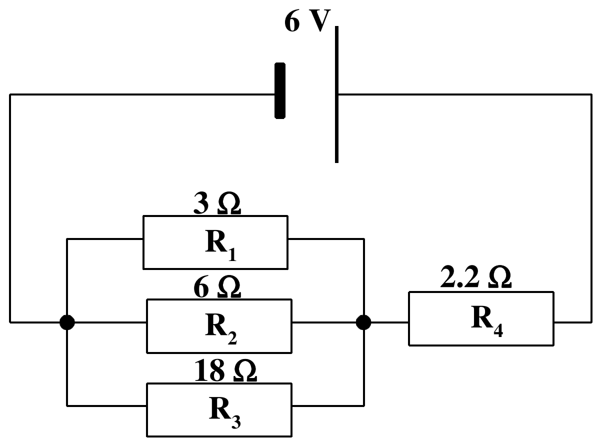
(c) Calculate the potential difference (voltage) across resistor R_3.

(d) Calculate the potential difference (voltage) across both resistors R_1 and R_2.

(e) Calculate the current through resistor R_1.

(f) Calculate the current through resistor R_2.

21) For this combined series-parallel circuit:



(a) Calculate the total resistance of the four resistors.

(b) Calculate the current supplied by the battery.

(c) Calculate the potential difference (voltage) across resistor R_4.

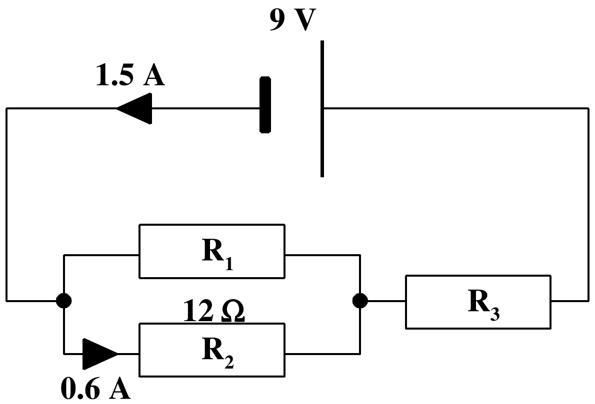
(d) Calculate the potential difference (voltage) across the resistors R_1, R_2 and R_3.

(e) Calculate the current through resistor R_1.

(f) Calculate the current through resistor R_2.

(g) Calculate the current through resistor R_3.

22) For this combined series-parallel circuit:



(a) Calculate the potential difference (voltage) across resistor R_2.

(b) State the potential difference (voltage) across resistor R_1.

(c) Calculate the current through resistor R_1.

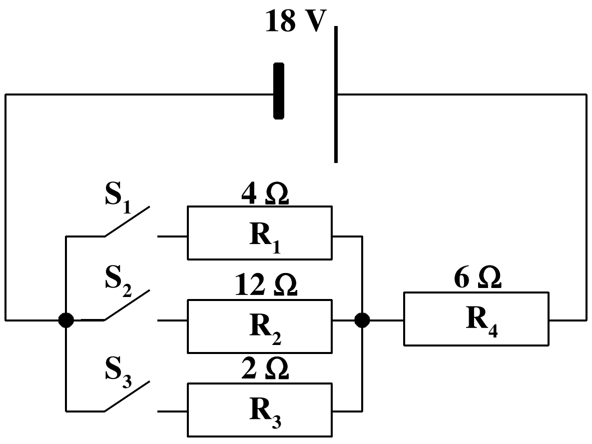
(d) Calculate the resistance of resistor R_1.

(e) Calculate the total resistance of the three resistors.

(f) Calculate the total resistance of resistors R_1 and R_2, connected in parallel.

(g) Calculate the resistance of resistor R_3.

23) For this combined series-parallel circuit:



(a) When only switch S_1 is closed:

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the current supplied by the battery.

A switch connected beside (in series with) a resistor can connect or disconnect that resistor from an electric circuit.
OPEN SWITCH = DISCONNECTED, CLOSED SWITCH = CONNECTED

(b) When only switches S_1 and S_2 are closed:

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the current supplied by the battery.

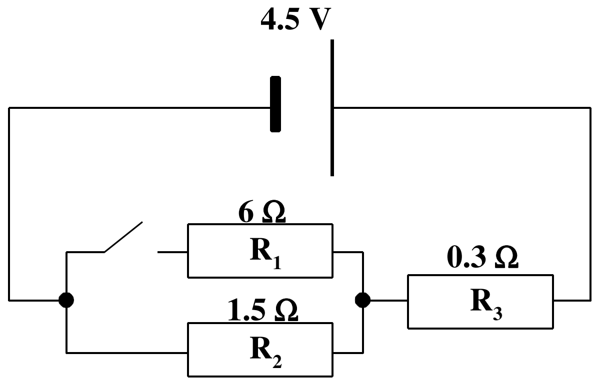
(c) When switches S_1, S_2 and S_3 are all closed:

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the current supplied by the battery.

24) For this combined series-parallel circuit:

A switch connected beside (in series with) a resistor can connect or disconnect that resistor from an electric circuit.
OPEN SWITCH = DISCONNECTED, CLOSED SWITCH = CONNECTED



(a) When the switch is open:

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the current supplied by the battery.

(iii) Calculate the potential difference (voltage) across resistor R_3.

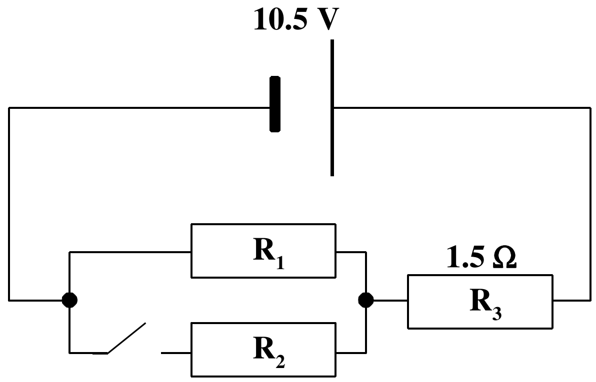
(b) When the switch is closed:

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the current supplied by the battery.

(iii) Calculate the potential difference (voltage) across resistor R_3.

25) For this combined series-parallel circuit:



(a) The battery supplies a current of 3 A when the switch is open.

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the resistance of resistor R_1.

A switch connected beside (in series with) a resistor can connect or disconnect that resistor from an electric circuit.
OPEN SWITCH = DISCONNECTED, CLOSED SWITCH = CONNECTED

(b) The battery supplies a current of 3.5 A when the switch is closed.

(i) Calculate the total resistance of the connected resistors.

(ii) Calculate the total resistance of resistors R_1 and R_2, connected in parallel.

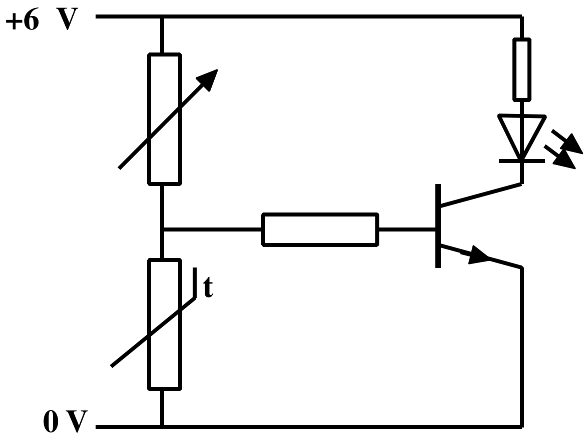
(iii) Calculate the resistance of resistor R_2.

