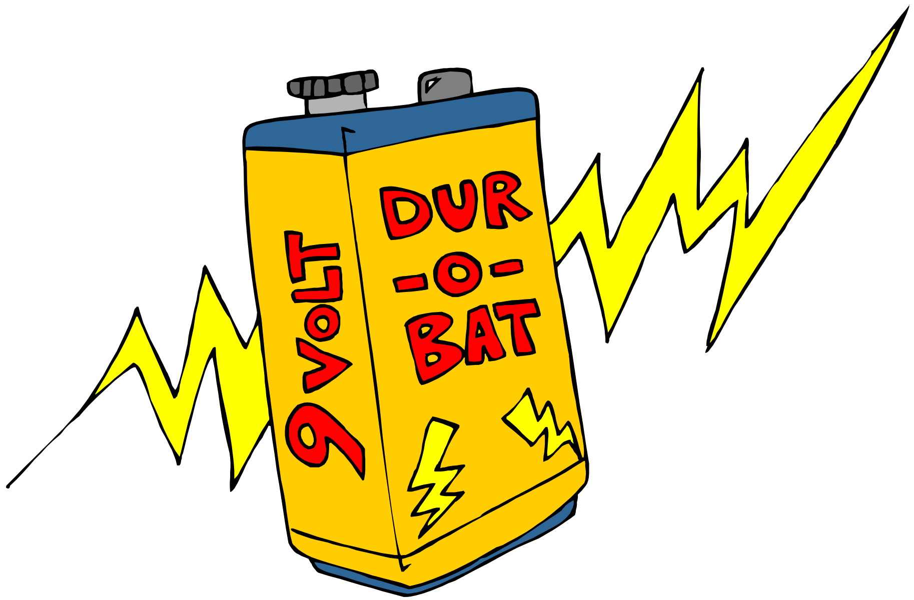
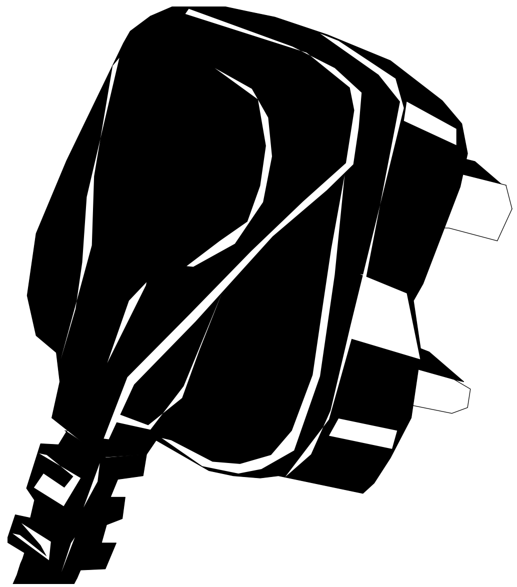
Standard Grade Physics

Measuring Electricity





Name: ______________________________ **Class:** ______ **Teacher:** ______________________

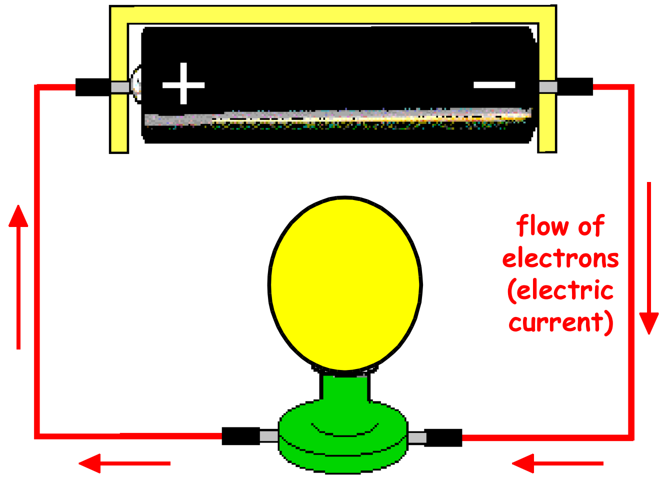
Measuring Electricity   Learning Outcomes   **Blue = general**   **red = credit**

Section 1 - Alternating and Direct Current						
1.	State that the mains supply is *a.c.*					
2.	State that a battery supply is *d.c.*					
3.	Explain what *a.c.* and *d.c.* mean in terms of current.					
4.	State that the frequency of the mains supply is 50 Hz.					
5.	State that the mains voltage is 230 V.					
6.	Draw and identify the circuit symbol for the following components: *cell; battery; fuse; lamp; switch; resistor; variable resistor; capacitor; diode.*					
7.	State that electrons are free to move in a conductor.					
8.	Describe electric current in terms of moving charges.					
9.	State that the unit of current is the ampere (*A*) and that the unit of voltage is the Volt (*V*).					
10.	State that the quoted value of an alternating voltage is less than its peak value.					
11.	Carry out calculations involving the relationship between charge (Q), current (I) and time (t).					
12.	State that the unit of charge is the Coulomb (*C*).					
13.	State that the voltage of a supply is a measure of the energy given to the charges in a circuit.					

Section 2 - Resistance					
1.	Draw and identify the circuit symbols for an ammeter and a voltmeter.				
2.	Draw circuit diagrams to show the correct positions of an ammeter and a voltmeter in a circuit.				
3.	State that in a circuit, an increase in resistance leads to a decrease in current.				
4.	Carry out calculations involving the relationship between resistance (R), current (I) and voltage (V).				
5.	State that the unit of resistance is the ohm (Ω).				
6.	Give two practical uses of variable resistors.				
7.	State that when there is an electric current in a wire, there is an energy transformation.				
8.	Give three examples of household circuits that use resistors to transform electrical energy to heat energy.				
9.	State that the electrical energy transformed each second = VI.				
10.	Carry out calculations involving the relationship between power (P), current (I) and voltage (V).				
11.	State the relationship between energy and power.				
12.	Use the terms *energy*, *power*, *joule* and *watt* correctly and in context.				
13.	State that electrical energy is transformed to heat and light in a lamp.				
14.	State that the energy transformation in an electric lamp takes place in: the *wire* for a filament lamp; the *gas* for a discharge tube.				
15.	State that a discharge tube is more efficient than a filament lamp.				
16.	State that the energy transformation in an electric heater takes place in the element.				
17.	State that for a resistor, the ratio $^V/_I$ remains approximately constant for different currents.				
18.	Explain why power can be calculated using $P = I^2R$				
19.	Carry out calculations using this relationship between power (P), current (I) and resistance (R).				

Section 3 - Useful Circuits					
1.	State a practical example in the home that needs two (or more) switches used in series.				
2.	State that in a series circuit, the current is the same at all points.				
3.	State that in a parallel circuit, the sum of the currents in the parallel branches is equal to the current drawn from the supply.				
4.	State that in a series circuit, the sum of the voltages across the components is equal to the voltage of the supply.				
5.	State that in a parallel circuit, the voltage across each branch is the same.				
6.	Explain that connecting too many appliances to one socket can be dangerous because a large current may be drawn.				
7.	Describe how to make a simple continuity tester.				
8.	Describe how this continuity tester may be used for fault finding.				
9.	Draw circuit diagrams to show how various car lighting circuits work.				
10.	Carry out calculations involving resistances in series: $R_t = R_1 + R_2 + \ldots$				
11.	Carry out calculations involving resistances in parallel: $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$				

1. CURRENT and VOLTAGE



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

Conductors & Insulators

The flow of electrons around an electric circuit is called an electric current.

Electric current is measured in units called amperes

Unit symbol: A.

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

Voltage is measured in units called volts. Unit symbol: V.

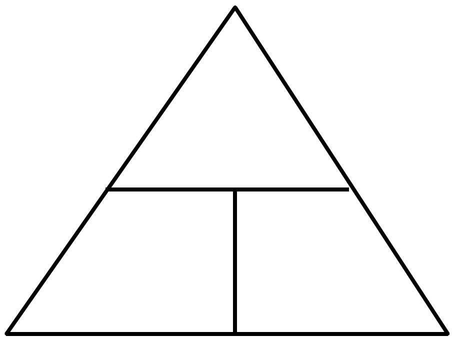
2. CURRENT, CHARGE and TIME

Total QUANTITY of CHARGE (Q) = CURRENT (I) × TIME (t)

Unit: coulombs/ C

Unit: amperes/ A

Unit: seconds/ s



1) What charge will have passed through a metal wire when:

- a current of 10 A flows for 20 seconds?
- a current of 15 A flows for 3 seconds?
- a current of 20 A flows for 1 minute?

