Unit 4: Electricity (Part 1)

Learning Outcomes

Students should be able to:

1. Explain what is meant by current, potential difference and resistance, stating their units
2. Draw and interpret circuit diagrams and set up circuits containing electrical sources, switches, lamps resistors (fixed and variable), ammeters and voltmeters
3. Recognize that the resistance of a circuit can be varied by arranging resistors in series or in parallel
4. Explain qualitatively the chemical, heating and magnetic effects of an electric current and list some of its applications.

What is Electricity?

Definition:
Electricity is a form of energy for making an electrical appliance work.

Electrical energy can be changed to other forms of energy.

Sources of Electricity

Electrical energy comes from 2 main sources:

1) Mains electricity
- is generated by power stations and obtained through mains sockets
- supplies a lot of energy and can give electric shocks
- is used for electrical appliances

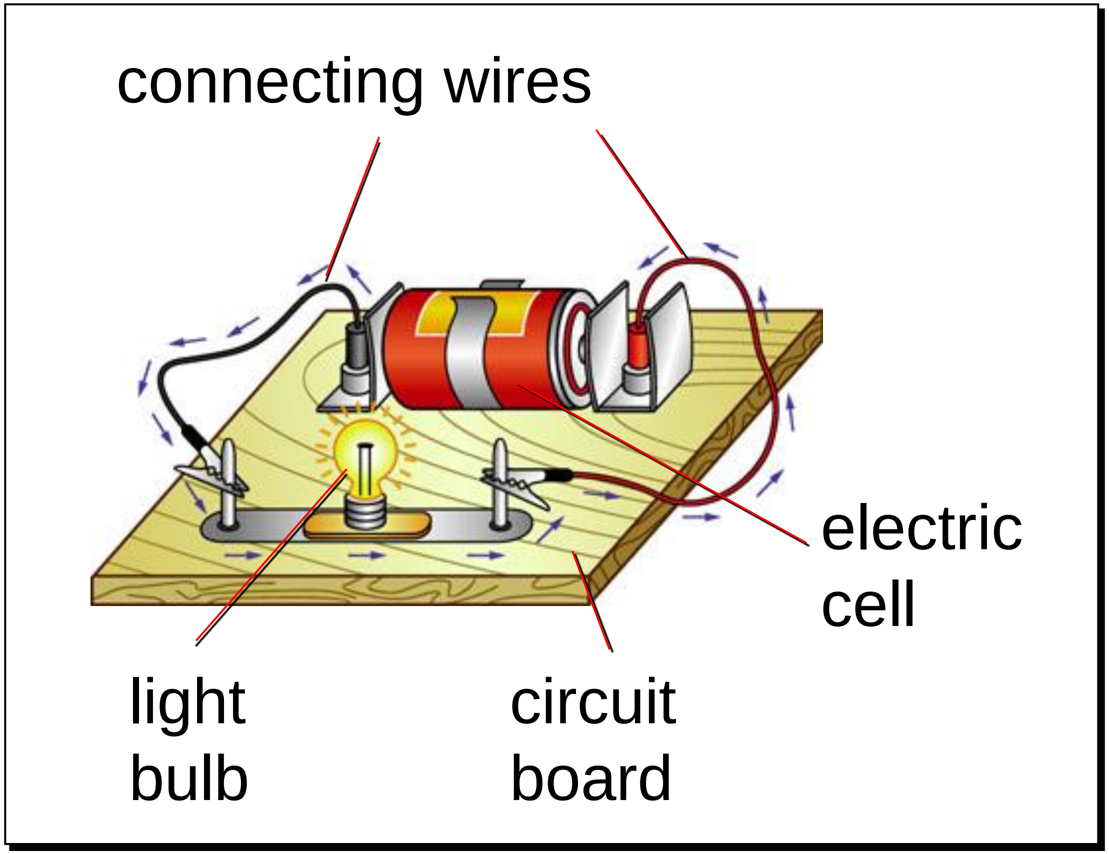
2) Electric cell
- comes in different voltages in portable forms
- supplies a little energy and is safe to use
- is used for portable electrical devices

Electric Circuits

- To make an electrical appliance work, electricity must flow through it. The path along which the electric current moves is called the electric circuit.

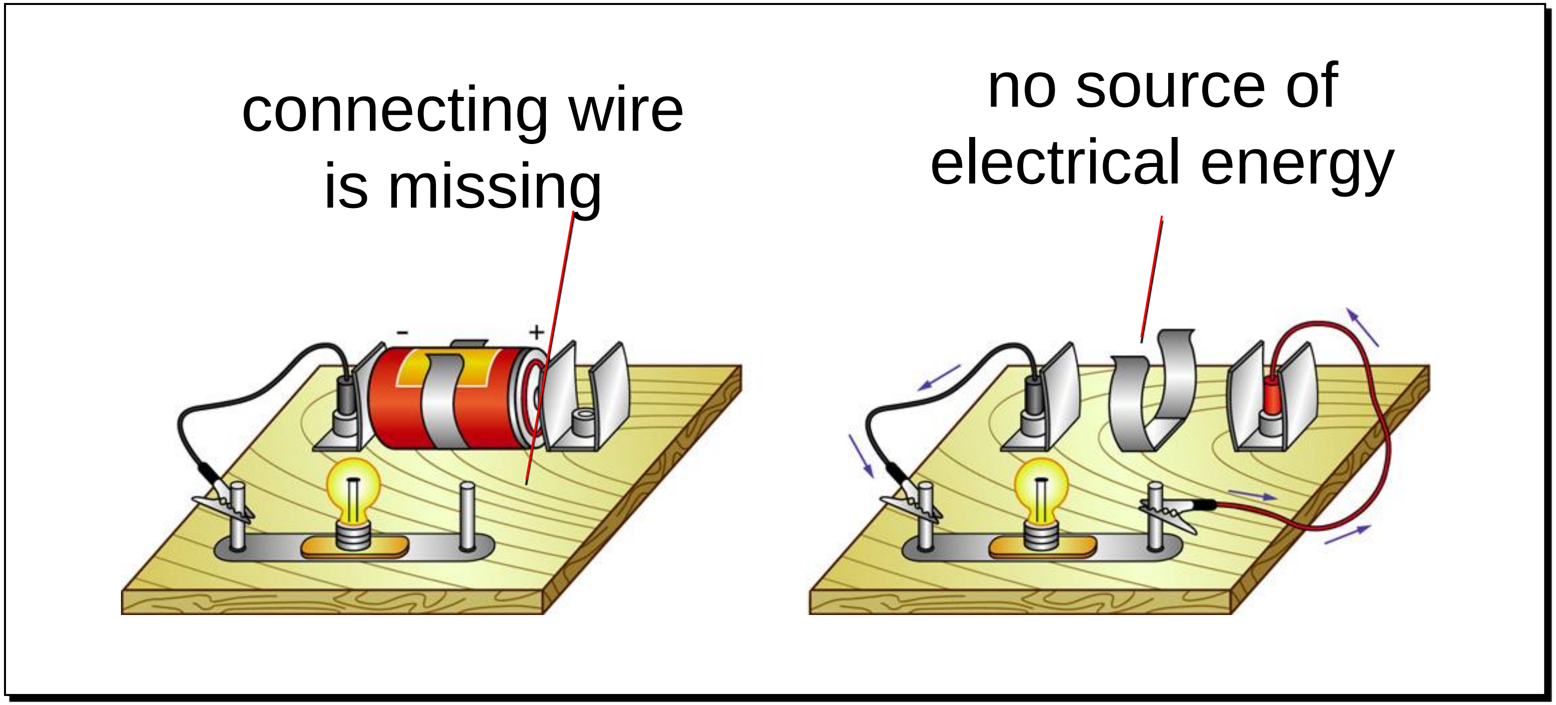
- Electric circuits are made up of electrical components.

- These components must be joined together without any gap in between to form a closed circuit.



Electric Circuits

- Incomplete circuits are called open circuits.

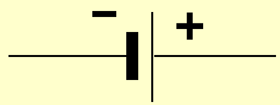
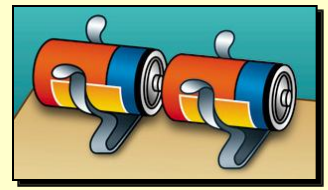
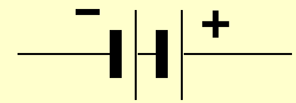
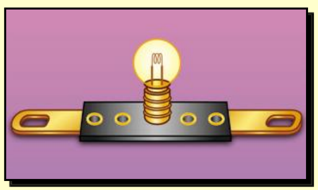
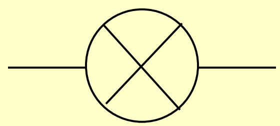
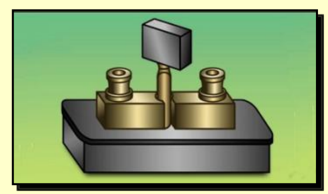
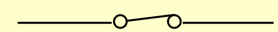
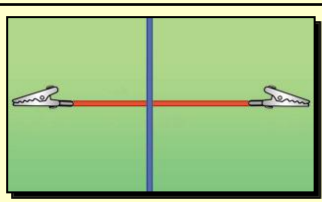
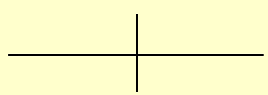
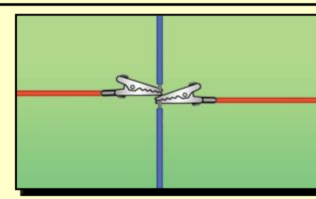
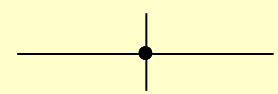