Notes

National 5 Physics

"ELECTRICITY"

Circuit Components in Practical Electronic Circuits



Name: ______________________________

This section of the "Electricity" unit initially introduces 'electronic systems'.
It then introduces some 'input devices', explaining their operation in an electronic circuit - this includes an explanation of 'voltage (potential) dividers'.
'Output devices' are then discussed, including the light emitting diode (LED) and the need for a protective resistor connected in series with the LED.
For 'process devices', the function of transistors (NPN and n-channel enhancement mode MOSFET) as electronic switches is explained.

By the end of this section, you should be able to:

☐ state and give examples of the three parts of an electronic system - input, process and output

☐ list various 'input devices' and explain their operation in an electronic circuit

☐ describe the layout of a 'voltage (potential) divider' and carry out related 'voltage (potential) divider' calculations

☐ list various 'output devices' and explain their operation in an electronic circuit

☐ explain why a protective resistor is connected in series with a light emitting diode (LED) and calculate the resistance of the resistor

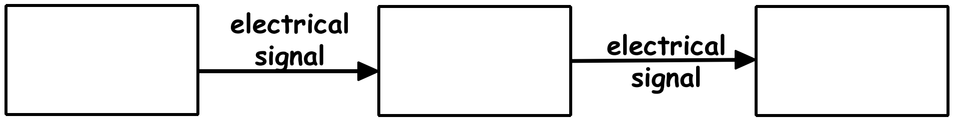
☐ state that a transistor is a 'process device' and explain the function of a transistor as an 'electronic switch' (NPN and n-channel enhancement mode MOSFET transistors)

☐ recognise and draw circuit symbols for various circuit components used in electronic circuits

1) ELECTRONIC SYSTEMS OVERVIEW

Any **electronic system** consists of **3 parts**
- **input**, **process** and **output**.

Label each box to show the 3 parts of an electronic system:



Information is passed along the system by **electrical signals**.

The table below gives examples of **electronic systems**.

Complete the table by naming appropriate components for the **input**, **process** and **output** part of each electronic system:

system	input	process	output
karaoke machine			
electronic calculator			
electronic stopwatch			
desktop computer			
mobile phone			

The Electrical Signals

The **electrical signals** are either **analogue** or **digital**.

Analogue Signals

These can have many __________ values.

Often, their value keeps __________.

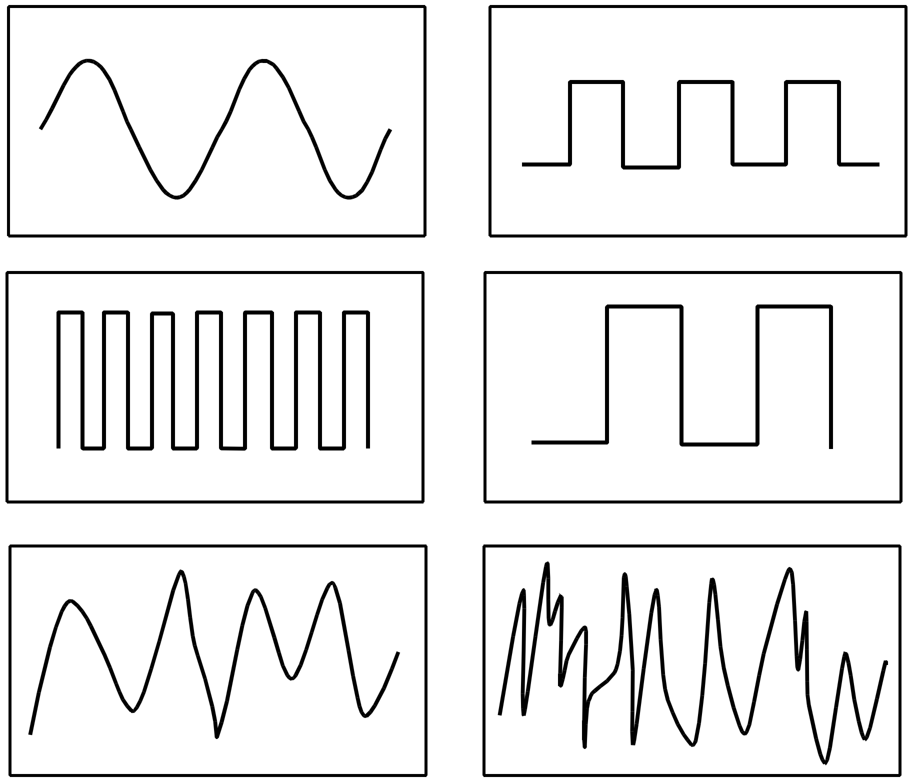
Digital Signals

These have only **2** values.

We describe these values in different ways:

_____/_____ or _____/_____ or _____/_____

Are these signals displayed on an oscilloscope **analogue** or **digital**?

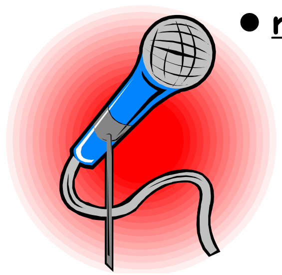


2) INPUT DEVICES

Input devices measure the **energy** surrounding them and change it into **electrical energy**.

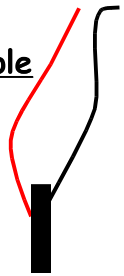
For example:

• **microphone**



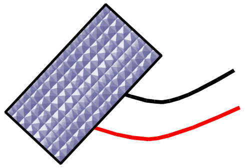
______ → ______

• **thermocouple**



______ → ______

• **photovoltaic cell**



______ → ______

The **electrical energy** is in the form of a **changing voltage**.

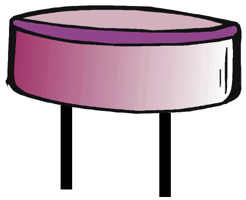
The **resistance** of some **input devices** changes as the **energy** they measure changes.

For example:

• **thermistor**

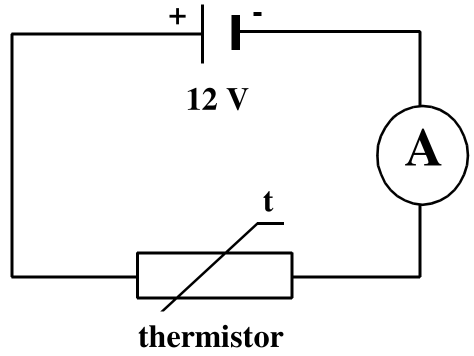
The **resistance** of a **thermistor** changes as its ______________ changes.