2) Calculate the current flowing in an electric circuit when:

- 20 C of charge is passed for 10 seconds.
- 0.5 C of charge is passed for 5 seconds.
- 100 C of charge is passed for 1 minute.

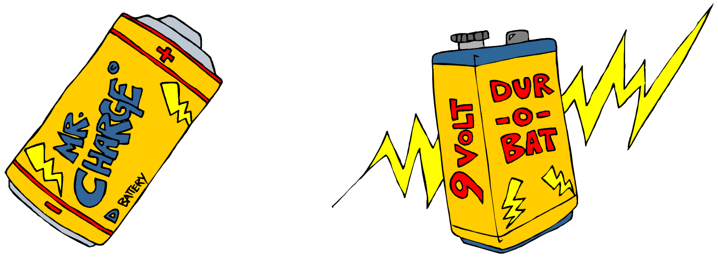
3) A lamp uses a current of 2 A. What time must the lamp be switched on for to allow:

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

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

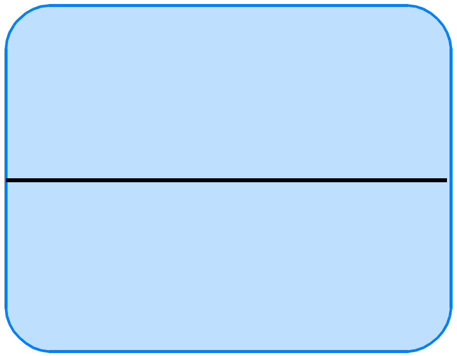
Electricity can be supplied in one of two forms - either **d _ _ _ _ _** **current** (**d.c.**) or **a _ _ _ _ _ _ _ _ _ _** **current** (**a.c.**)

direct current (d.c.)

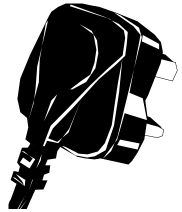


Direct current (d.c.) is supplied by b _ _ _ _ _ _ _ _ _.

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

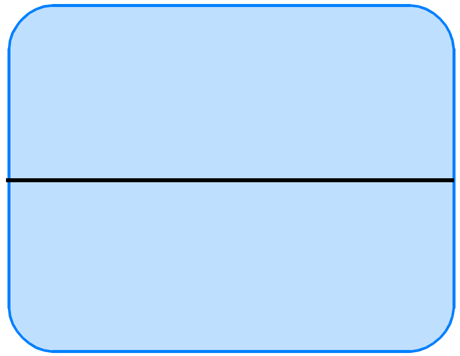


alternating current (a.c.)



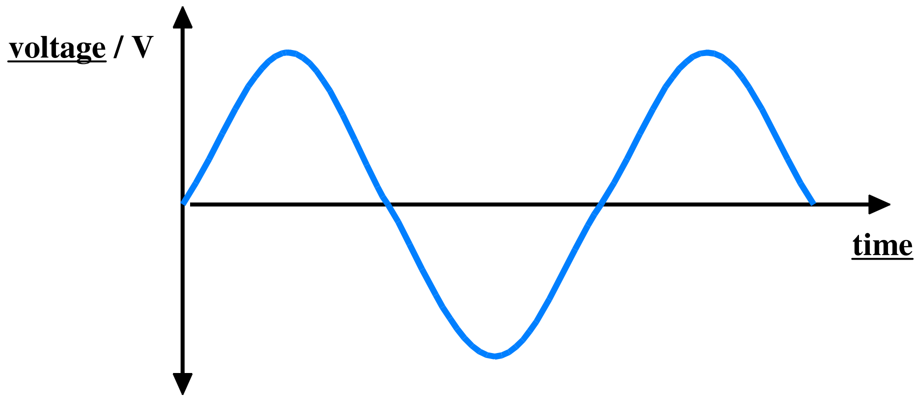
Alternating current (a.c.) is supplied from the m _ _ _ _ s _ _ _ _ _.

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



4. VOLTAGE OF THE MAINS SUPPLY

The trace you observed on the oscilloscope screen for the **mains supply** is in fact a graph of **mains voltage against time** - It shows how the **mains voltage** changes with **time**.



5. SYMBOLS FOR CIRCUIT COMPONENTS

In the following sections, a number of different **circuit components** will be used.

- In the table below, draw the **circuit symbol** for each component:

• connecting wire	• cell/battery	• a.c. supply
• lamp (bulb)	• switch	• resistor
• variable resistor	• fuse	• capacitor
• LED	• ammeter	• voltmeter

1. RESISTANCE

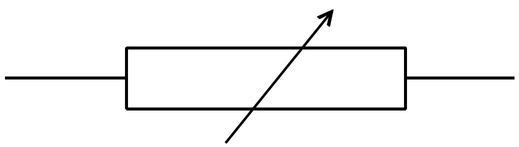
In an electric circuit, electrons flow through metal wires and circuit components.

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

- **FIXED RESISTORS**

Each fixed resistor has only one value of resistance.

- **VARIABLE RESISTORS**



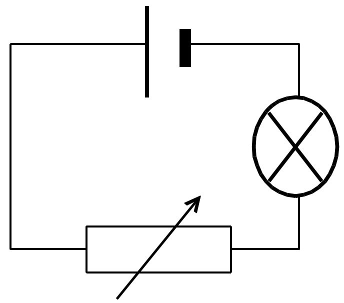
You can change the resistance of a variable resistor. (To change the resistance of a simple variable resistor, you turn a dial or move a slider on the resistor).

Resistance is measured in o _ _ _ (__)

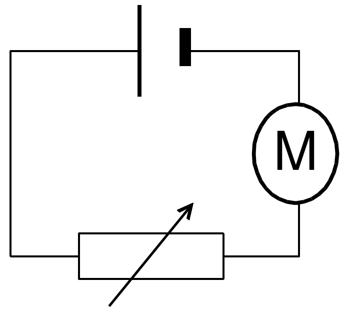
1) Label every **circuit component** below.

2) What is the purpose of the **variable resistor** in each circuit?

____
____
____



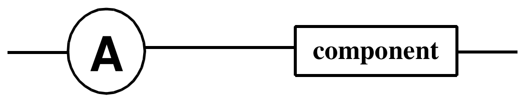
____
____
____

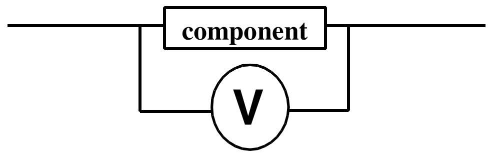


Ammeters and Voltmeters

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

Connecting ammeters and voltmeters

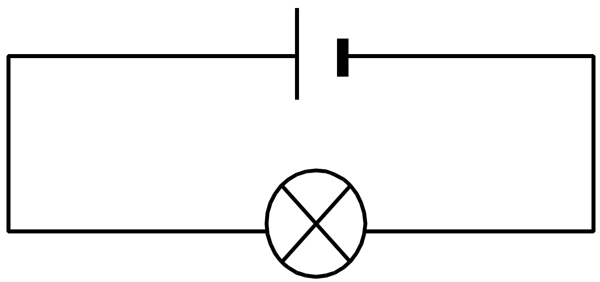




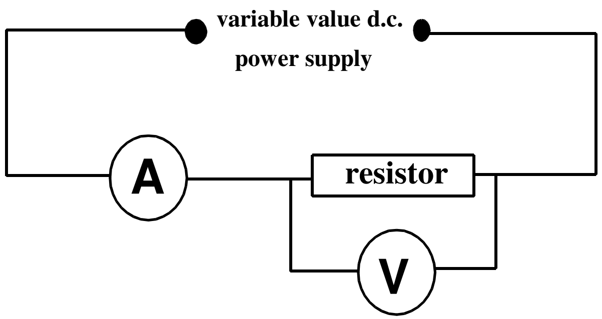
3) Which **circuit component** would you use to measure the **current** flowing through a lamp? ____________________

4) Which **circuit component** would you use to measure the **voltage across** a lamp? ____________________

5) Show this by drawing these **circuit components** in the correct place on this circuit diagram:



Current Through a Component - Resistance and Ohm's Law



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

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

Typical pairs of values are shown in this table:

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
$\frac{\text{voltage}}{\text{current}}$						

No matter which pair of voltage and current values you take, when you divide 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.