- An electric current flows only when there is
- a source of electrical energy and
- a closed circuit

http://www.article19.com/shockwave/oz.htm **Circuit simulation**

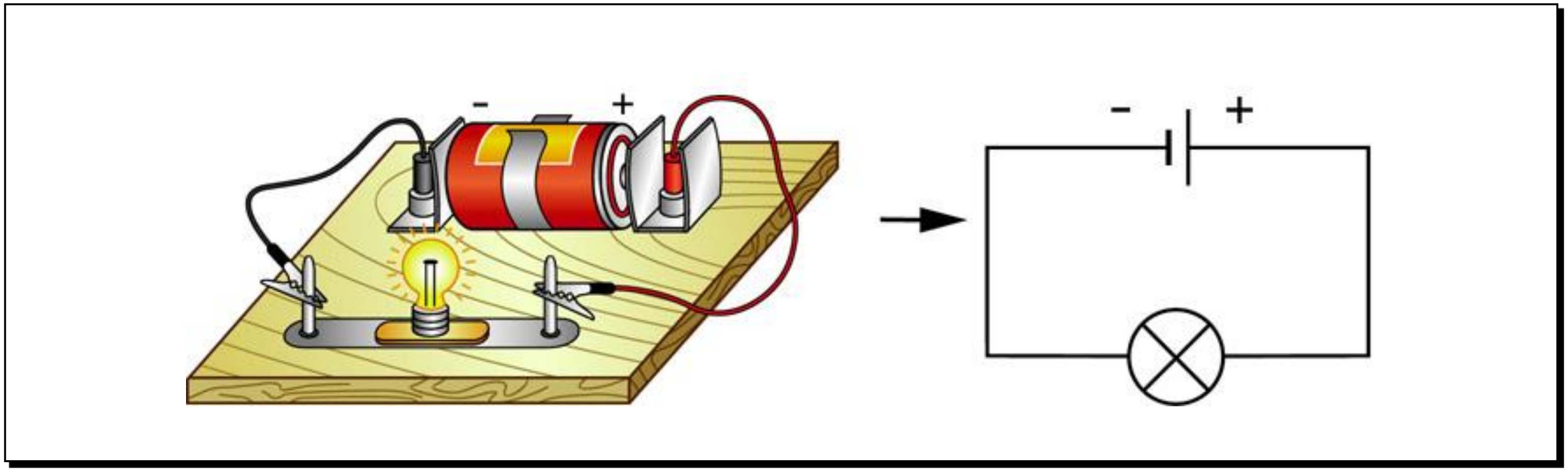
Circuit Diagrams

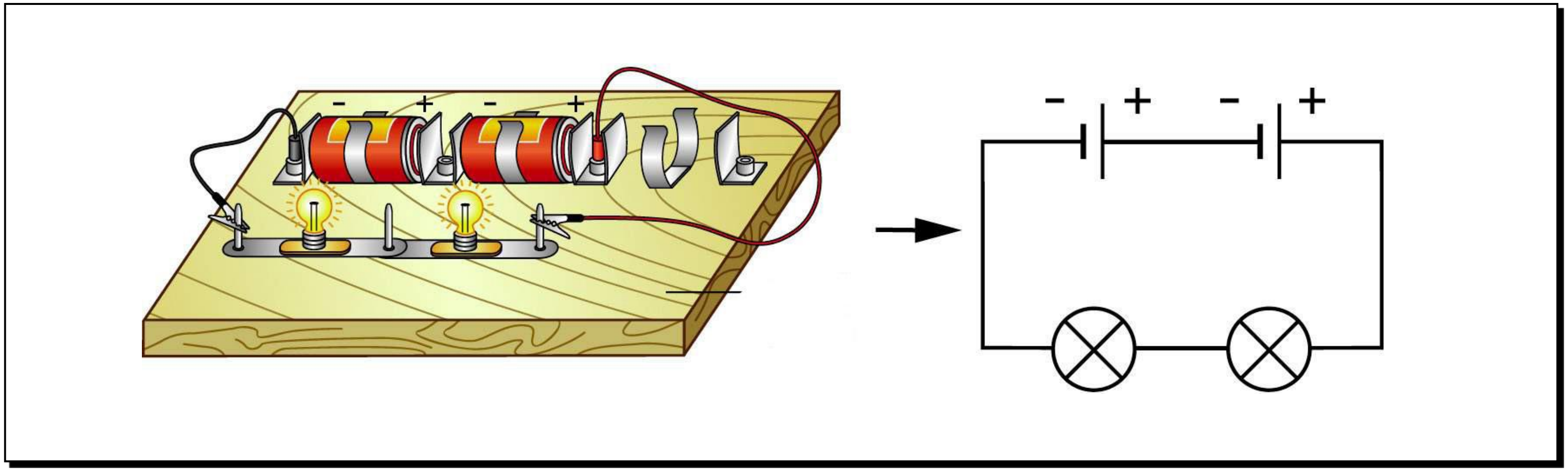
- Symbols are used to represent the various electrical components in circuits. Some of these are:

Component	Symbol	Component	Symbol
 An electric cell		 Battery	
 Light bulb (lamp)		 Switch	 Switch (open)  Switch (closed)
 Connecting wires (not joined)		 Connecting wires (joined)	

Circuit Diagrams

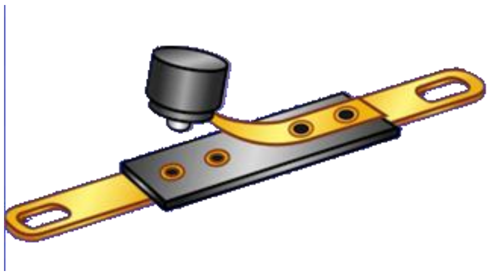
- Examples of circuit diagrams:

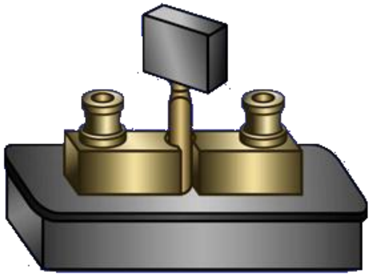




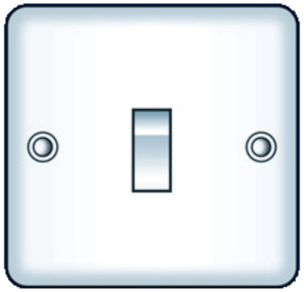
Switches

- A switch is used to open or close a circuit.



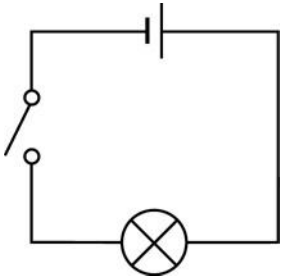


- switches used on circuit boards

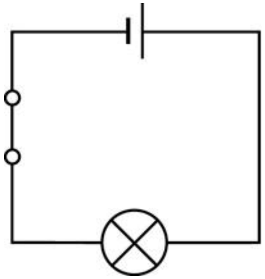


- main switch used in buildings

- Circuit diagrams for open and closed circuits:



- Open circuit. Bulb does not light up when the switch is open.

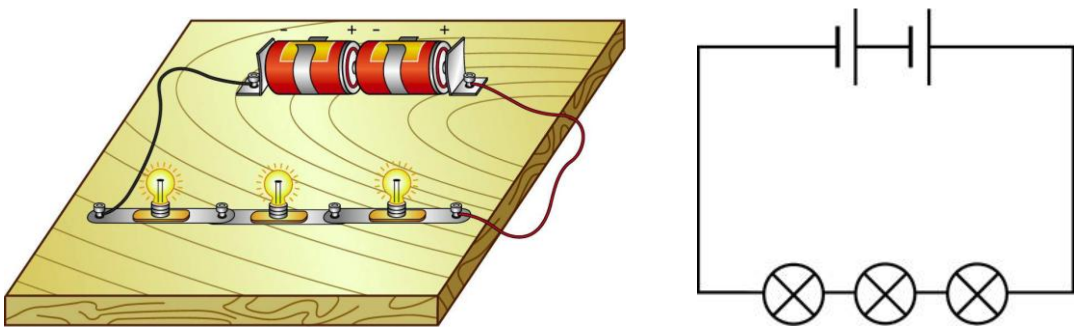


- Closed circuit. Bulb lights up when the switch is closed.

Series and Parallel Circuits

Two types of electric circuits:

1) Series circuits



- Each component (eg. bulb) is joined to the next component to form a single path. The current that flows through each component in series is the same.

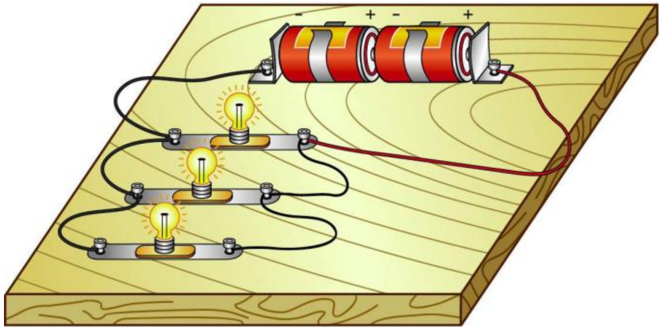
- A break in any part of a series circuit stops the flow of current in the whole circuit.

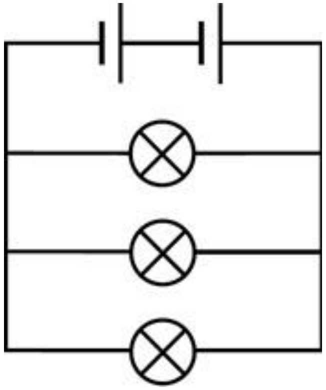
http://www.mste.uiuc.edu/nwaight/ohm/TRY%20IT%20OUT.html

- circuit demo

Series and Parallel Circuits

2) Parallel circuits





- A parallel circuit divides into two or more branches with electrical components (eg. bulb) in each branch. The current divides and flows through each parallel branch.

- If a component breaks or is removed, the other components remain on.

Electric Current

- What is it?

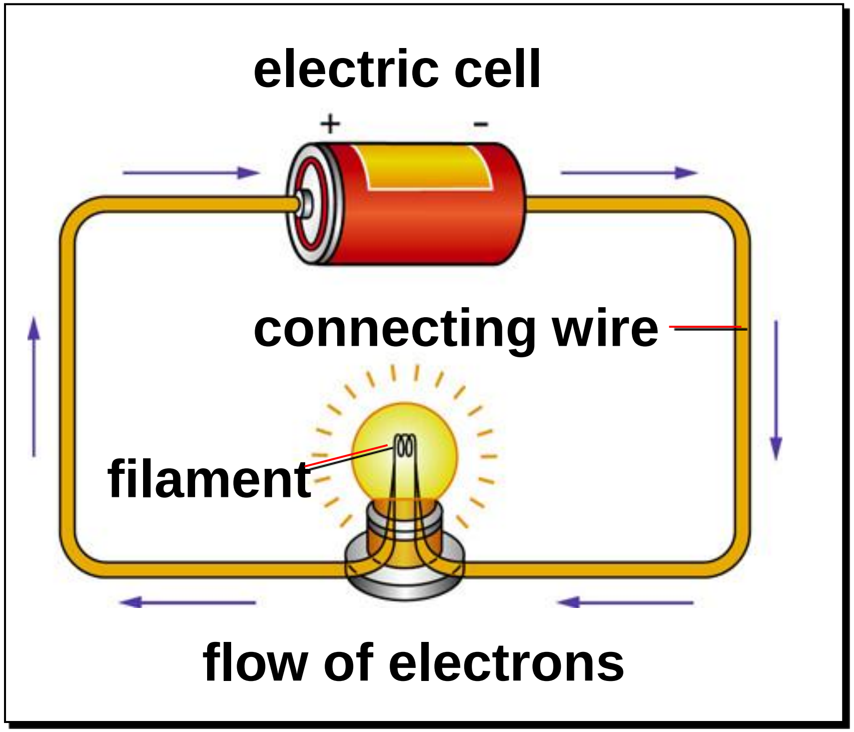
- Can we measure it?