• **light dependent resistor (LDR)**

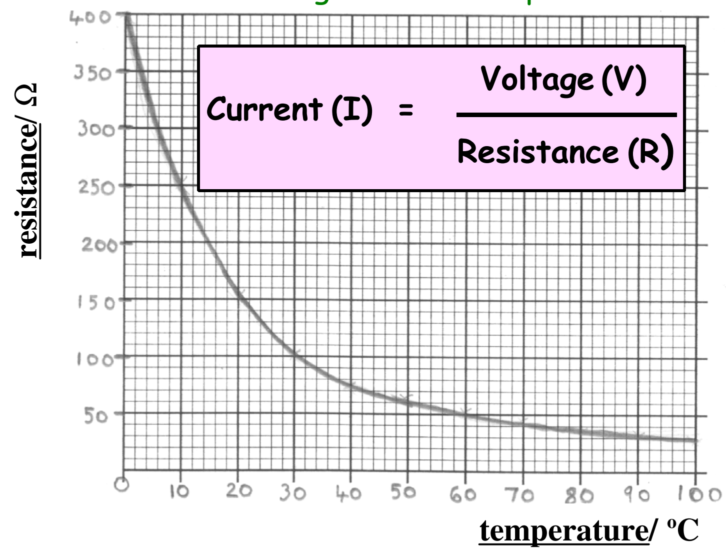


The **resistance** of a **LDR** ______________ as the **light level** ______________ (and vice versa).

The **thermistor** in this circuit controls the size of the **current** flowing around the circuit. As the **temperature** changes, the **resistance** of the **thermistor** changes, so the size of the **current** changes.



This graph shows how the resistance of the thermistor in the above circuit changes as its temperature changes.



$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

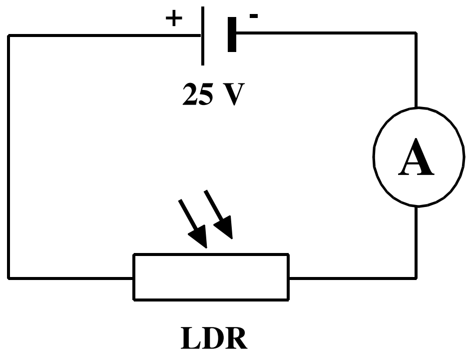
Determine the **current** flowing through the circuit when the temperature of the surroundings is:

(a) 10 °C

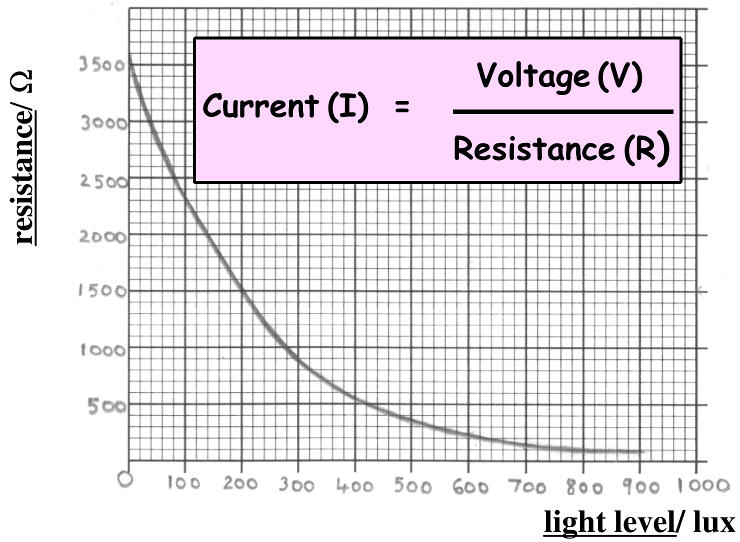
(b) 30 °C

(c) 60 °C

The **LDR** in this circuit controls the size of the **current** flowing around the circuit. As the **light level** changes, the **resistance** of the **LDR** changes, so the size of the **current** changes.



This graph shows how the resistance of the LDR in the above circuit changes as the light level changes.



Determine the **current** flowing through the circuit when the light level of the surroundings is:

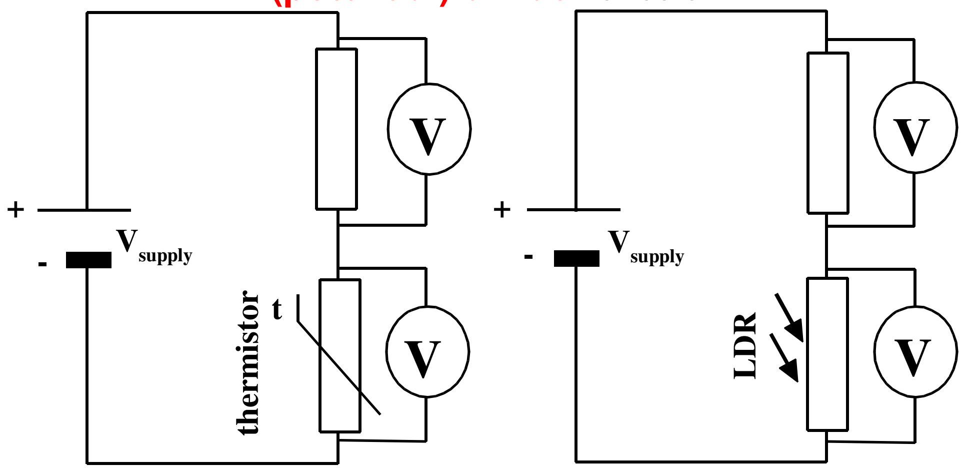
(a) 100 lux

(b) 400 lux

(c) 800 lux

Voltage (Potential) Divider Circuits

To obtain a **voltage (potential difference)** from a **thermistor** or **LDR**, we connect them in a **voltage (potential) divider** circuit:



As the **resistance** (**R**) of the **thermistor** or **LDR** changes, the **voltage (potential difference)** [**V**] across it changes.

To calculate the **voltage (potential difference)** [**V**] across the **top** or **bottom resistor** in a **voltage divider**, we use the **"voltage (potential) divider equation"** :

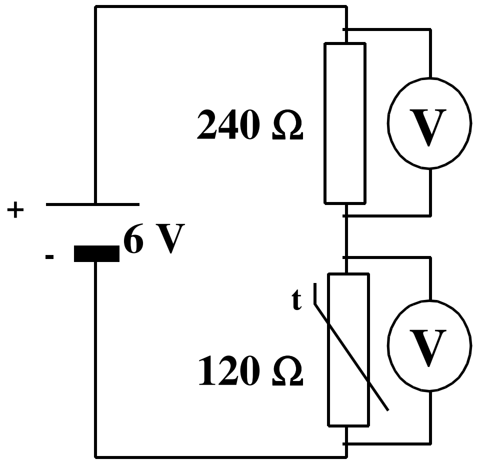
$$V_{top} = \frac{R_{top}}{R_{top} + R_{bottom}} \times V_{supply}$$