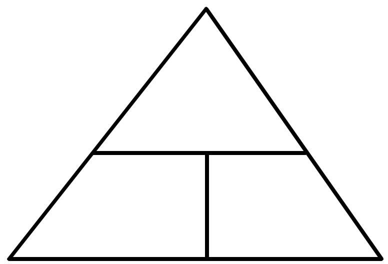
This relationship, discovered in 1827 by a teacher in Germany called Georg Simon Ohm, is known as "Ohm's law".

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

Unit: volts/ V

Unit: amperes/ A

Unit: ohms/ Ω



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

Calculate the **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** passing 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:

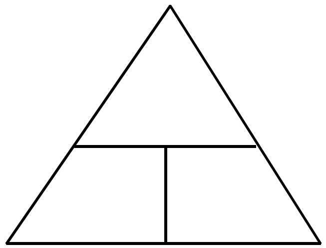
- a light bulb marked "6 V, 0.05 A";
- a resistor with 30 V across it and a current of 5 A passing through it;
- the heating coil of an electric fire which has 230 V across it and carries a current of 2.3 A.

2. ELECTRICAL ENERGY and POWER

In Section 1 of this topic, you learned that.....

The power rating of an electrical appliance tells us how much electrical energy it changes (transforms) into other forms of energy every second.

ELECTRICAL POWER is the amount of ELECTRICAL ENERGY transformed every second.



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

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

7) How much electrical energy does a 2 000 W electric kettle change into heat energy in 15 s?

8) How much electrical energy does a 100 W electric light bulb transform in 1 minute?

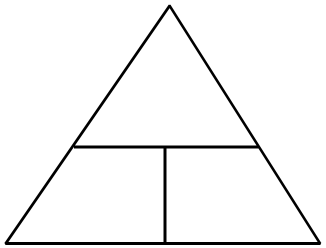
9) Calculate the power of an electric motor which transforms 5 000 J of electrical energy into kinetic energy every 2 s.

10) What is the power rating of an electric shaver which transforms 2 000 J of electrical energy in 50 s?

11) How many seconds does it take an 800 W electric blanket to transform 3 200 J of electrical energy?

12) How long does a 60 W television set take to transform 720 J of electrical energy?

The **electrical power** of an appliance can be calculated if we know the **voltage across the appliance** and the **current passing through the appliance**.



Power (P) = Voltage (V) x Current (I)

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

13) Calculate the **power rating** of:

- a 230 V soldering iron which uses a current of 0.1 A;
- a 12 V electric heater using a current of 2.5 A;
- a 230 V electric kettle which requires a current of 5 A.

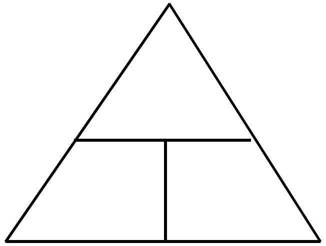
14) Calculate the **voltage** across:

- a 36 W light bulb using a current of 3 A;
- a 750 W electric drill carrying a current of 1.5 A;
- a 1 000 W electric oven using 5 A of current.

15) Determine the current pasing through:

- a 230 V, 100 W food mixer;
- a 230 V, 4 600 W electric cooker;
- a 12 V, 2 W electric motor for a toy car.

The **electrical power** of an appliance can also be calculated if we know the **current passing 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)

You are going to show that you obtain the same value for **electrical power** whether you use the equation **P = VI** or **P = I^2R**.

Complete columns 2 - 5 of the table below using the equations **V = IR** and **P = VI**.

1	2	3	4	5	6
electric appliance	current (A)	voltage (V)	resistance (Ω)	power (W)	I^2R
torch bulb	0.3	6		1.8	
car headlamp	2	12			
fish tank heater	5	12			
electric drill		230		920	

Now calculate **I^2R** for each appliance and put your results in column 6 of the table.

16) How do the results in column 5 of the table (obtained using P = VI) compare with those in column 6 (obtained using P = I^2R)? ________________________________

____

17) What can you say about the equations P = VI and P = I^2R?

____

____

You should now attempt the following **"$P = I^2R$"** problems:

18) 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.

19) Calculate the **current** passing through:

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

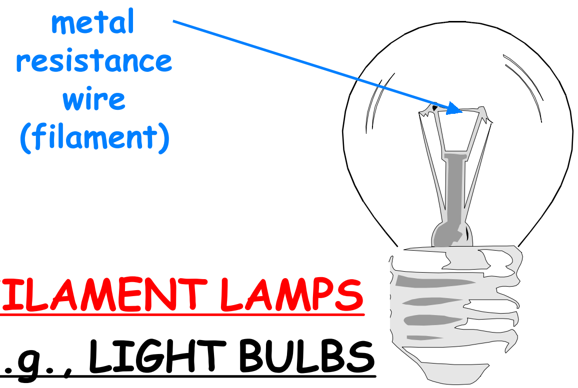
20) Calculate the **resistance** of:

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

3. HOUSEHOLD ELECTRIC LIGHTING

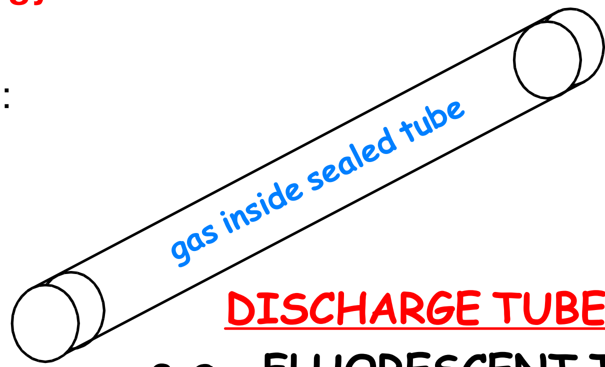
Lighting is one of the major uses for **electrical energy** in our homes.

There are **2 main types** of light:



FILAMENT LAMPS

e.g., LIGHT BULBS



DISCHARGE TUBES

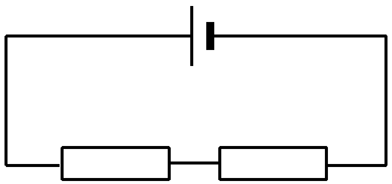
e.g., FLUORESCENT TUBES

	filament lamp	discharge tube
For example		
Energy transformation		
Where energy transformation takes place		
efficiency		

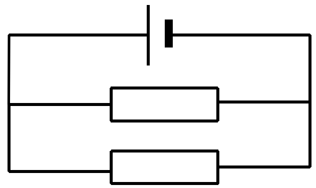
SERIES and PARALLEL ELECTRIC CIRCUITS

Circuit components can be connected to a **battery/power supply** in 2 different ways:

(1) in a **series circuit**



(2) in a **parallel circuit**



Current and Voltage Rules for Components in Series and Parallel Circuits

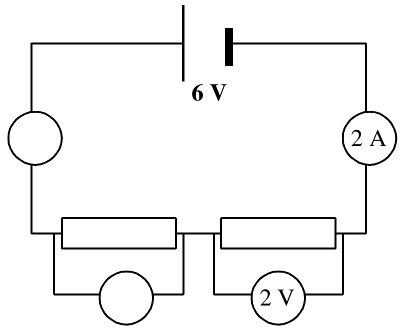
Current in a Series Circuit

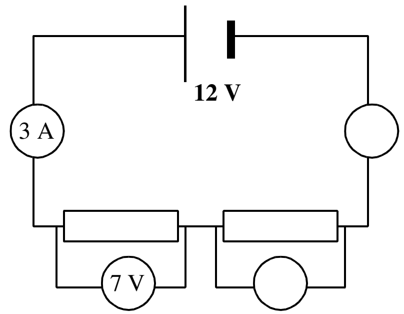
Voltages in a Series Circuit

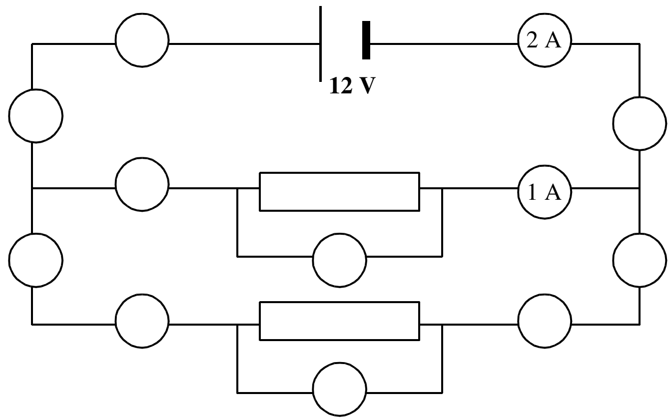
Currents in a Parallel Circuit

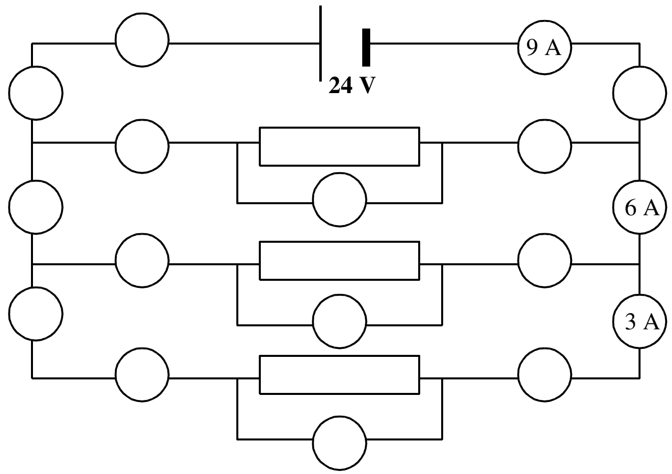
Voltage in a Parallel Circuit

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

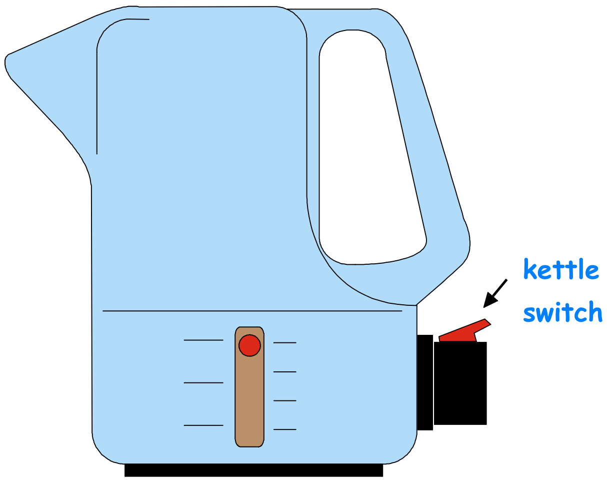








HOUSEHOLD ELECTRICAL APPLIANCES - 2 or More Switches Used in Series



When you use an electric kettle, you:

1) Plug the kettle into a mains socket and turn the socket **switch on**.
2) Press the **on switch** on the kettle.

You use **2 s** _ _ _ _ _ _ _ _ connected in **s** _ _ _ _ _. You can switch the kettle on or off using either switch.

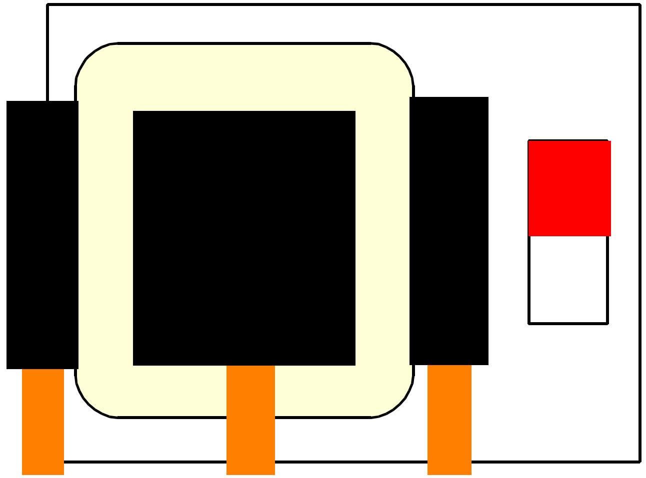
2) List some other household appliances which, when connected to a mains socket, make use of 2 (or more) switches connected in series:______________________

____

____

____

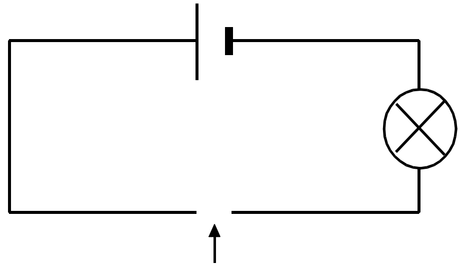
TOO MANY HOUSEHOLD ELECTRICAL APPLIANCES CONNECTED TO THE SAME SOCKET/ADAPTOR - A Fire Hazard!



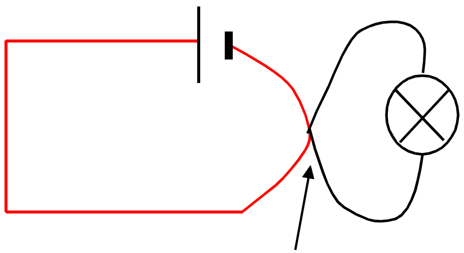
CIRCUIT FAULTS
- Open and Short Circuits

Electric circuits can develop 2 kinds of common **fault**:

(1) an Open Circuit

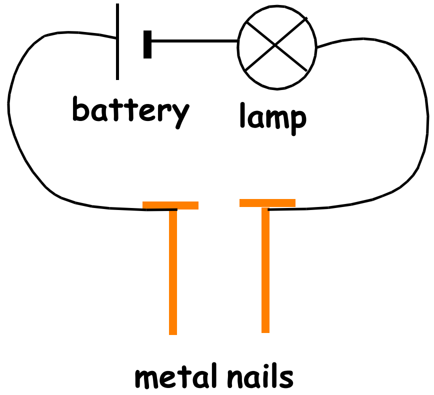


(2) a Short Circuit



TESTING FOR CIRCUIT FAULTS
- the Continuity Tester

The diagram shows how to make a simple **continuity tester**:



Score out the **incorrect option** in each case:

- If you place the metal nails across an **open circuit**, the lamp **will** / **will not** **light**.

- If you place the metal nails across a **short circuit**, the lamp **will** / **will not** **light**.

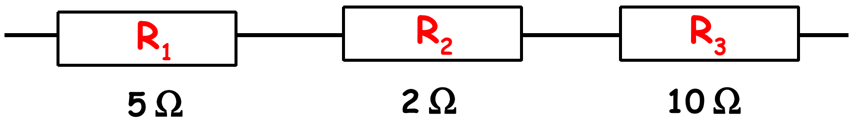
NEVER USE A CONTINUITY TESTER ON ELECTRIC CIRCUITS CONNECTED TO THE MAINS SUPPLY - YOU COULD RECEIVE AN ELECTRIC SHOCK WHICH COULD KILL YOU !