- How do we measure?

What is an **Electric Current**?

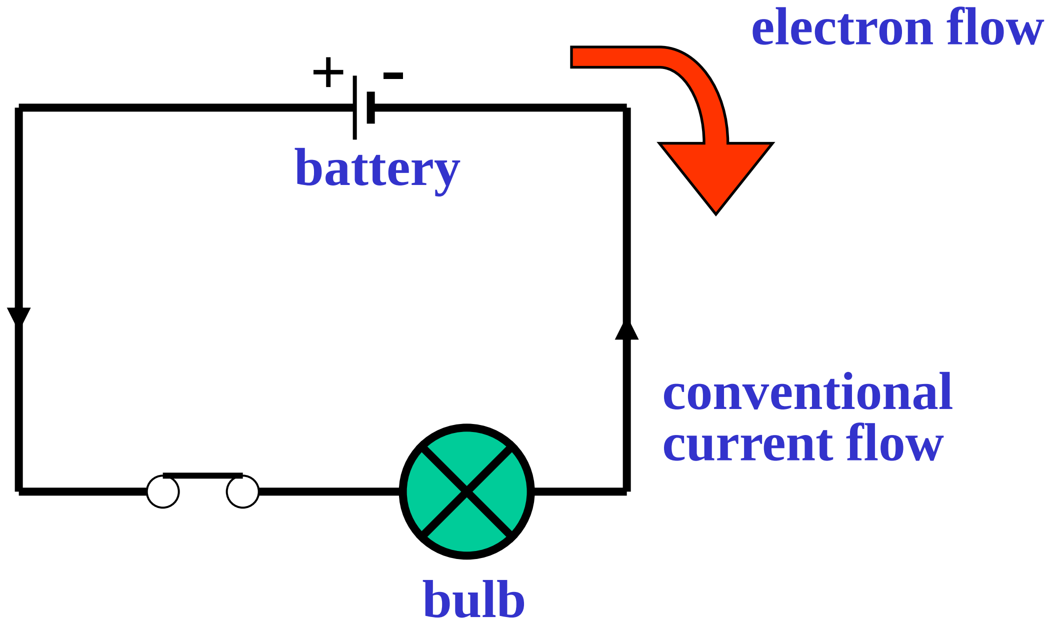
Definition:
An electric current is the flow of electrons in a circuit.

The electric cell in a circuit gives energy to the electrons and pushes them around a circuit, from the negative terminal of the cell, round the circuit and back to the positive terminal of the cell.



electric current

- For historical reasons, the direction of conventional current flow is the direction of a positive charge flow.
- In a circuit, the current is due to the flow of electrons



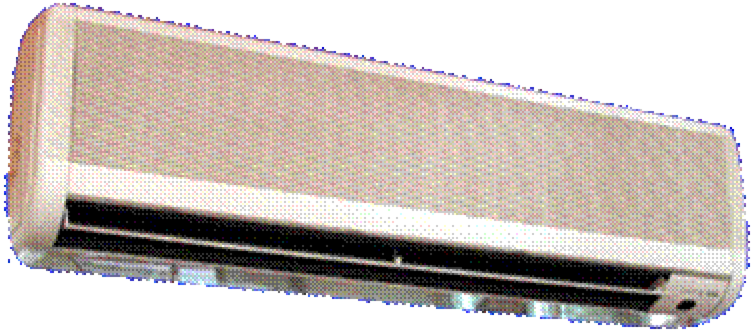
Measuring Electric Current

- The SI unit for electric current is ampere (A).
- Smaller currents are measured in milliamperes (mA).

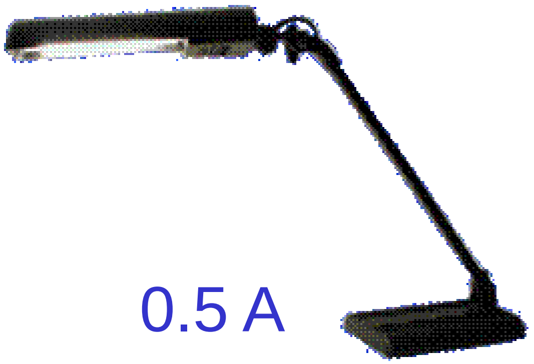
$$1\ \text{A} = 1000\ \text{mA}$$

$$1\ \text{mA} = \frac{1}{1000}\ \text{A or } 0.001\text{A}$$

- Different electrical components and appliances require different sizes of current to turn them on.



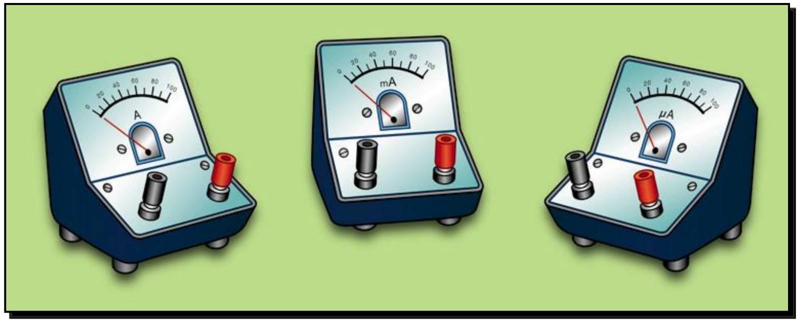
10 A

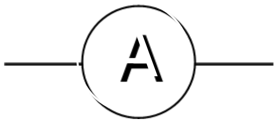


0.5 A

Measuring Electric Current

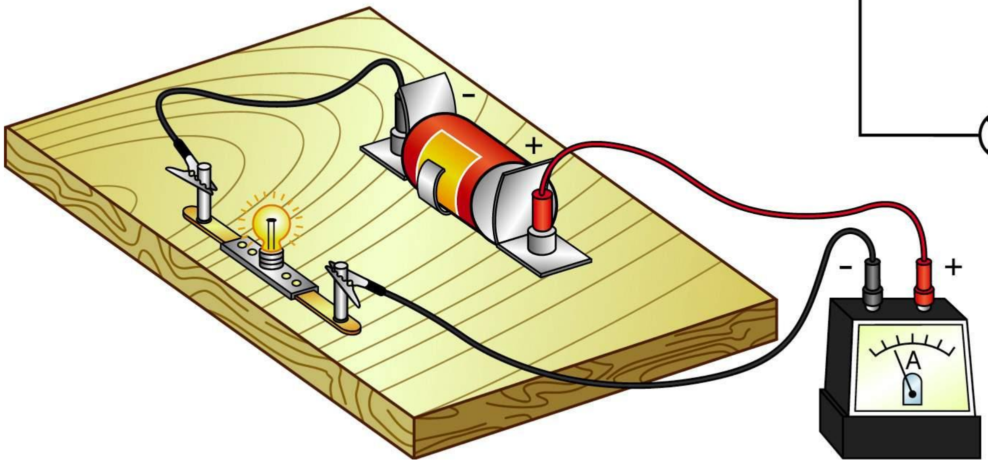
An ammeter is an instrument used for measuring electric current. It is connected in series to the circuit.

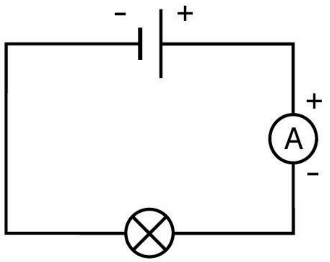




ammeter symbol

Positive (red) side of ammeter is connected nearest to the positive terminal of the cell. Similarly the negative (black) terminal of ammeter always joins to the negative terminal of the cell.





Voltage

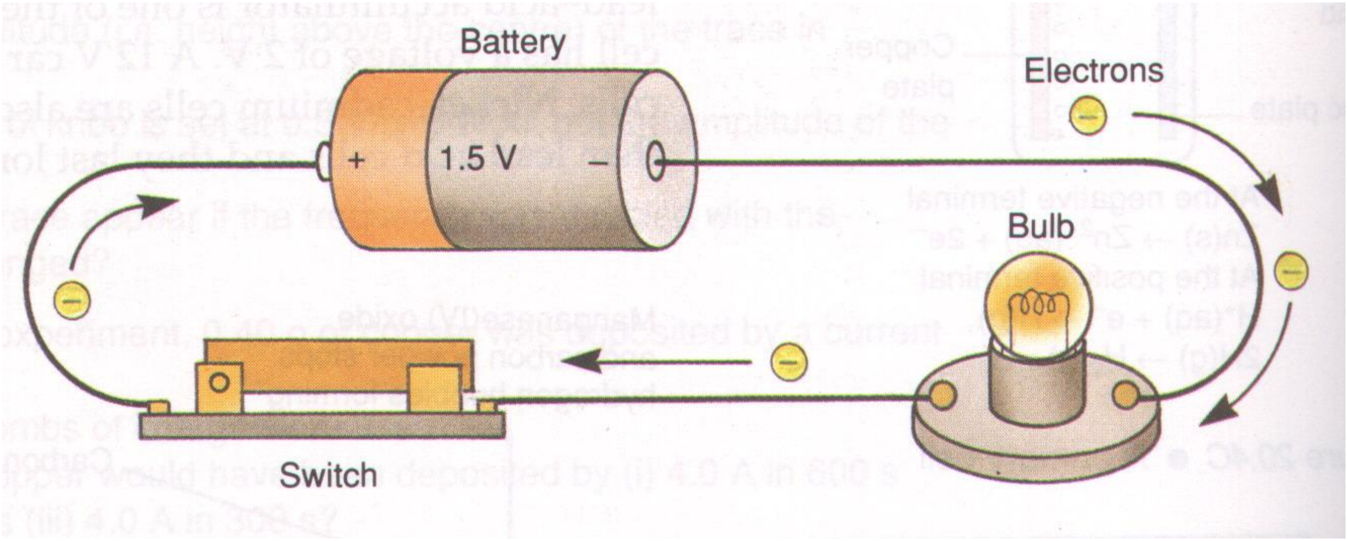
- Potential Difference
- Electromotive Force

What are they? Why the 2 names? How are they related? How are they different?