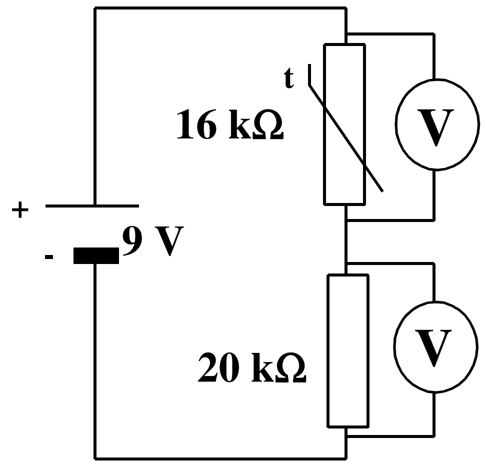
or

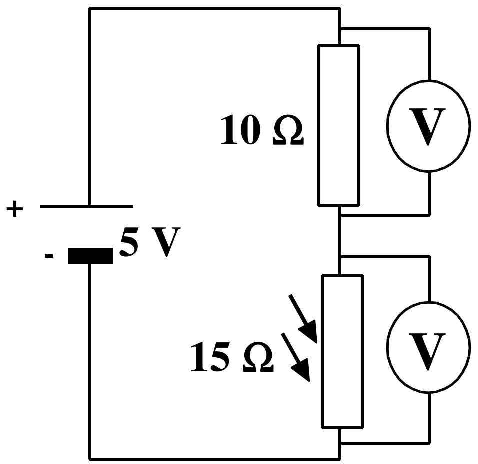
$$V_{bottom} = \frac{R_{bottom}}{R_{top} + R_{bottom}} \times V_{supply}$$

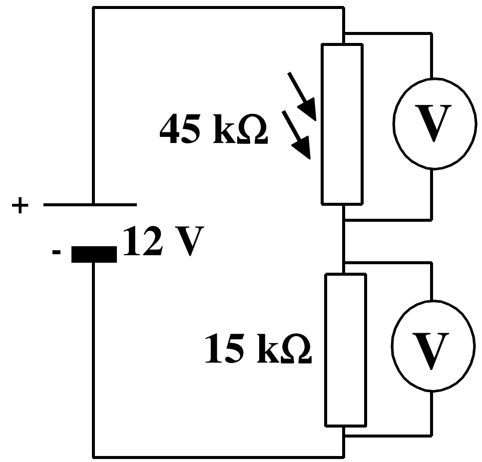
voltage across top resistor + voltage across bottom resistor = supply voltage

For each voltage (potential) divider circuit, calculate the **voltage (potential difference)** across the **bottom resistor** and the **voltage (potential difference)** across the **top resistor**:







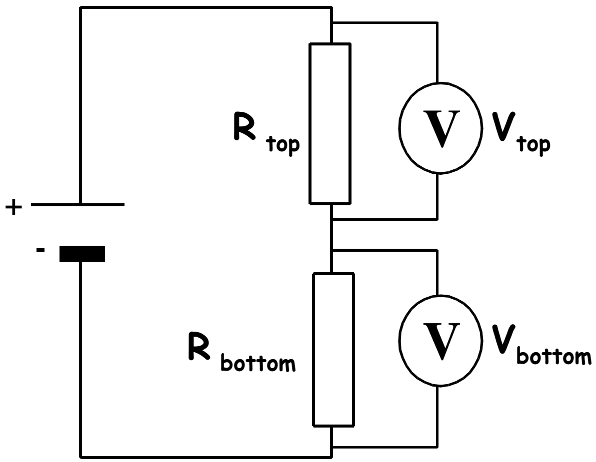


In a **voltage (potential) divider circuit**, the **voltage (potential difference)** across a resistor is related to its **resistance**.

The **h** _ _ _ _ _ the **resistance** of a resistor, the **h** _ _ _ _ _ the **voltage (potential difference)** across it.

This equation applies:

$$\frac{V_{top}}{V_{bottom}} = \frac{R_{top}}{R_{bottom}}$$



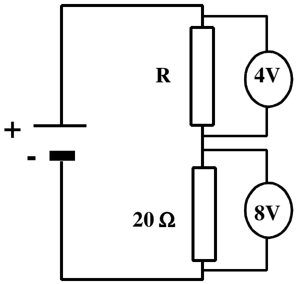
Because a **voltage (potential) divider circuit** is a **series circuit**, the **current** passing through both resistors is the **s** _ _ _.

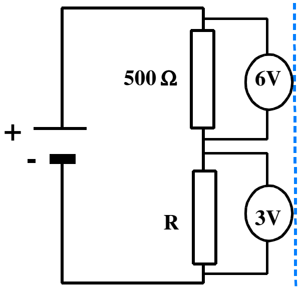
$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

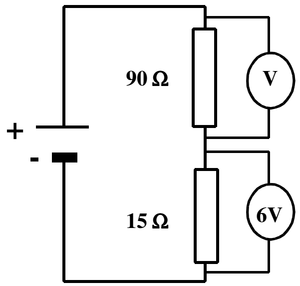
For each voltage (potential) divider circuit below:

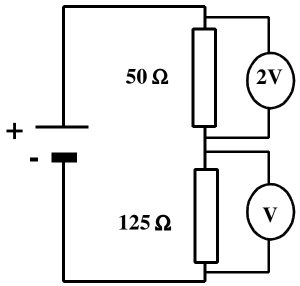
(a) Determine the **missing quantity**;

(b) Calculate the **current** passing through both resistors.



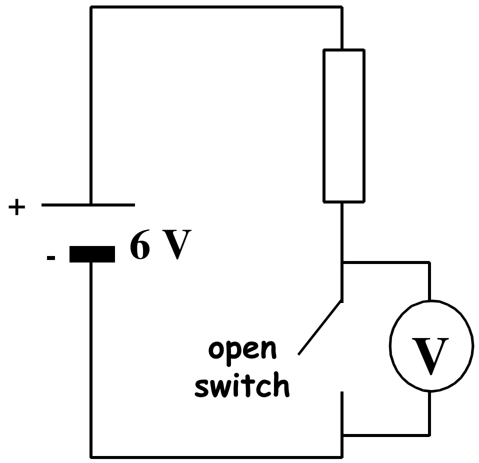






Two other **input devices** which can be placed in a **voltage (potential) divider circuit** are a **switch** and a **capacitor**:

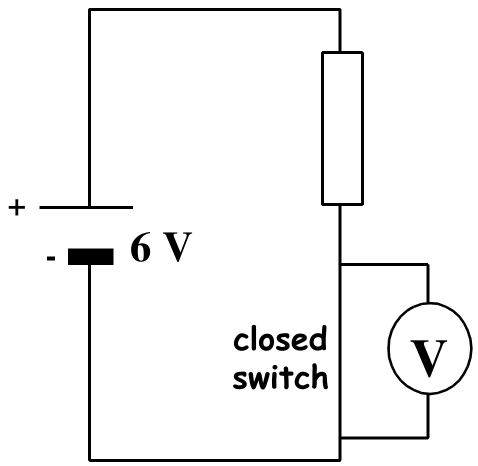
switch



When the **switch** is **open**, the **voltmeter** reads ______ (which is the _________ **voltage**).

The supply voltage splits between the **top resistor** and the **switch** depending on the **resistance** of each.

Because the **open switch** has an **infinitely high** (______________) **resistance** compared to the **top resistor**, ______ of the **voltage** is found across the **open switch**.



When the **switch** is **closed**, the **voltmeter** reads _____.