RESISTORS IN SERIES

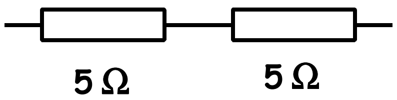
For resistors connected in **series**, the **total series resistance** (R_s) can be calculated using the formula:

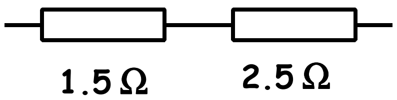
$$R_s = R_1 + R_2 (+ R_3 + \ldots)$$

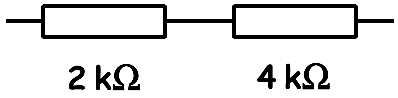
For example, for the resistors connected below:

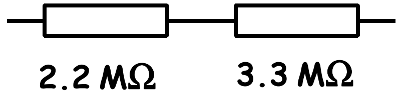


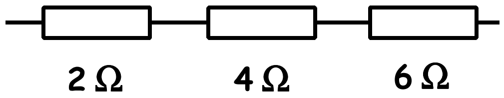
4) Calculate the **total series resistance** of each resistor combination:

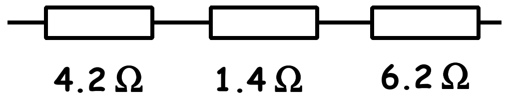


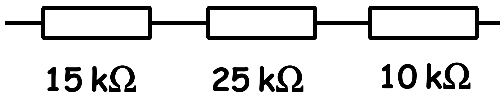


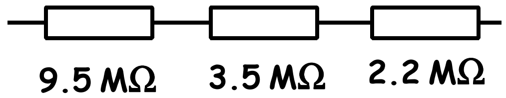


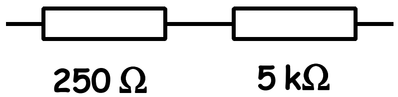


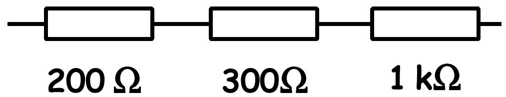










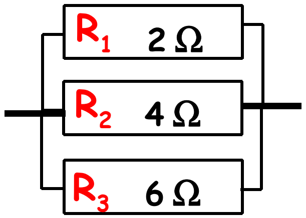


RESISTORS IN PARALLEL

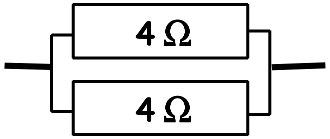
For resistors connected in **parallel**, the **total parallel resistance** (R_p) can be calculated using the formula:

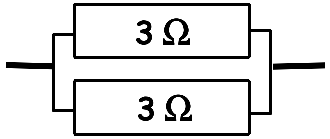
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \left(+ \frac{1}{R_3} + \ldots \right)$$

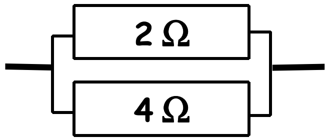
For example, for the resistors connected below:

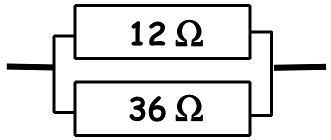


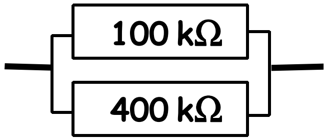
5) Calculate the **total parallel resistance** of each resistor combination:

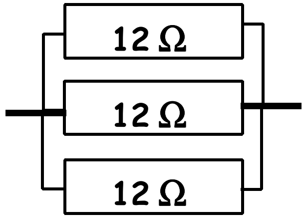


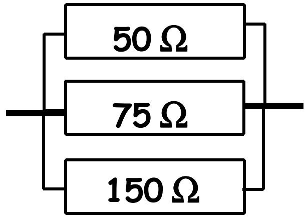


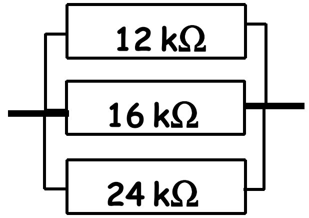




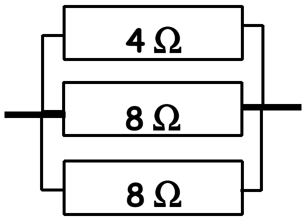

100 kΩ
400 kΩ

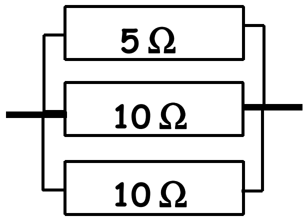

12 Ω
12 Ω
12 Ω

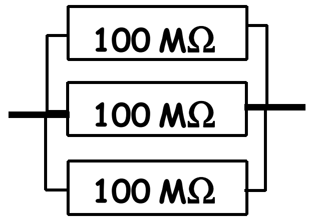

50 Ω
75 Ω
150 Ω


12 kΩ
16 kΩ
24 kΩ

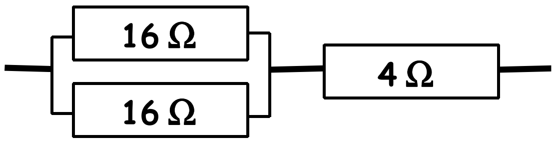

200 MΩ
800 MΩ

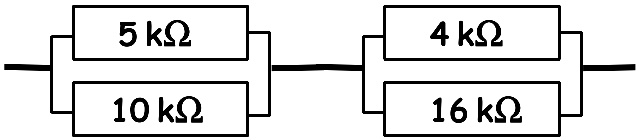

4 Ω
8 Ω
8 Ω

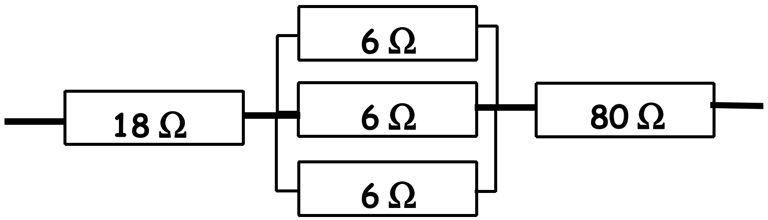

5 Ω
10 Ω
10 Ω

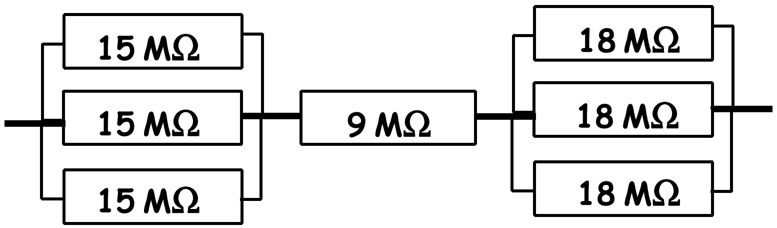

100 MΩ
100 MΩ
100 MΩ

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





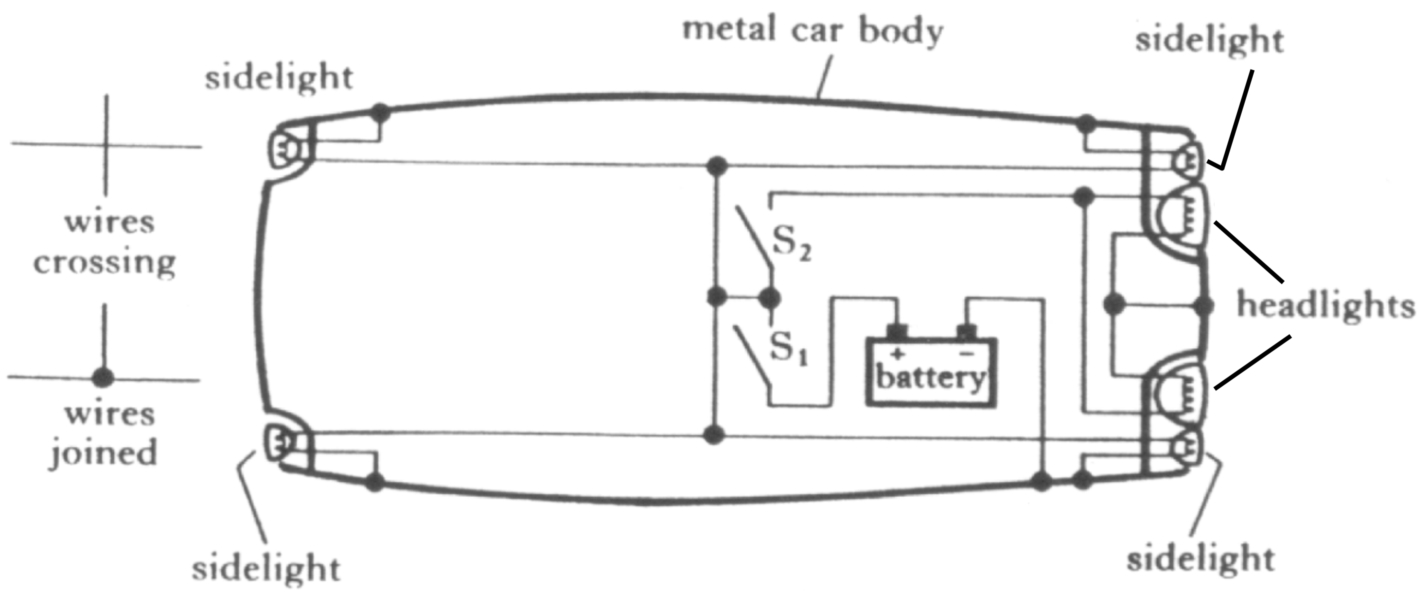




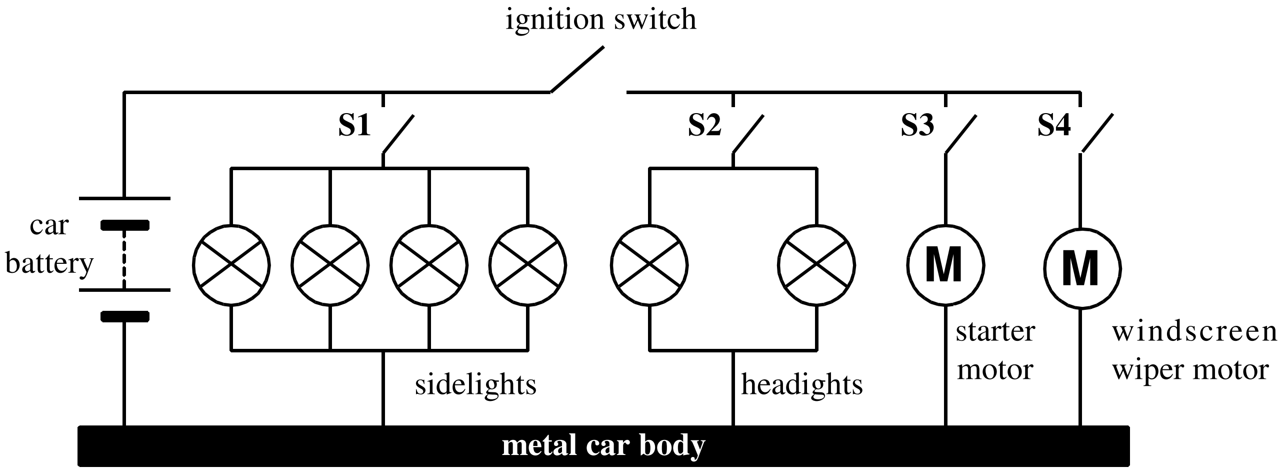
CAR WIRING

In the **CREDIT PHYSICS EXAM**, you may be asked to draw or explain circuit diagrams which describe how the various car lighting requirements are achieved.

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



7) 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": ______________________

____

____

(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: __________________________________

____

____

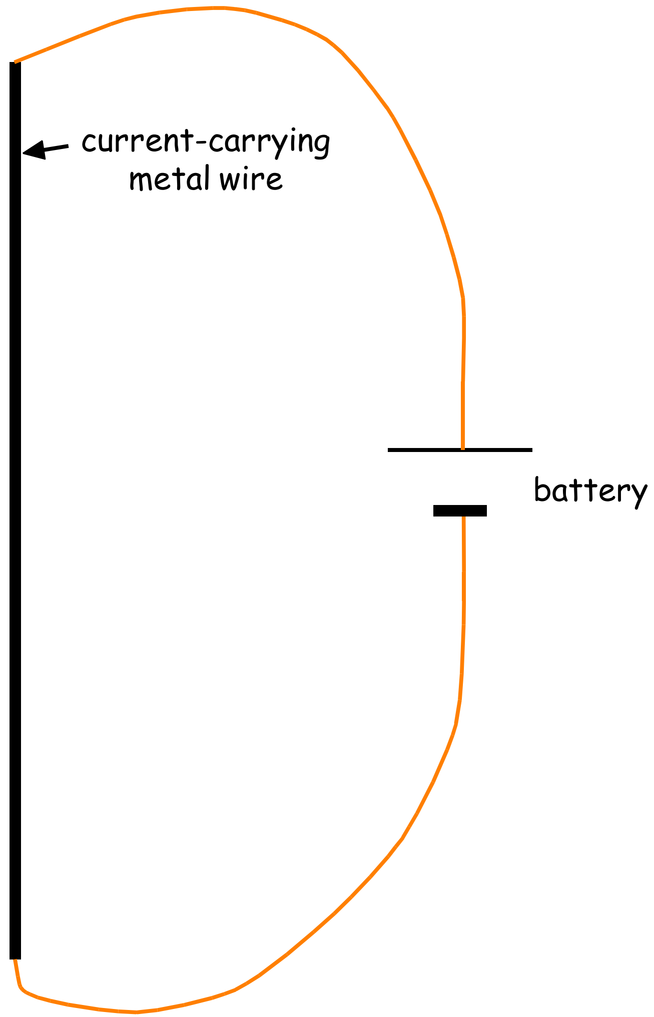
8) In a typical **4 door car**, a **lamp** lights inside the passenger compartment when __**either**__ of the 4 doors is __**opened**__.

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

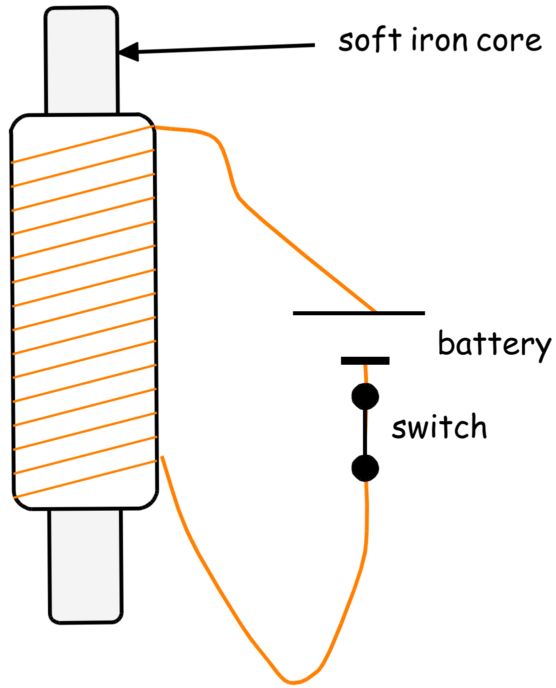
MAGNETIC FIELDS AROUND CURRENT-CARRYING METAL WIRES

When we pass an **electric current** through a **metal wire**, a **m** _ _ _ _ _ _ _ _ **f** _ _ _ _ is created around the wire.

Draw the shape of the **magnetic field** surrounding this **current-carrying metal wire**:



Draw the shape of the **magnetic field** surrounding this **electromagnet**:



- How do we turn the **magnetic field** **ON**?

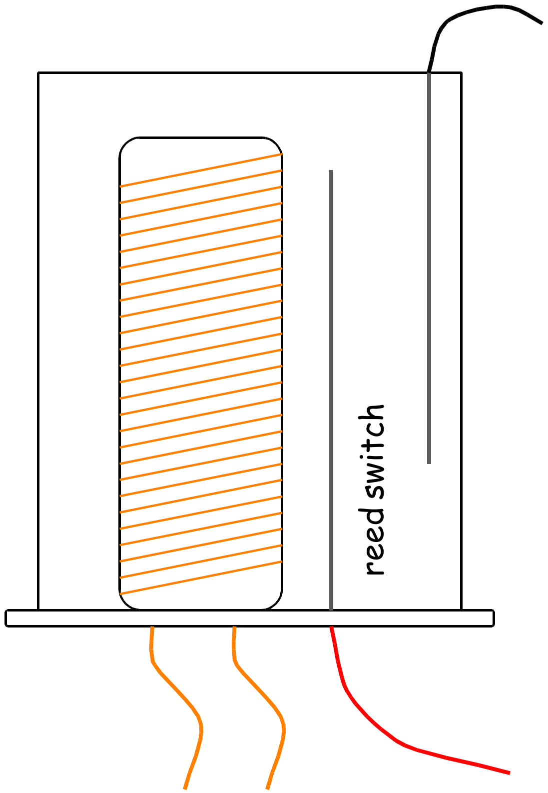
- How do we turn the **magnetic field** **OFF**?