Electromotive Force

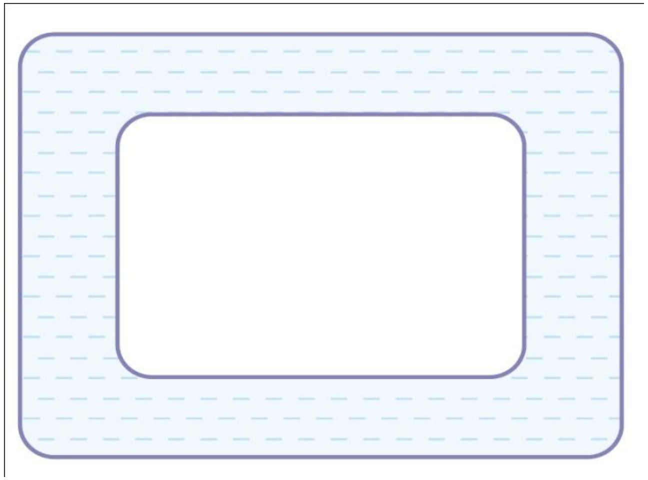
The electromotive force (e.m.f) of an electrical energy source is defined as the work done by the source in driving a unit charge ***round a complete circuit.***

The SI unit for e.m.f is volt (V).

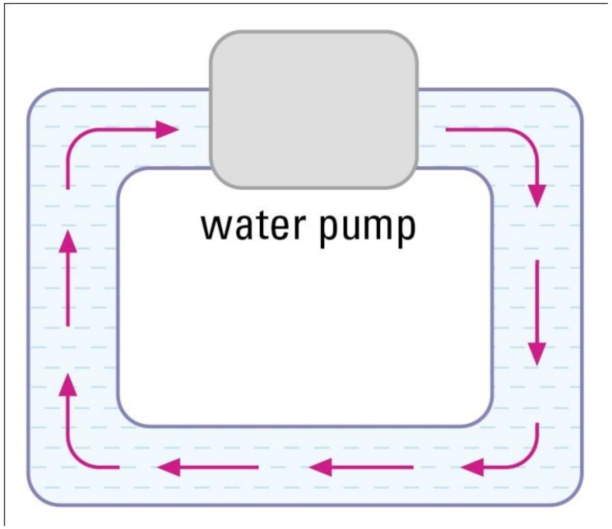


Electromotive Force

Analogy of a water pump as an emf source



The water in the pipe will remain stationary

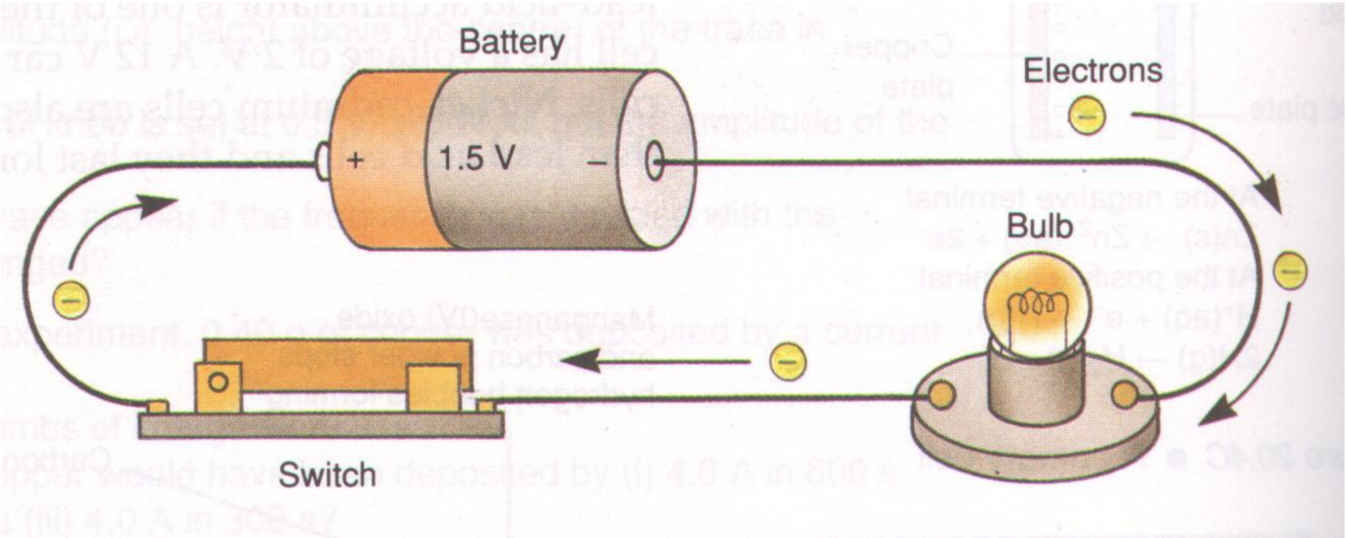


With a pump, the water will be forced to move through the pipe

Potential Difference

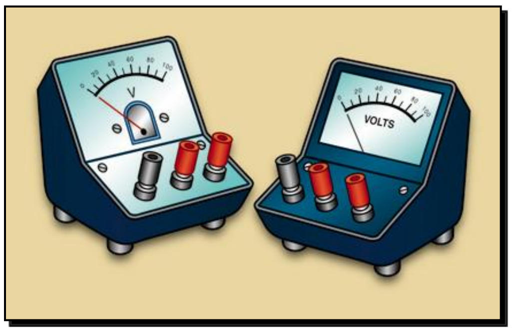
The potential difference across the bulb is a measure of the amount of electrical energy converted to other forms of energy when one unit of charge flow ***between two points.***

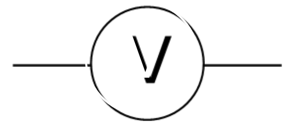
The SI unit for potential difference is volt (V).



Measuring potential difference and e.m.f

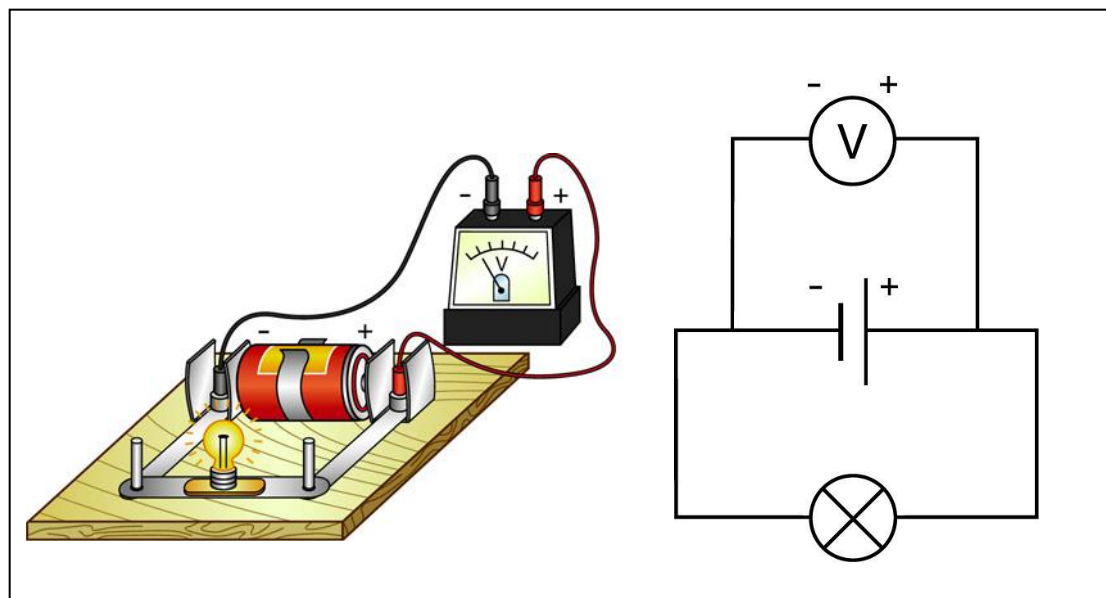
A voltmeter is an instrument used for measuring potential difference and e.m.f. It is connected in parallel to the circuit.





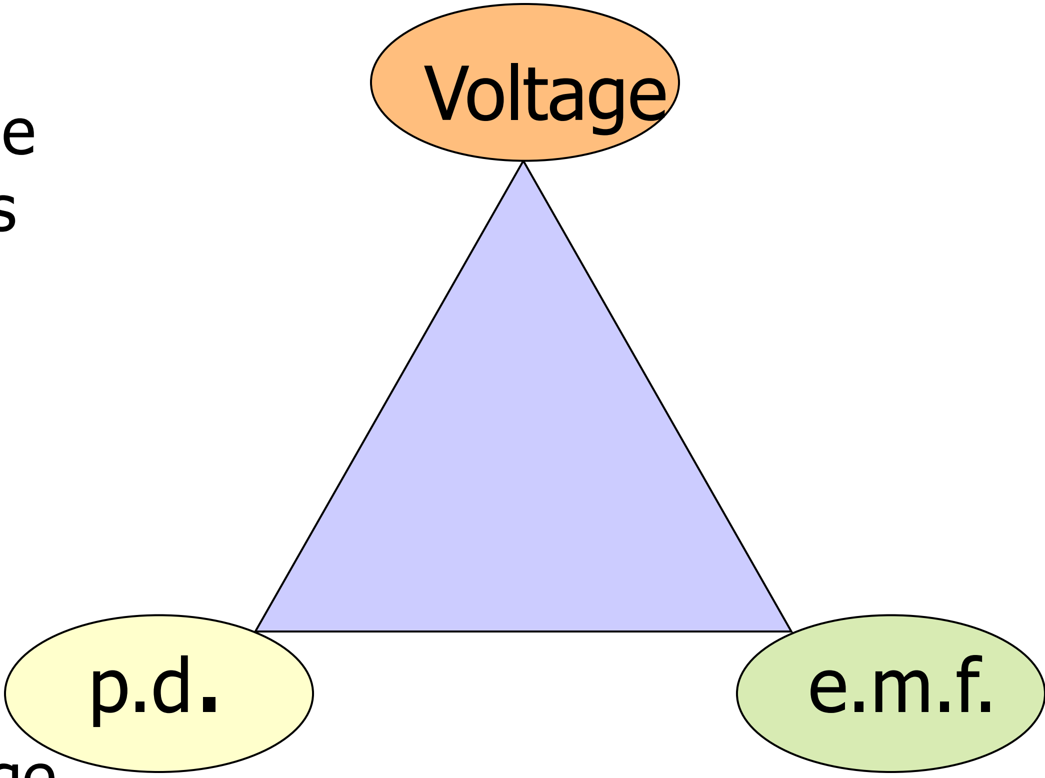
voltmeter symbol

Positive (negative) side of voltmeter is connected nearest to the positive (negative) terminal of the cell.