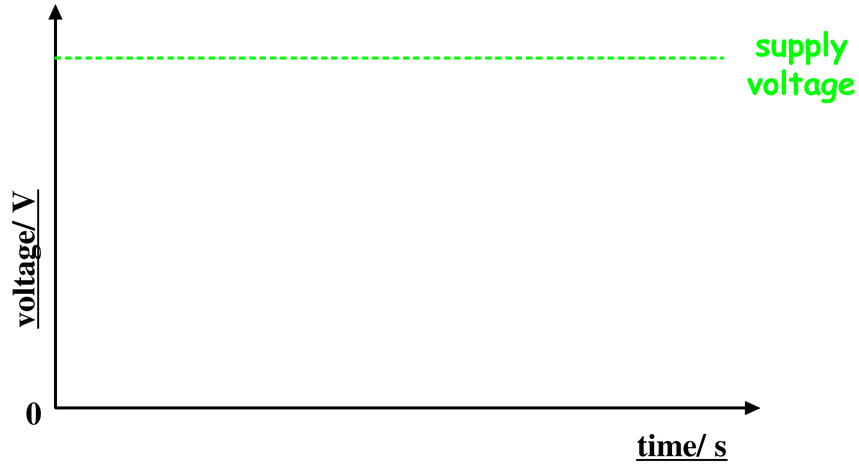
The **supply voltage** splits between the **top resistor** and the **switch** depending on the **resistance** of each.

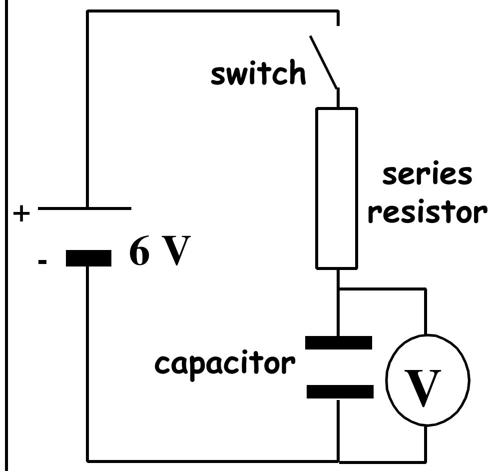
Because the **top resistor** has a much _________ **resistance** compared to the **closed switch**, ______ of the **voltage** is found across the **top resistor** and ______ is found across the **closed switch**.

capacitor

A **capacitor** is a device which stores **electric charge**.

As a **capacitor** **charges up**, the **voltage (potential difference) across it** increases from ______ up to the ____________ **voltage**:





When the **switch** is **closed**, the **capacitor** starts to **charge up** and the **voltage (potential difference) across it** increases.

The **time** taken for the capacitor to **charge up fully** to the **supply voltage** depends on the **value of the** ____________ and the value of the **series** ______________.

By drawing lines, match each **input device** with the **input job** it does for a particular **electronic system**:

- The "singing input" for a karaoke machine.

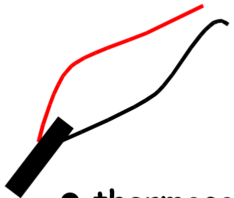
- The "temperature sensor" for a small electronic thermometer.

- The "light input" for an electronic calculator's power supply.

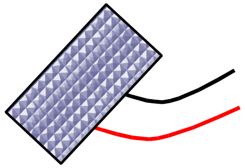
- The "light detector" for the flash system of a camera.

Input devices

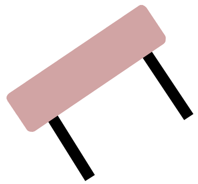
- microphone



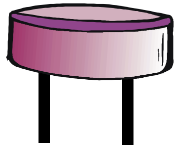
- thermocouple



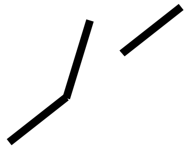
- photovoltaic (solar) cell



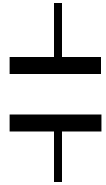
- thermistor



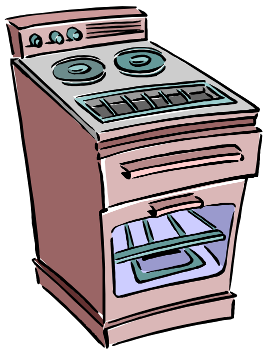
- light dependent resistor (LDR)



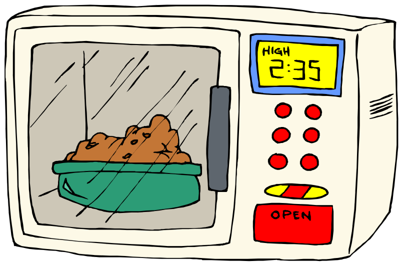
- switch



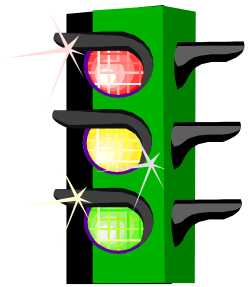
- capacitor



- The "temperature sensor" for a very hot electric oven.



- The "on/off input" for a microwave oven.



- The "time delay input" for a pedestrian-controlled crossing. (The red light switches on when someone has pressed the "wish to cross" button and the voltage has built up from zero to a high enough value).

Notes

3) OUTPUT DEVICES

Output devices take the **electrical signal** (**electrical energy**) from the **process part** of an electronic system and change it into **a useful form of energy**.

For example:

• Analogue Output Devices

The output can have many ___________ values.

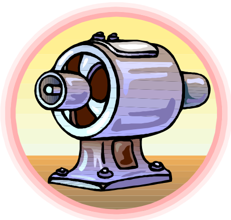
Often, the value keeps ___________.

• loudspeaker

__________ → ___________

The **v** _ _ _ _ _ _ and **f** _ _ _ _ _ _ _ _ _ _ of the sound keep changing.

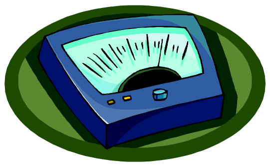
• electric motor



__________ → ___________

The **s** _ _ _ _ _ of the turning motor can be changed to many different values.

• moving coil meter



__________ → ___________

The **p** _ _ _ _ _ _ _ _ of the pointer on the scale can change from anywhere between the **far l** _ _ _ and **far r** _ _ _ _ _.

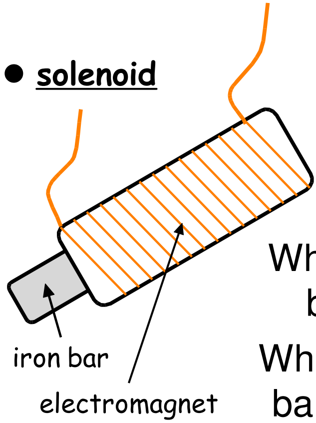
• Digital Output Devices

These have only ___ values.

We describe these values in different ways:

_____/_____ or _____/_____ or _____/_____

• solenoid

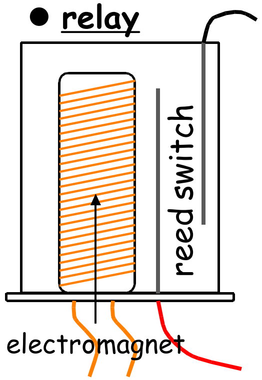


__________ → ___________

When the solenoid is **ON**, the iron bar in the centre is pulled **i** _.

When the solenoid is **OFF**, the iron bar in the centre is pushed **o** _ _.

• relay

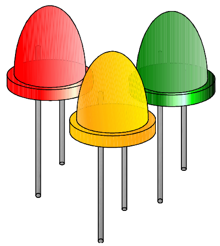


__________ → ___________

When the relay is **ON**, the reed switch is **c** _ _ _ _ _.

When the relay is **OFF**, the reed switch is **o** _ _ _.