PRACTICAL EXAMPLES OF THE MAGNETIC EFFECT OF A CURRENT

• Relay Switch

A **relay** is a device which uses a **low voltage** to switch on a **high voltage** circuit.

Complete the **relay** diagram below by adding **wires** and **circuit symbols**. You should show a **low voltage circuit** **below** switching on a **high voltage circuit** **to the right**:



• Electric Bell

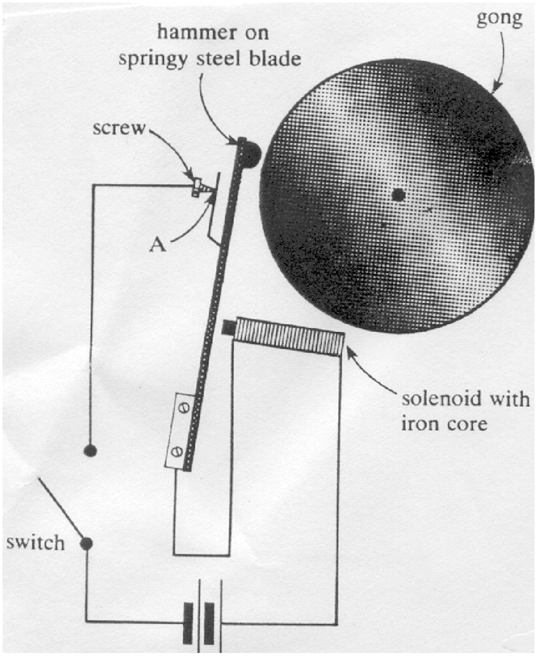


Diagram taken from page 67 of "O-GRADE PHYSICS", by Alistair Reid, publisher: Edward Arnold, ISBN 0 7131 0435 X.

CURRENT-CARRYING METAL WIRE IN A MAGNETIC FIELD

When a **current-carrying metal wire** is placed in a **magnetic field**,

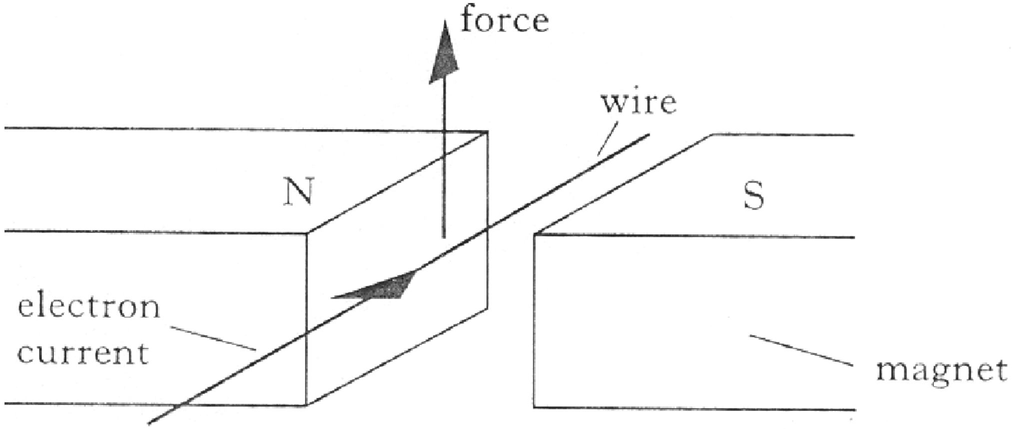


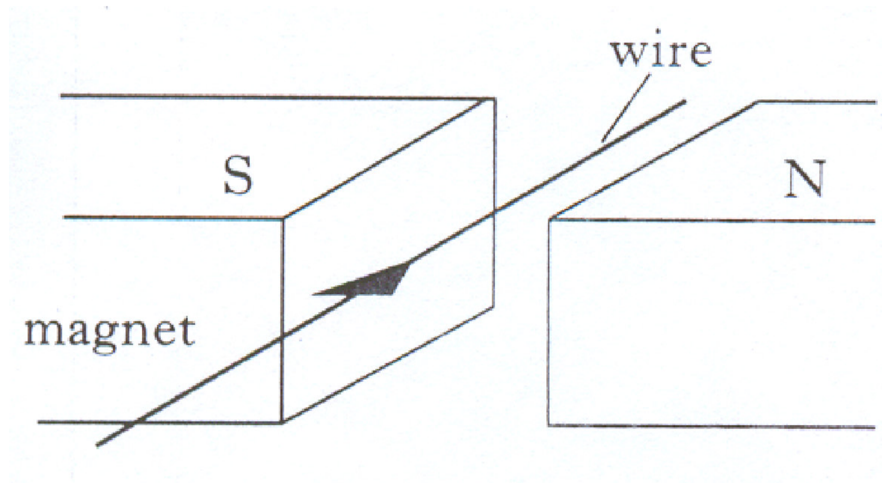
Diagram copyright SQA.

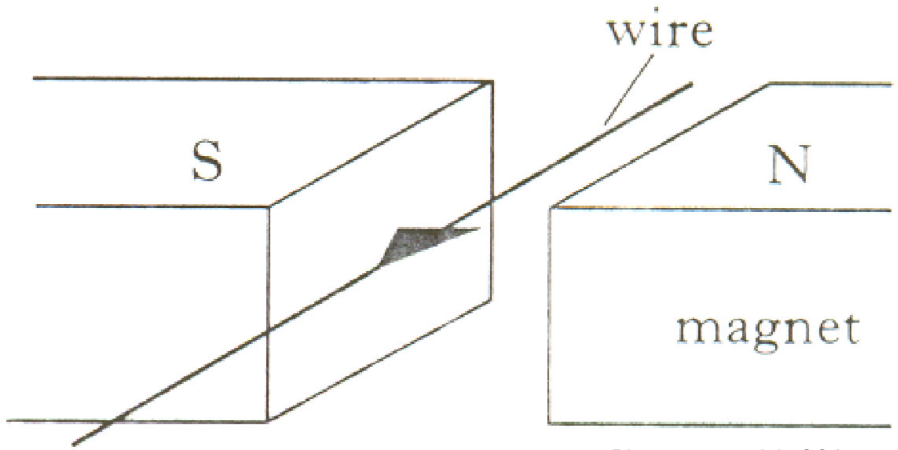
The **direction** of the **force** acting on the **current-carrying metal wire** depends upon:

1) The **direction** of the **e** _ _ _ _ _ _ _ _ **c** _ _ _ _ _ _ _.

2) The **direction** of the **m** _ _ _ _ _ _ _ _ **f** _ _ _ _.

On each diagram below, draw an **arrow** to show the ***direction*** of the **force** acting on the **current-carrying metal wire**:





Diagrams copyright SQA.