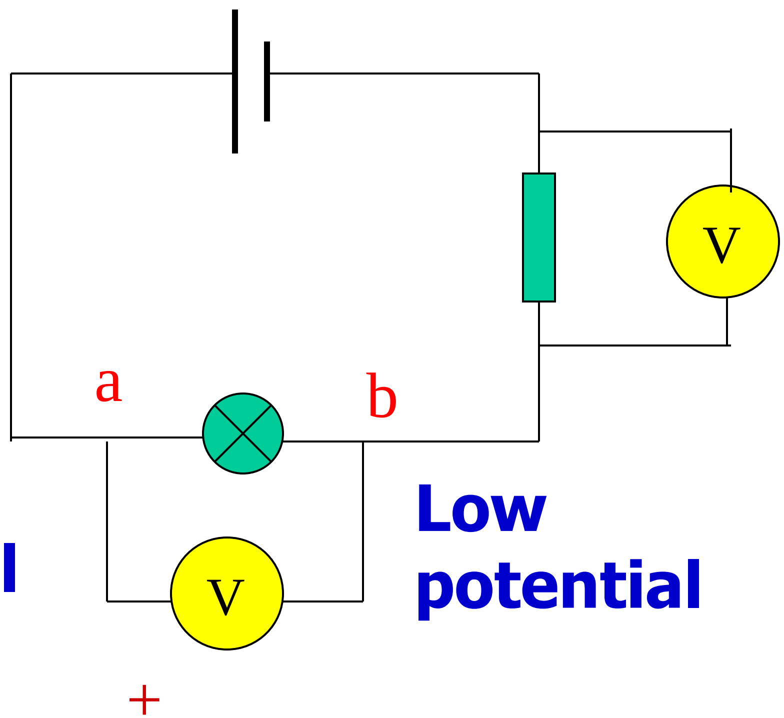
Potential Difference & Electromotive Force

- The term Voltage is commonly used to describe how many volts are across an electrical device.
- The term potential difference is used for the voltage between any two points in a circuit.
- The term electromotive force is used for the voltage between the two terminals of a battery or cell.



Potential Difference & Electromotive Force

E.m.f. of battery = 1.50 V



P.d. across the resistor

= 1.00 V

High potential

Low potential

P.d. across the light bulb = 0.50 V

Resistance

- How are we going to measure?
- In series?
- In parallel?

Resistance

An electric current does not always flow easily in a circuit because the circuit wires and the components resist the flow of electrons. The wire and components are said to have resistance.

The greater the resistance in a circuit, the lower the current.

Different conductors have different resistances. Resistance wires, made of nichrome have a higher resistance than copper wires.

The SI unit for resistance is the ohm (Ω).

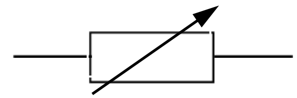
Resistors

An electrical component that is specially made to have a certain resistance is called a resistor. Resistors that have one fixed resistance are called fixed resistors.

fixed resistor symbol

Variable Resistors

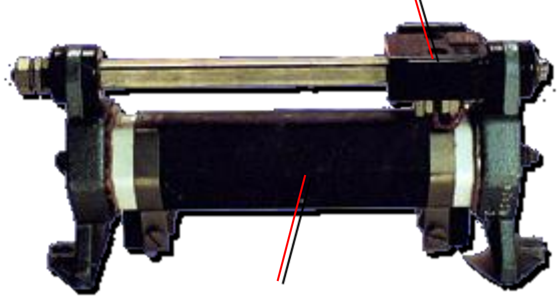
A variable resistor (or rheostat) allows resistances to be changed easily. When the resistance changes, current through the circuit also changes.



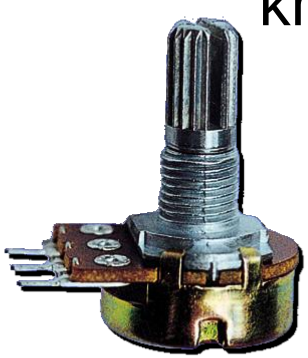
variable resistor symbol

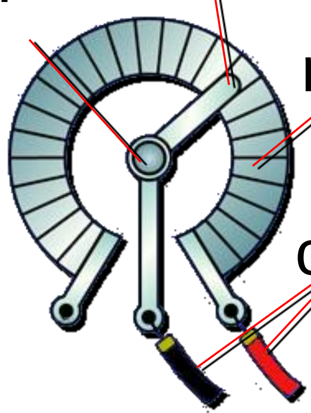
Two types of rheostats:

1) Sliding rheostat



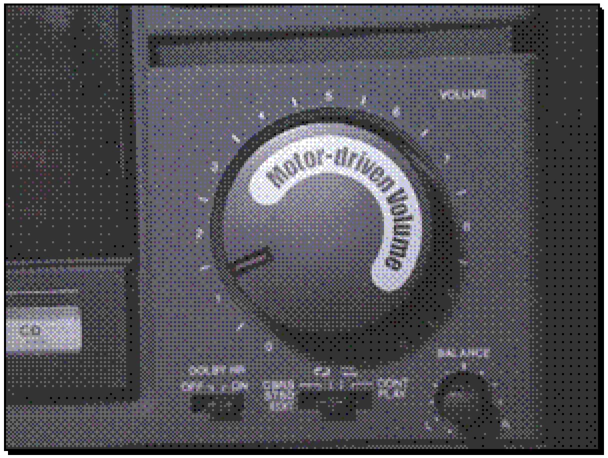
2) Rotating rheostat





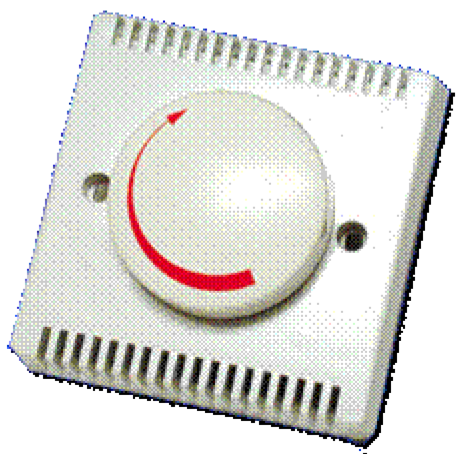
Variable Resistors

Rheostats have many uses.



volume control on radios

light dimmers



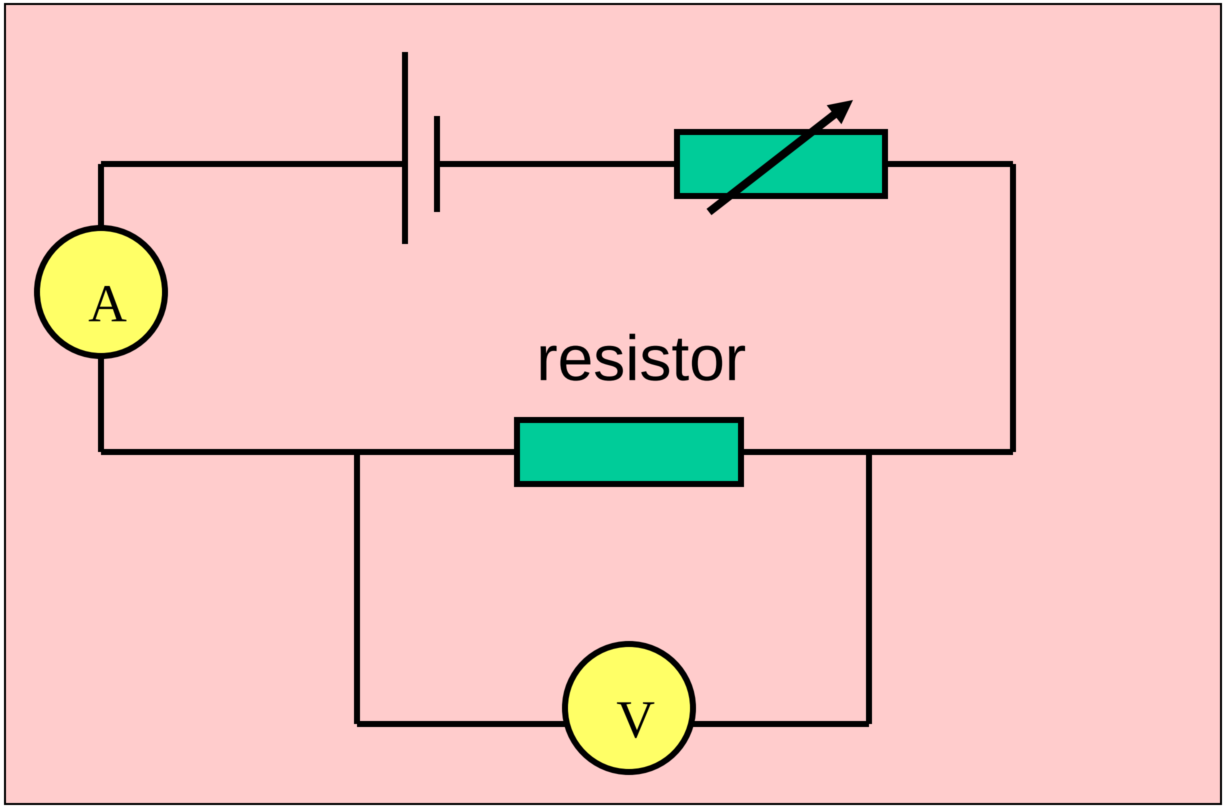
speed controller of a remote-control car

Ohm's Law

- In 1826, a German scientist, Georg Simmon Ohm, discovered the relationship between the current flowing through a metal conductor and the potential difference across its ends of the conductor.

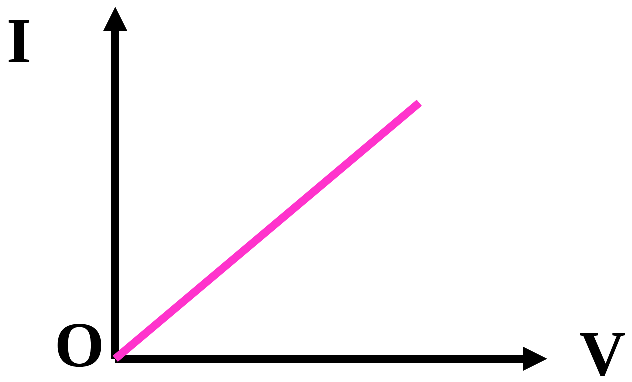
The current I, passing through a conductor is directly proportional to the potential difference, V, between its ends, provided that physical conditions and temperature remain constant.