• light emitting diode (LED)

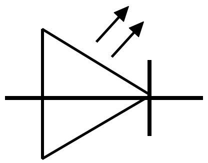


__________ → ___________

The **LED** is either **o** _ or **o** _ _.

Its **b** _ _ _ _ _ _ _ _ _ does not change.

Connecting LED's in a Circuit

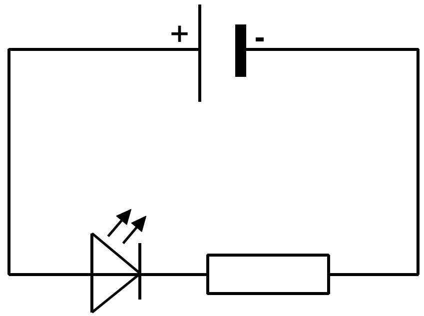


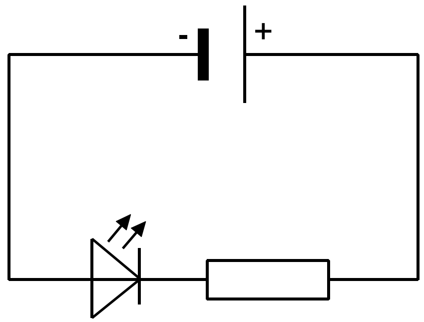
LED symbol

An **LED** will only light if it is connected **one way round**:

Put a **tick** or **cross** in each box below to show the circuit in which the LED will light.

For the circuit in which the LED lights, draw **arrows** to show the direction in which electrons flow.





A **r** _ _ _ _ _ _ _ _ is connected beside (in **s** _ _ _ _ _ _ with) the **LED**.

This is needed to ______________________________________

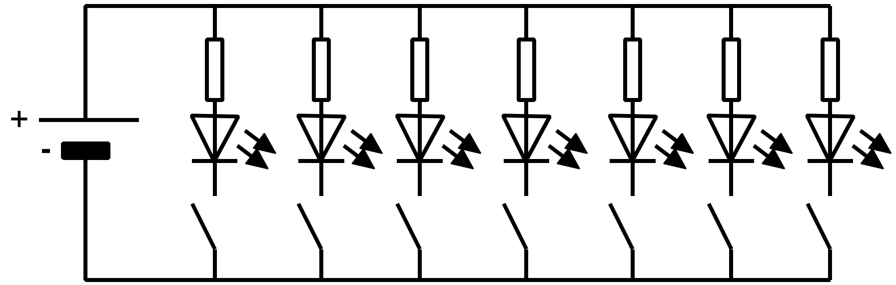
____

____

The Seven-Segment Display

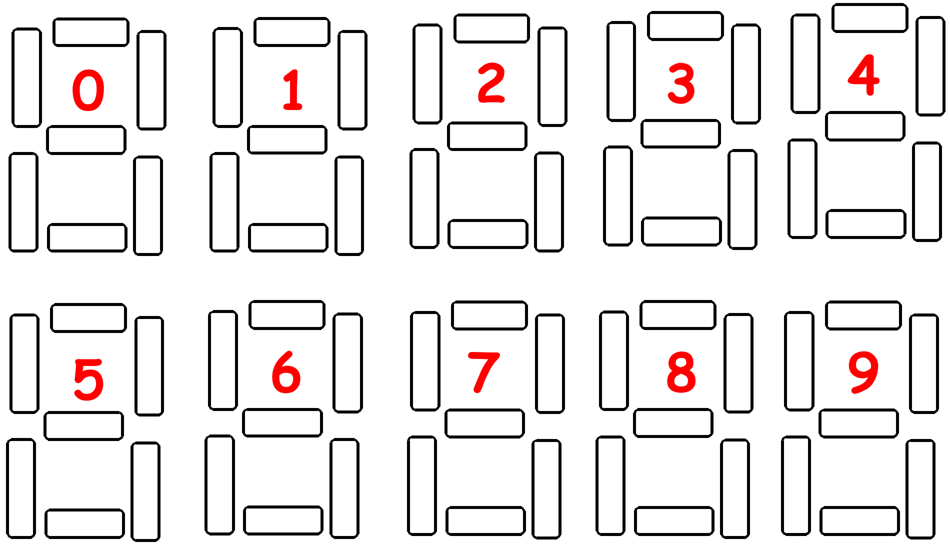
Seven separate **LED's** can be arranged to form the shape of a **number e** _ _ _ _ - this is called a **7- s** _ _ _ _ _ _ _ **d** _ _ _ _ _ _ _.

Each **LED** can be switched **on** or **off** **s** _ _ _ _ _ _ _ _ _ _ using the electric circuit below:



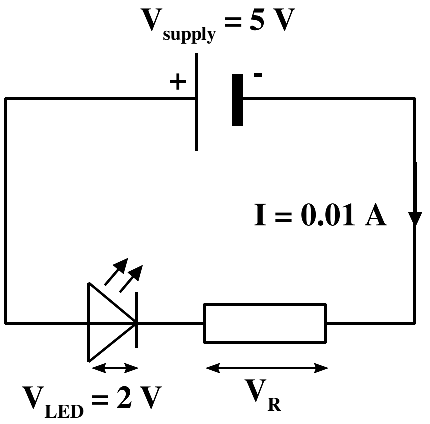
This allows **any number** from __ to __ to be displayed.

Colour in the **LED's** which must be lit to produce these numbers:



Calculating the Resistance of the Series Resistor Protecting an LED

For the electric circuit shown below, the maximum voltage the **LED** can safely take is 2 V. The current is 0.01 A.



Voltage across resistor (V_R) = V_{supply} - V_{LED}

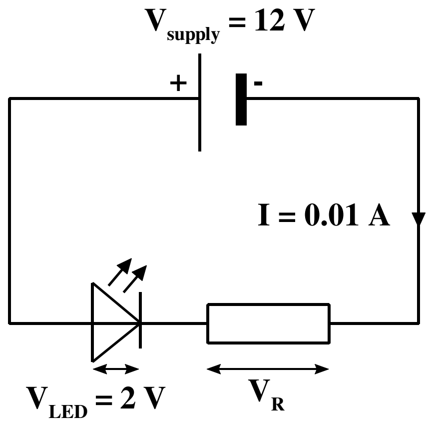
= 5 V - 2 V

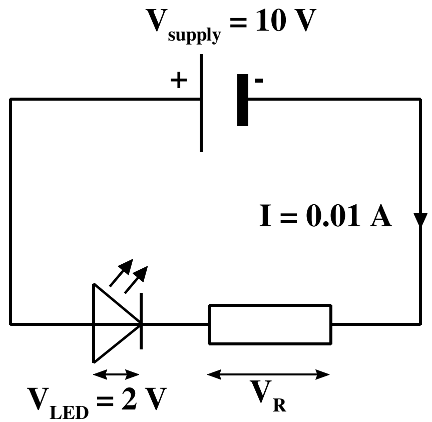
= 3 V

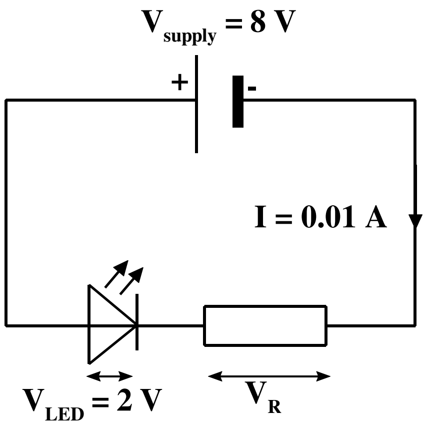
Resistance of resistor (R) = $\frac{V_R}{I}$