ELECTRIC MOTORS

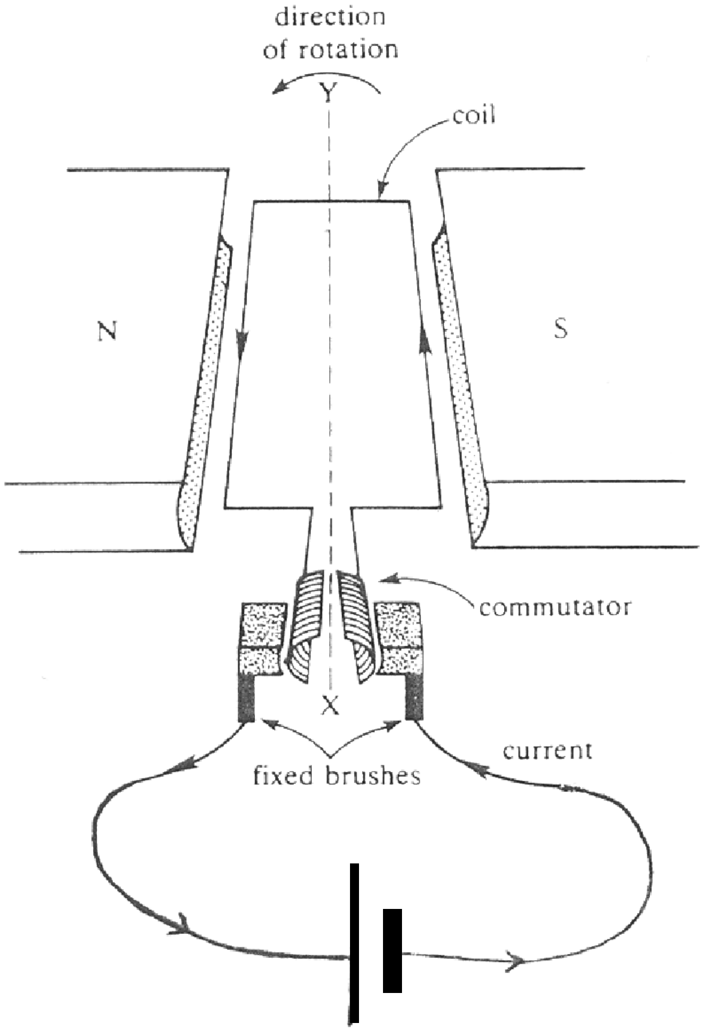
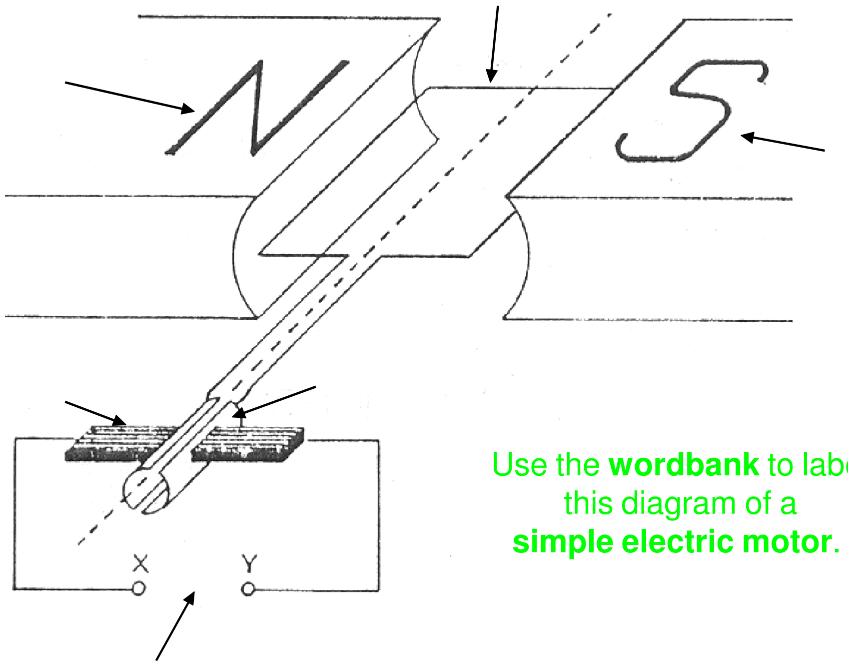


Diagram adapted. Original diagram taken from page 68 of "O-GRADE PHYSICS",
by Alistair Reid, publisher: Edward Arnold, ISBN 0 7131 0435 X.

- Explain the purpose of the **brushes**:

- Explain the purpose of the **commutator**:



Use the **wordbank** to label this diagram of a **simple electric motor**.

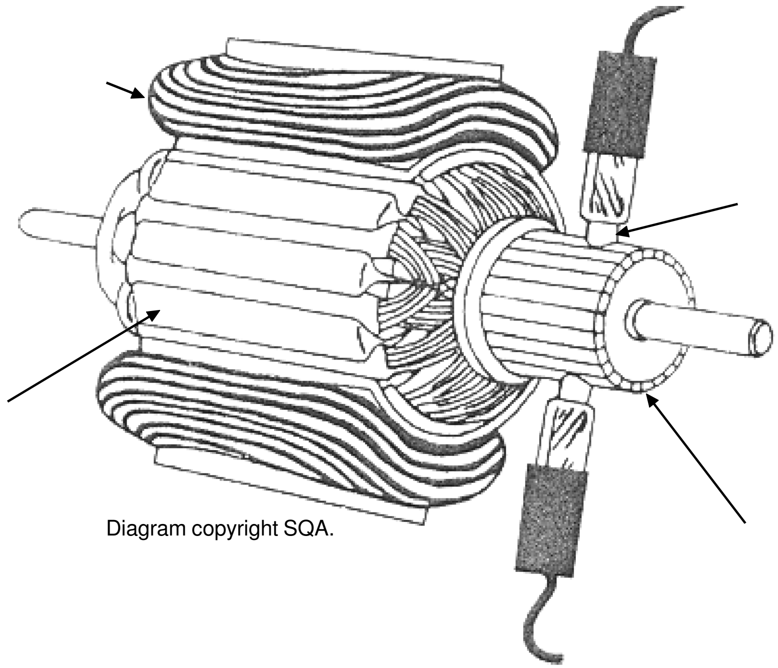
- brush
- commutator
- d.c. power supply (or battery)
- North magnetic pole
- South magnetic pole
- rotating metal coil

What **2** things could you change to make the motor turn in the **opposite direction**?

1)____

2)____

A **commercial electric motor**, like those used in **washing machines**, is shown below:



Use this **wordbank** to label the diagram of the **commercial electric motor**.

- carbon (graphite) brush
- field coil (electromagnet)
- multi-section commutator
- rotating coil

This is a diagram of a **commercial electric motor**.

Name the **3** parts indicated and state the reasons for their use in the **motor**.

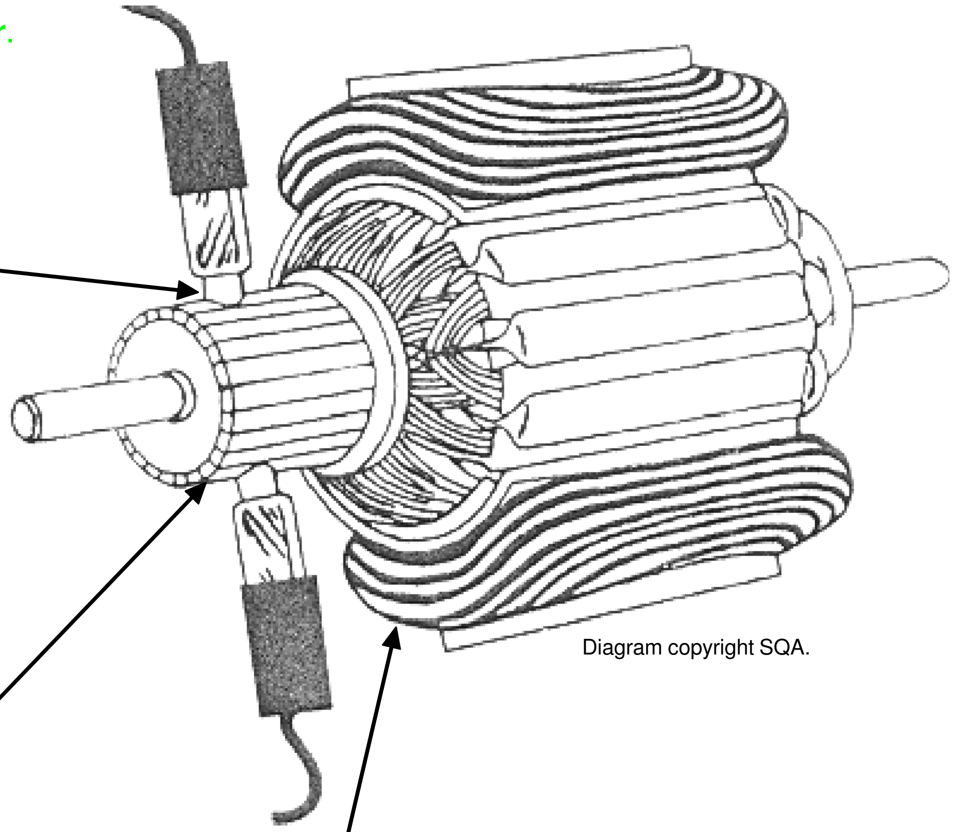


Diagram copyright SQA.

Name of part: ______________________________

Reason for use: ______________________________

____

____

____

____

____

____

____

____

____

Name of part: ______________________________

Reason for use: ______________________________

____

____

____

____

____

____

____

____

____

Name of part: ______________________________

Reason for use: ______________________________

____

____

____

____

____

____

____

____

____