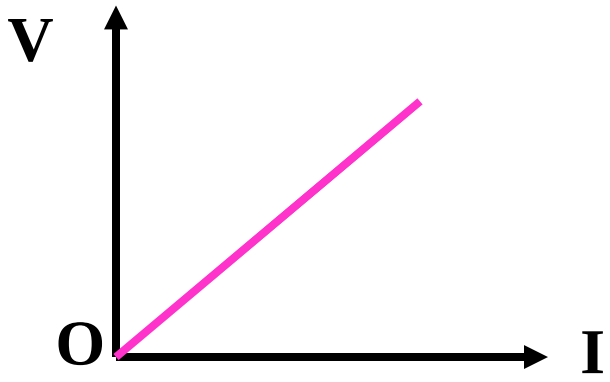
Experiment to investigate Ohm's Law



By varying the variable resistor, a graph of current I against potential difference V is plotted.

Ohm's Law





I α V

or V/I = constant

V/I = R

where **V =p.d. of the component in volts (V)**

I =current through the component in ampere(A)

R=resistance of the component in ohm (Ω)

Example

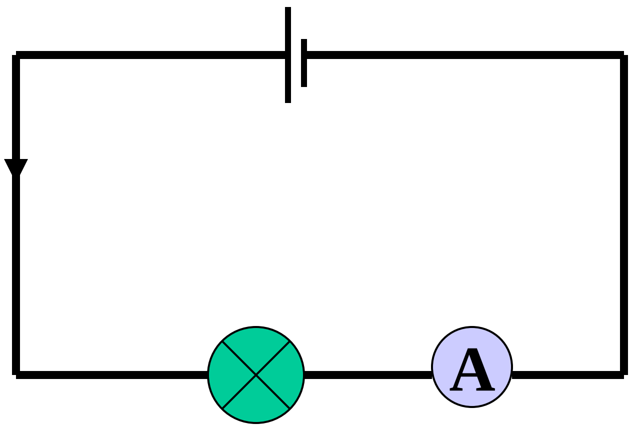
- A lamp draws a current of 0.25 A when it is connected to a 240V source. What is the resistance of the lamp ?

Solution

Since $\mathbf{V = IR}$

$$\mathbf{240 = 0.25\,R}$$

$$\mathbf{R = \underline{960\Omega}}$$



Example

- Calculate the current flowing through a 5Ω resistor when the potential difference across the resistor is 2 V.

Solution

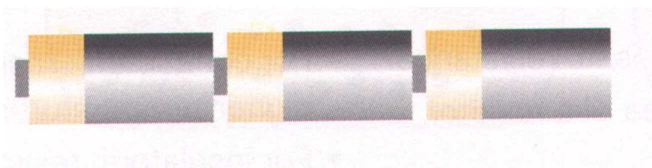
since $\mathbf{V = IR}$

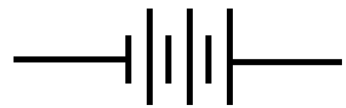
$$\mathbf{2 = I\,5}$$

$$\mathbf{I = \underline{0.4\ A}}$$

Series and Parallel circuits

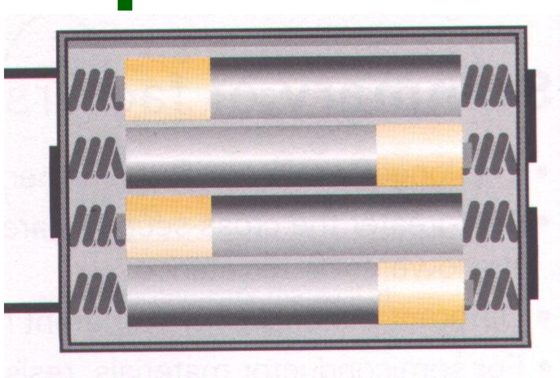
- **Cell :**
  - **In series**

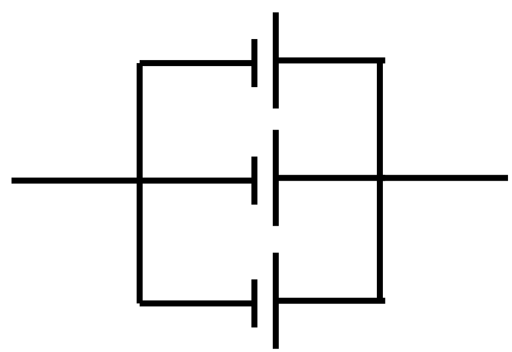




If a cell has emf = 2V, then total emf = 6V

In parallel



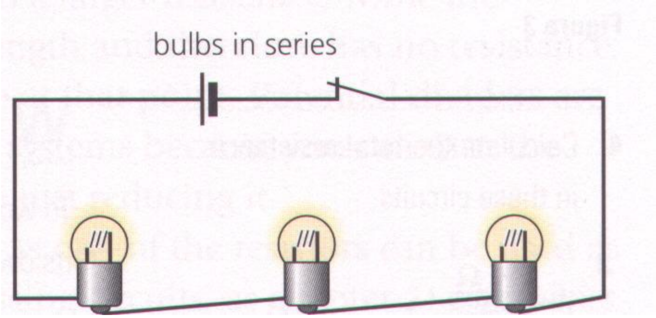


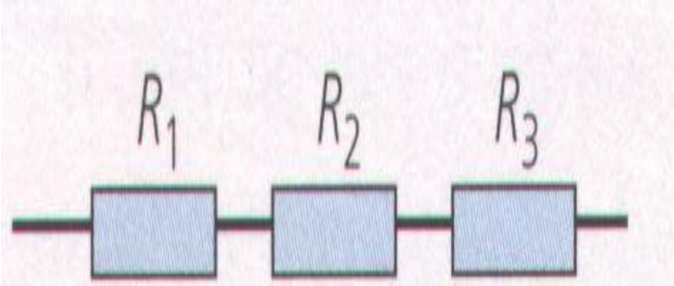
If a cell has emf = 2V, then total emf = 2V

Series and Parallel circuits

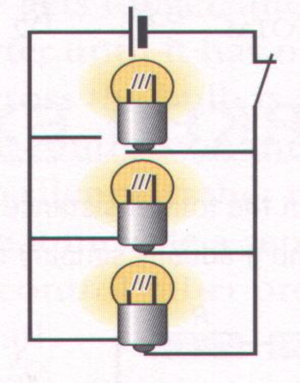
- **Resistance:**

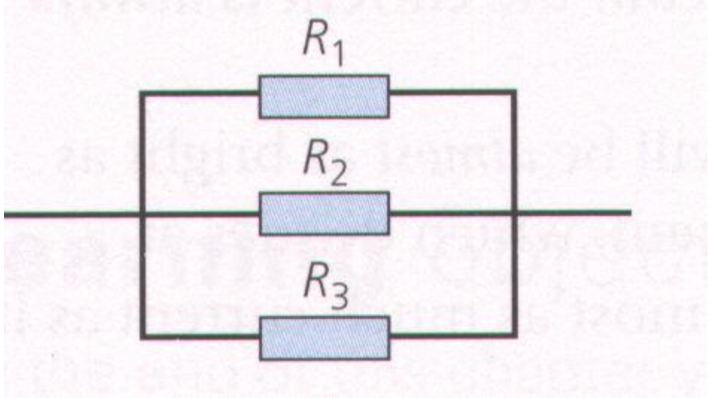
In series





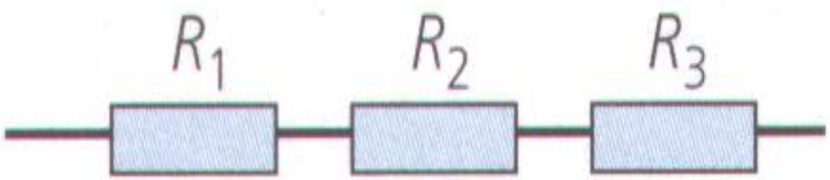
In parallel





In Series

- When resistors are connected **in series**,



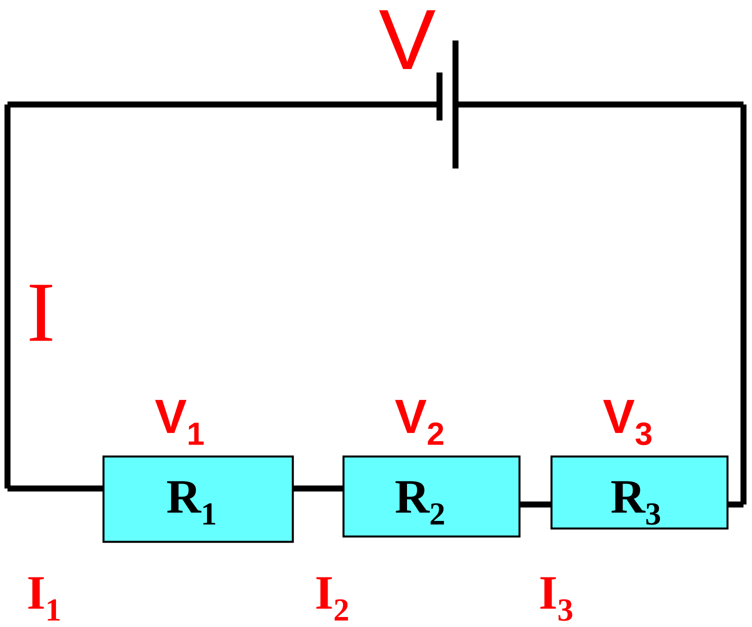
the **total resistance** (**effective resistance** or **resultant resistance**) is equal to the sum of the individual resistances.

Thus,

$$R_{total} = R_1 + R_2 + R_3$$

Each resistor added in series increases the effective resistance of the circuit and reduces the current flow.