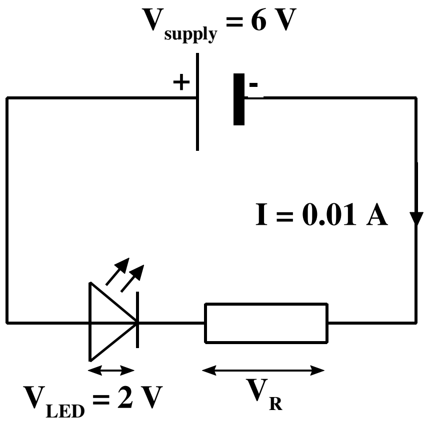
$= \frac{3\text{ V}}{0.01\text{ A}}$ = <u>300 Ω</u>

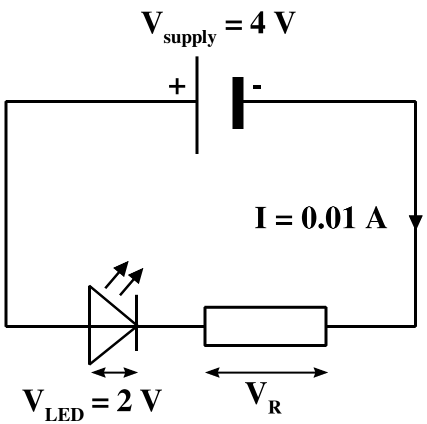
Calculate the **resistance** of the protective resistor in each of the following LED circuits:

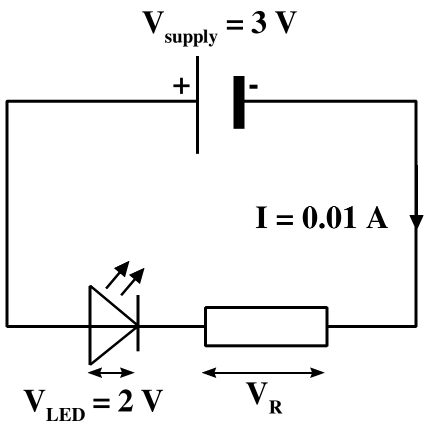





V supply = 8 V
+
-
I = 0.01 A
V LED = 2 V
V R


V supply = 6 V
+
-
I = 0.01 A
V LED = 2 V
V R

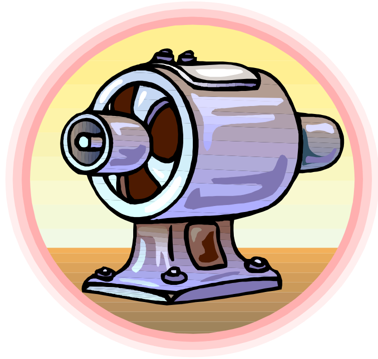

V supply = 4 V
+
-
I = 0.01 A
V LED = 2 V
V R


V supply = 3 V
+
-
I = 0.01 A
V LED = 2 V
V R

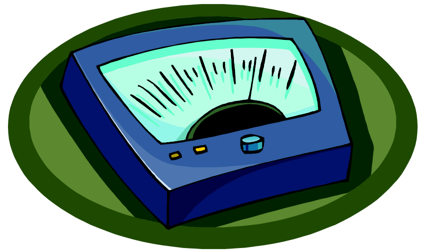
By drawing lines, match each **output device** with the **job** it does in **2** different **electronic systems**:

- **loudspeaker**

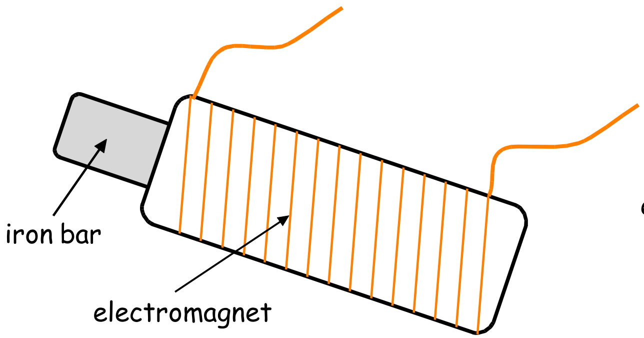
- **electric motor**



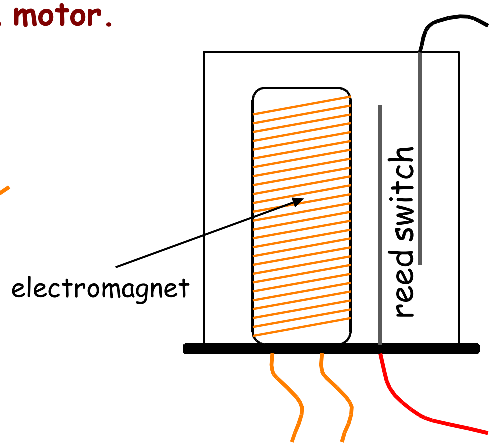
- **moving coil meter**



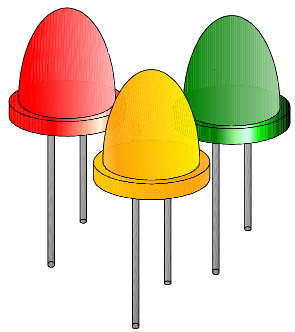
- Giving out sound from a telephone earpiece.
- Displaying numbers in a seven segment display.
- Showing a voltage reading.
- An electrically-operated door bolt.
- Turning the chuck of an electric drill.
- Switching on a device in a nuclear reactor.
- Pushing boxes off a conveyor belt.
- Turning the blades of a fan.
- Showing a current reading.
- Giving out sound from a radio.
- Switching on a motor.
- Showing that a radio is switched on.



- **solenoid**



- **relay**



- **light emitting diode**

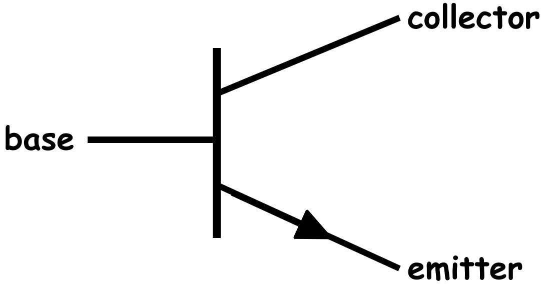
Notes

4) PROCESS DEVICES

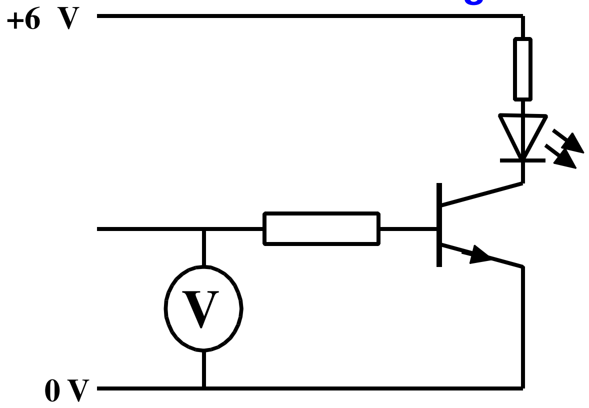
The Transistor as an Electronic Switch

A **transistor** can be used in an electronic circuit as an **electronic s _ _ _ _ _ _** - a **process device**.