In Series

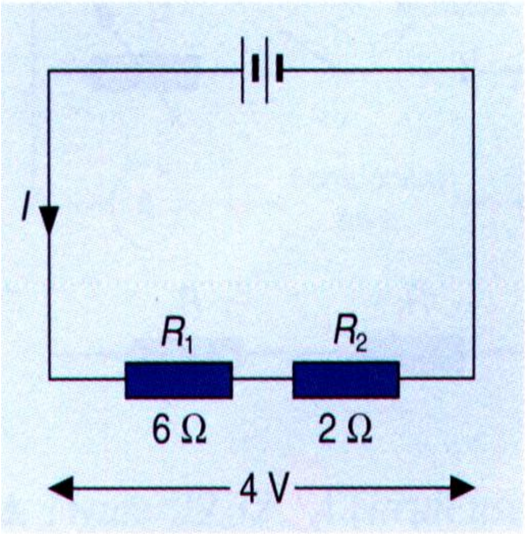


$V = V_1 + V_2 + V_3$

- $IR = I_1R_1 + I_2R_2 + I_3R_3$
- *but* $I = I_1 = I_2 = I_3$
- $R = R_1 + R_2 + R_3$

- Current is the same throughout.
- Voltage is shared.

Example

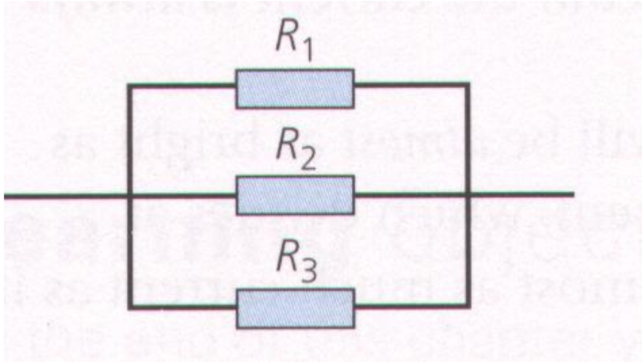


- A voltage of 4V supplied by the battery is applied to two resistors of 6Ω and 2Ω connected in series.
- Calculate :
- a) the combined resistance,
- b) the current flowing,
- c) the p.d. across the 2Ωresistor.
- d) the p.d. across the 6Ωresistor.

- 8 ohms, 0.5A, 1V, 3V

In Parallel

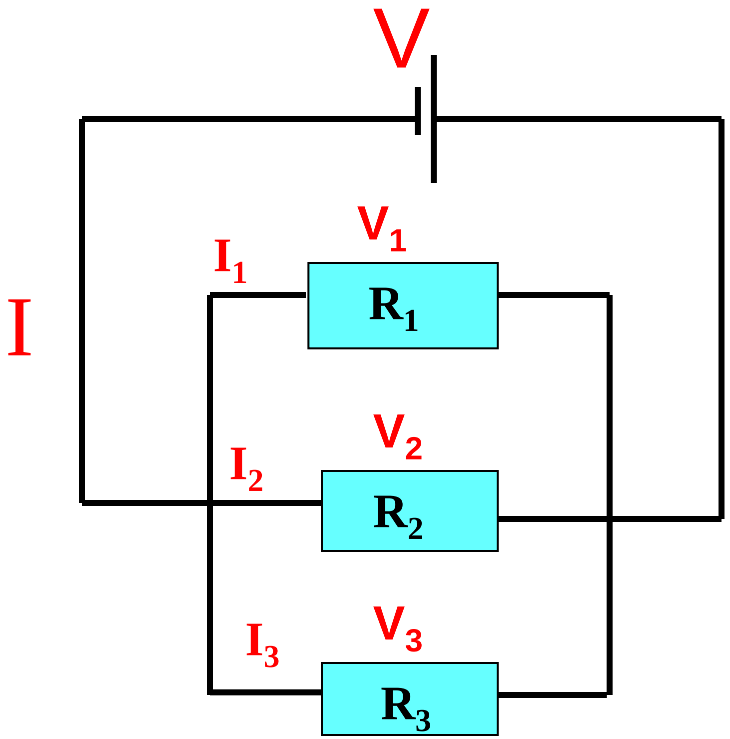
- When resistor connected in parallel ,the total resistance (or effective resistance or resultant resistance) is less.



Each resistor added in parallel decreases the effective resistance of the circuit and increases the current flow

$$\frac{1}{R_{\text{TOTAL}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

In Parallel

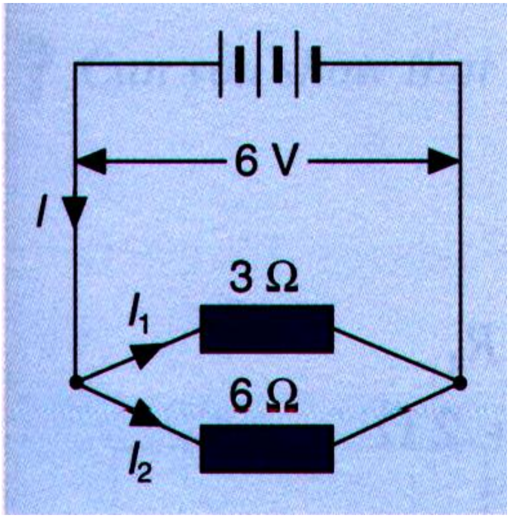


$$I = I_1 + I_2 + I_3$$

- $V/R = V_1/R_1 + V_2/R_2 + V_3/R_3$
- *but* $V = V_1 = V_2 = V_3$
- $1/R = 1/R_1 + 1/R_2 + 1/R_3$

- Voltage is the same throughout.
- Current is shared.

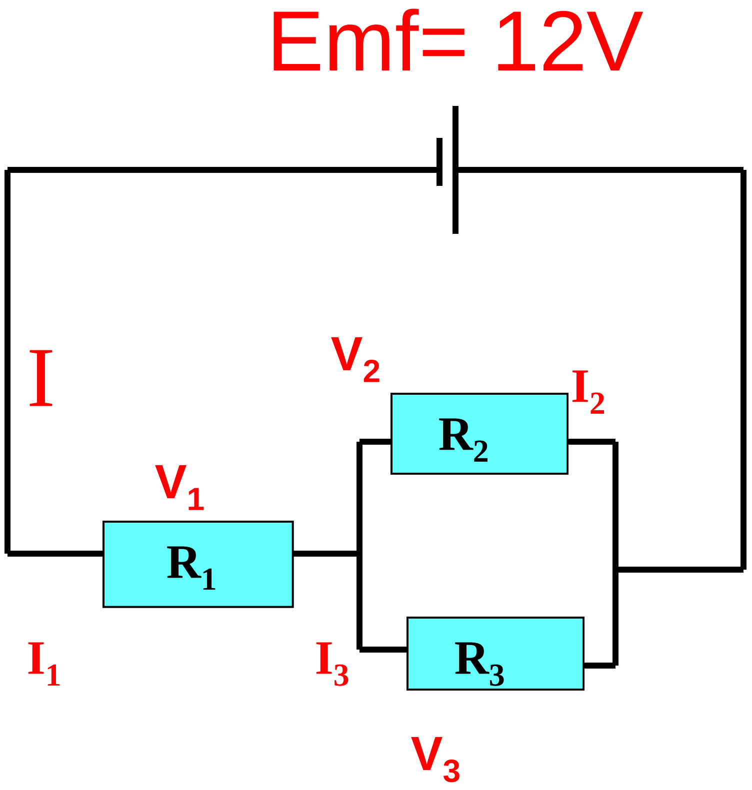
Example



- **A voltage of 6V is applied to two resistors of 3 Ω and 6 Ω connected in parallel.**
- **Calculate:**
- **a) the combined resistance,**
- **b) the current flowing in the main circuit,**
- **c) the current in the 3 Ω resistor,**
- **d) the current in the 6 Ω resistor.**

- **2 Ω ,3A, 2A, 1A**

Example - Combined Circuit



- If R_1= 2.0 Ω

R_2 = 4.0 Ω, R_3 = 6.0 Ω ,

- What is the effective resistance?
- What is the circuit current I ?
- Find V_1,V_2 and V_3
- Find I_2 and I_3.

- 4.4 Ω, 2.7A, 5.4V, 6.6V, 6.6V 1.6A, 1.1A,

Effects of an Electric Current

Heating Effect of an Electric Current

When an electric current flows through a wire, the wire heats up. Electrical energy has been converted into heat energy.

The greater the resistance of the wire, the greater the amount of heat produced. This heating effect is used in common electrical appliances.

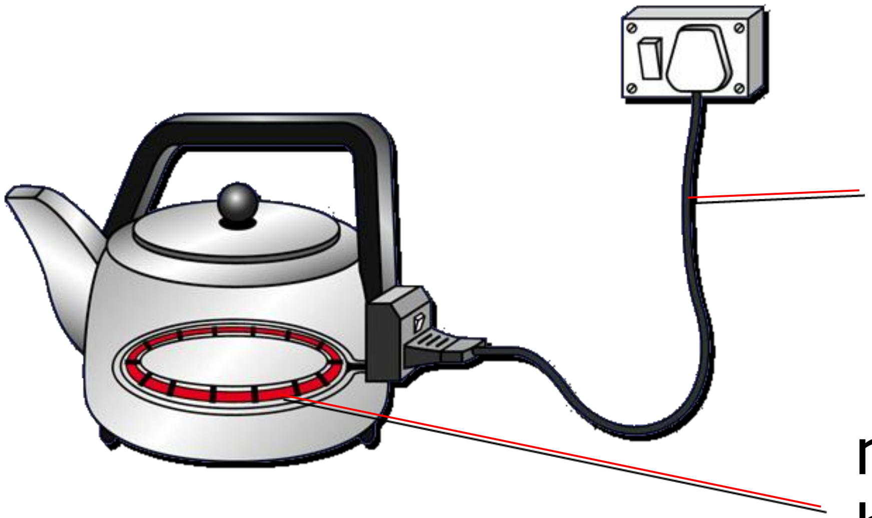
iron

kettle

hair dryer

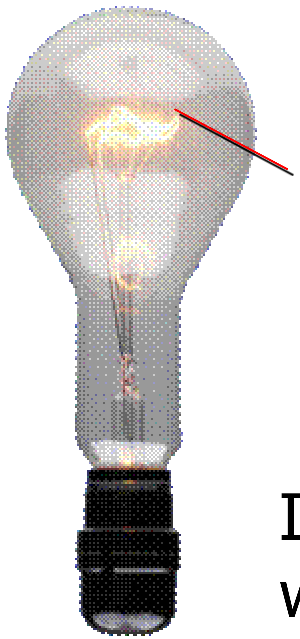
Heating Effect of an Electric Current

A kettle uses both copper and nichrome wires.