The **circuit symbol** for an **NPN transistor** is shown:



A **transistor switching circuit** is shown:

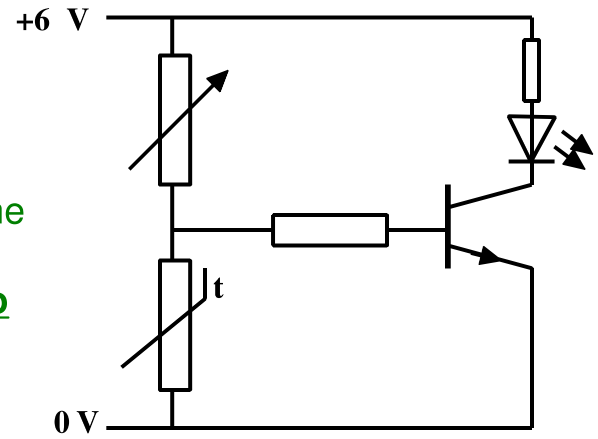


The **transistor** may be **conducting** (**ON**) or **non-conducting** (**OFF**).

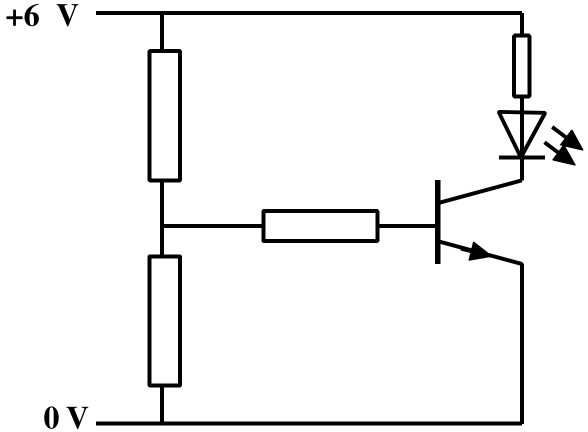
When a **h _ _ _ voltage** (___ **V or more**) is applied across the **transistor base**, the **transistor** is switched ___. The **transistor** then switches the **LED** ___.

When a **l _ _ voltage** (**less than** ___ **V**) is applied across the **transistor base**, the **transistor** is switched ___. The **transistor** then switches the **LED** ___.

This **transistor switching circuit** is used to switch **on** a warning **LED** when the **temperature** in a greenhouse gets **too low**. Explain how it works:

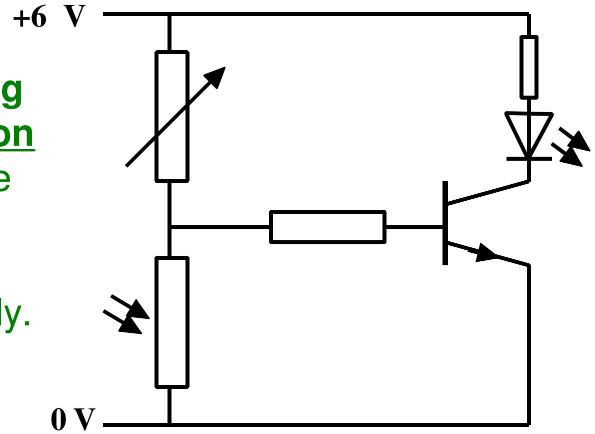


Complete this circuit, showing the **variable resistor** and **thermistor** swapped about. Explain what happens this time when the **temperature falls**.

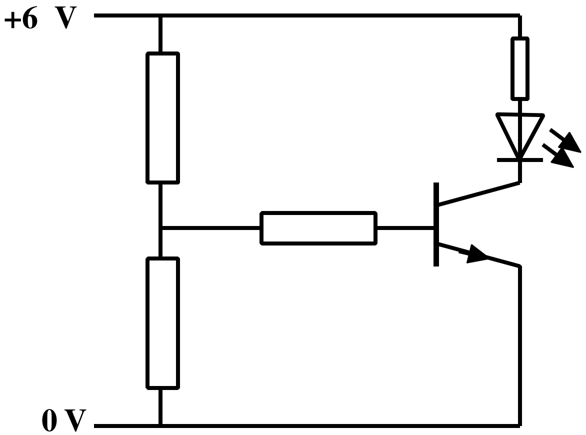


What is the purpose of the **variable resistor**?

This **transistor switching circuit** is used to switch **on** a warning **LED** when the **light level** in a school library gets **too low** for people to read comfortably. Explain how it works:

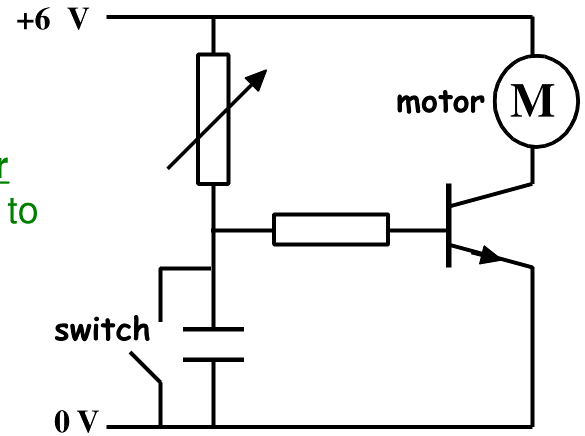


Complete this circuit, showing with the **variable resistor** and **LDR** swapped about. Explain what happens this time when the **light level falls**.



What is the purpose of the **variable resistor**?

This **transistor switching circuit** contains a **capacitor** and **switch**. It is used to **delay** the **motor switching on**.



WHEN SWITCH S IS OPEN, THE MOTOR IS ON.

Explain what happens when the **switch** is **closed:**

Explain what happens when the **switch** is **opened** again:

What is the purpose of the **variable resistor**?

Another Type of Transistor - the n-Channel Enhancement Mode MOSFET

There is another type of transistor you may come across in the National 5 Physics exam
- the n-channel enhancement mode MOSFET.

Using the internet and textbooks, carry out some research on this type of transistor.

Write your finding in the space below. You should include the circuit symbol for an n-channel enhancement mode MOSFET and state the voltage (potential difference) value at which it is switched on/off.

5) CIRCUIT COMPONENTS - SUMMARY

On this and the next page, draw the circuit symbol for each named circuit component and state at least one function/application of each.

	circuit symbol	function/application
cell		
battery		
lamp		
switch		
resistor		

	circuit symbol	function/application
voltmeter		
ammeter		
light emitting diode (LED)		
motor		
microphone		

loudspeaker	circuit symbol	function/application
photovoltaic cell	circuit symbol	function/application
fuse	circuit symbol	function/application
diode	circuit symbol	function/application
capaqcitor	circuit symbol	function/application
thermistor	circuit symbol	function/application
LDR	circuit symbol	function/application
relay	circuit symbol	function/application
npn transistor	circuit symbol	function/application
n-channel enhancement mode MOSFET	circuit symbol	function/application