copper wire with low resistance produces less heat

nichrome wire with high resistance produces a lot of heat

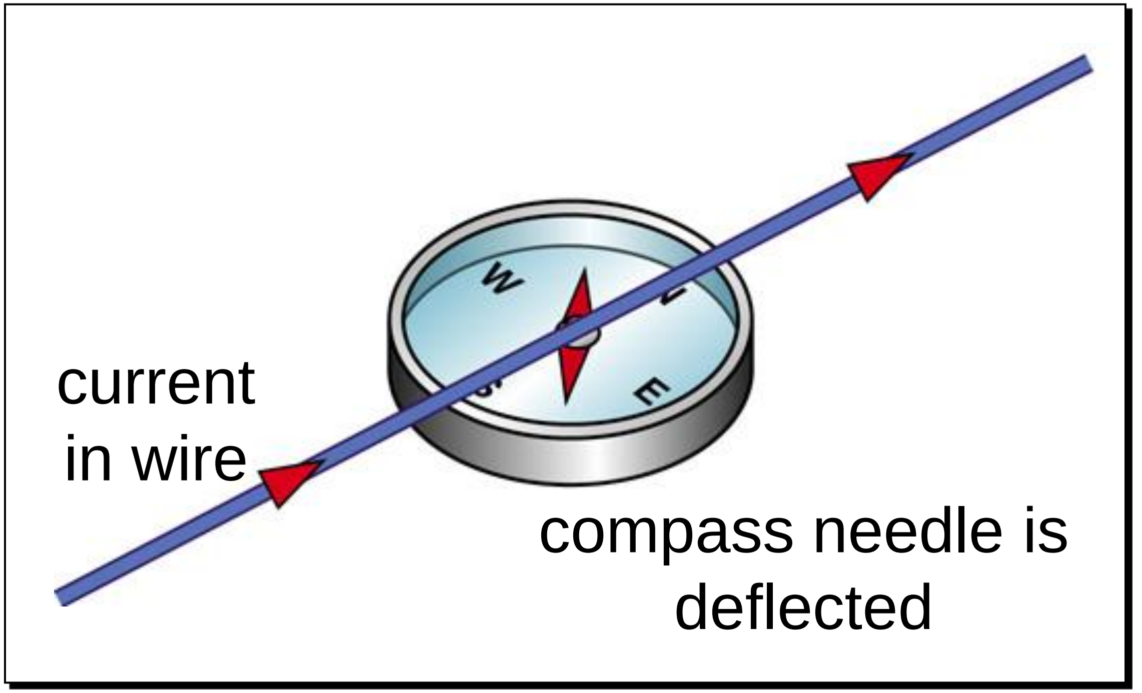


filament wire produces heat and light

In a light bulb, the heated filament (resistance wire) becomes so hot that light is also emitted.

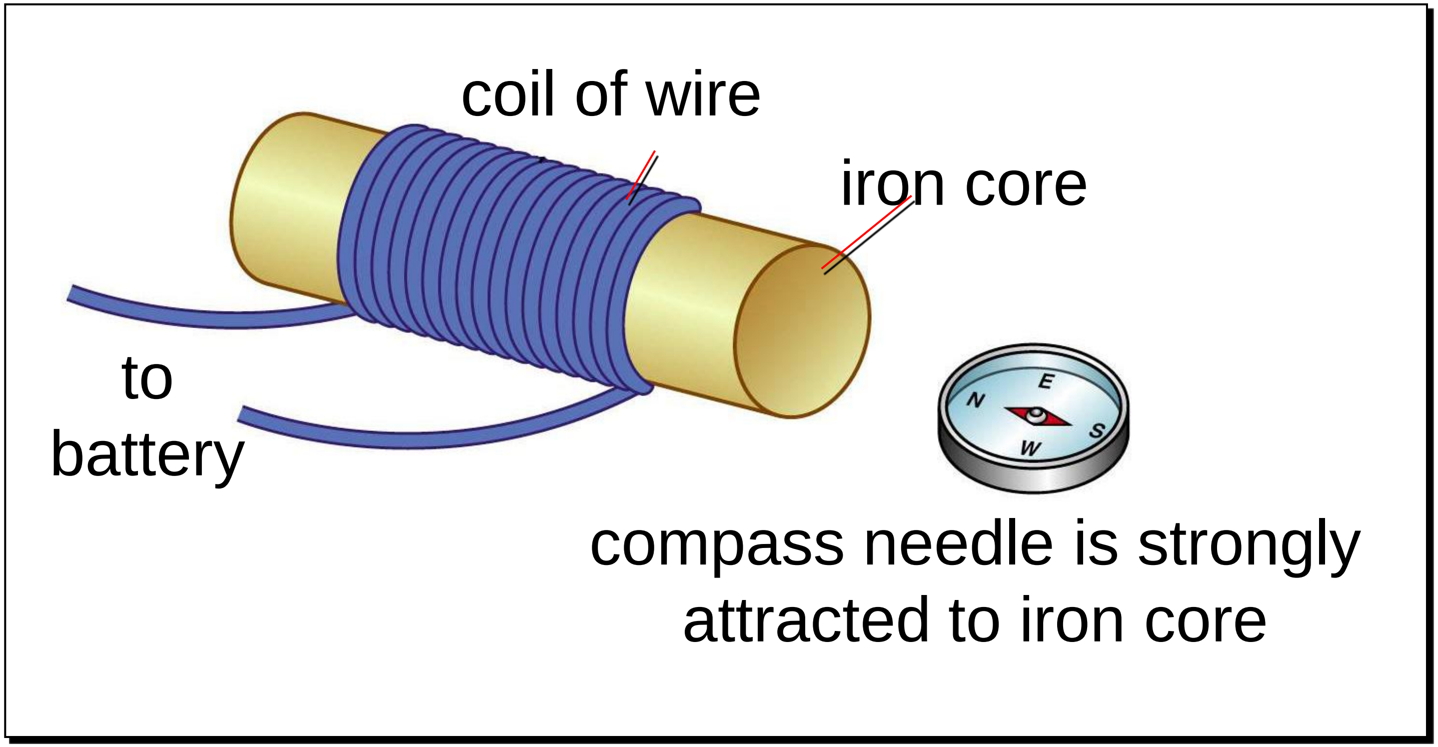
Magnetic Effect of an Electric Current

A straight wire is placed near a compass. When an electric current flows through the wire, the compass needle is deflected. This shows that an electric current has a magnetic effect.



Magnetic Effect of an Electric Current

An electromagnet consists of a coil of wire usually wound around a piece of iron. It is a temporary magnet which can be turned on and off using electric current.



Uses of Electromagnets

Cranes that lift iron/steel

Iron/steel separators

Electric bells

Magnetically levitated trains

Electric motors

Speakers

crane

electric bell

electric motor in fan

http://home.howstuffworks.com/home-improvement/repair/doorbell3.htm

http://electronics.howstuffworks.com/speaker6.htm

Uses of Electromagnets

Shanghai's flashy new Maglev, the world's fastest train.

The train can reach almost 322 km/h in 2 min, with a maximum speed of 430 km/h.

http://www.youtube.com/watch?v=IT-mVT-ORww

Chemical Effect of an Electric Current

What is Electrolysis?

Definition:
Electrolysis is the chemical change that occurs when an electric current passes through solutions or molten compounds.

Chemical Effect of an Electric Current

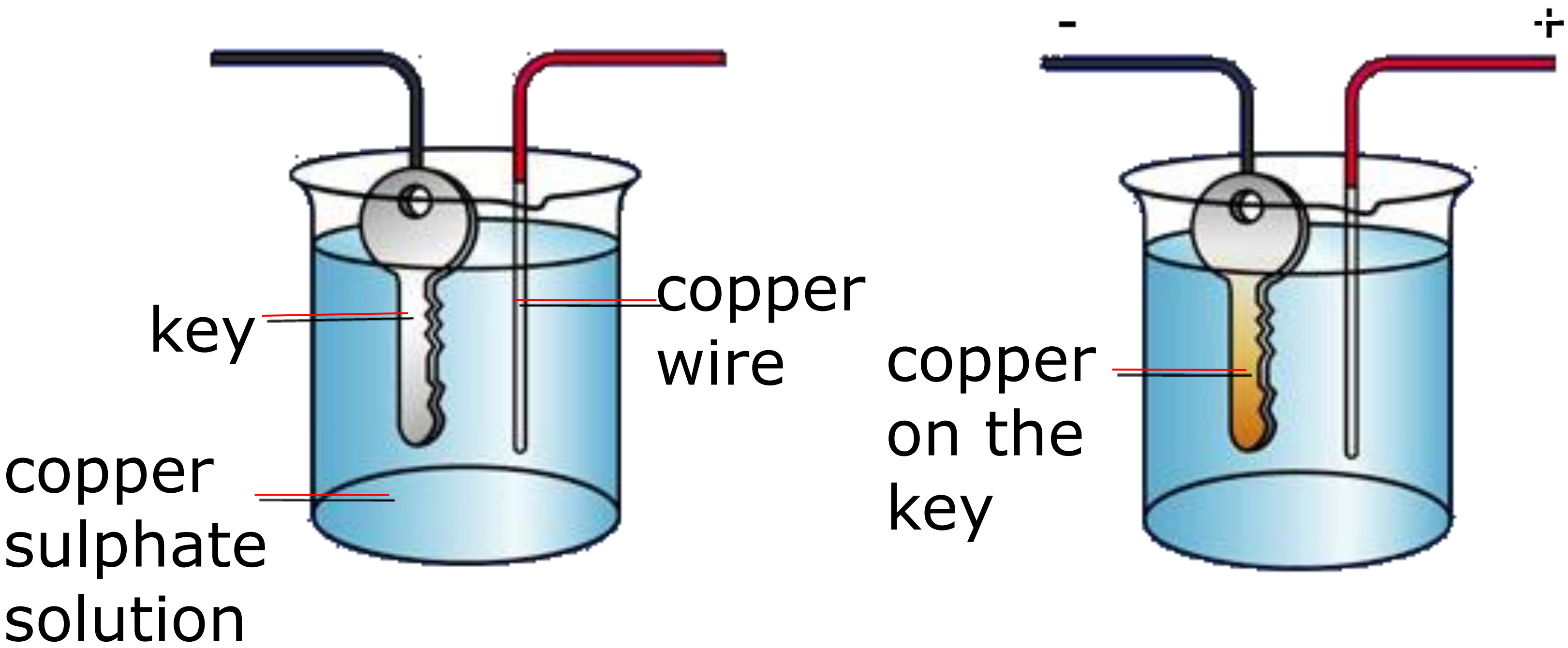
Uses of electrolysis

Electroplating

Metal objects can be plated with a thin layer of another metal.

Chemical Effect of an Electric Current

In electroplating, a key is covered with a thin layer of copper when electricity is passed through the solution.



start

after a few minutes

http://learningat.ke7.org.uk/scienceweb/GCSE/Metals/Electrolysis%20Simple.htm

Electrolysis demo