Magnetism-
Magnetic & Electric Circuits

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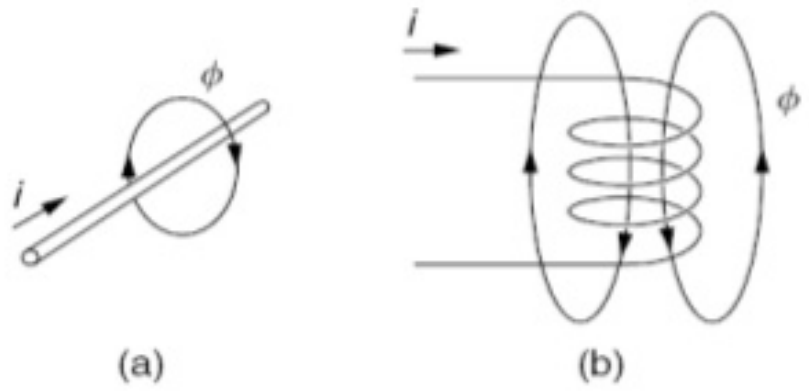
MAGNETIC CIRCUITS

Electrical current flowing along a wire creates a magnetic field around the wire, as shown in Fig. That magnetic field can be visualized by showing lines of magnetic flux, which are represented with the symbol φ.

The direction of that field that can be determined using the "right hand rule"



- Faraday discovered is that current flowing through the coil not only creates a magnetic field in the iron, it also creates a voltage across the coil that is proportional to the rate of change of magnetic flux φ in the iron.

- That voltage is called an electromotive force, or emf, and is designated by the symbol *e*.

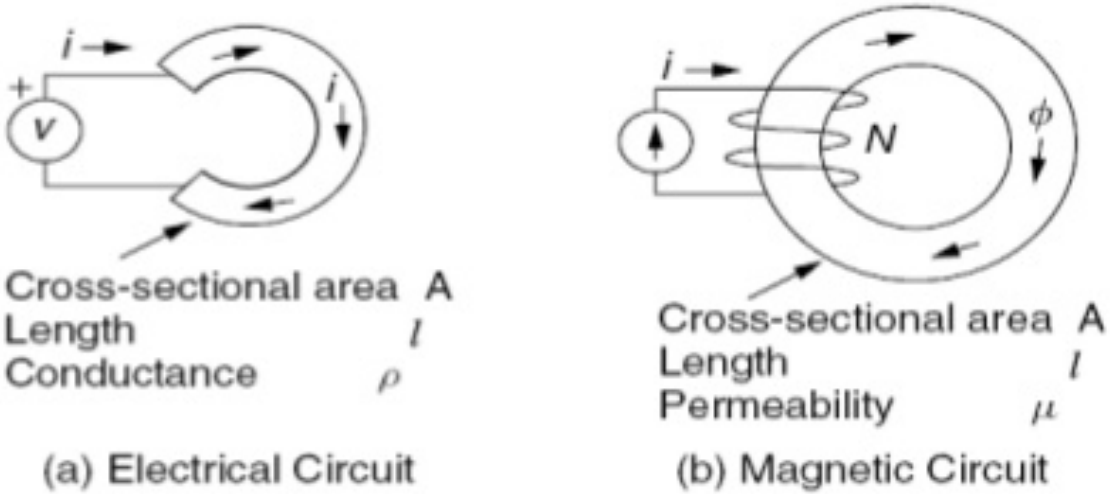
Faraday's law of electromagnetic induction:

$$e = N\frac{d\phi}{dt}$$

•The sign of the induced emf is always in a direction that opposes the current that created it, a phenomenon referred to as *Lenz's law*.

- In the magnetic circuit of Fig, the driving force, analogous to voltage, is called the *magneto motive force* (mmf), designated by F. The magneto motive force is created by wrapping *N* turns of wire, carrying current *i*

*Magneto motive force (mmf)*F = *Ni (ampere − turns)*



(a) Electrical Circuit

(b) Magnetic Circuit

$$\text{Magnetic flux density } B = \frac{\phi}{\text{A}} \text{ webers/m}^2 \text{ or teslas (T)}$$

$$\text{Electric current density } J = \frac{i}{\text{A}}$$

Magnetic field intensity (H):

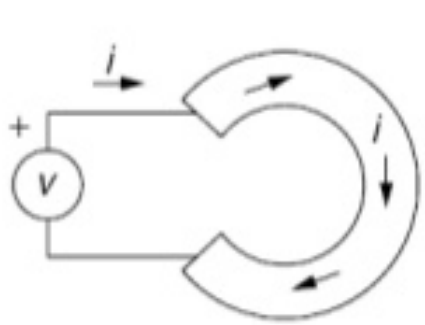
With *N* turns of wire carrying current *i*, the mmf created in the circuit is *Ni* ampere-turns. With *l* representing the mean path length for the magnetic flux, the magnetic field intensity is

$$\text{Magnetic field intensity } H = \frac{Ni}{l} \text{ ampere-turns/meter}$$

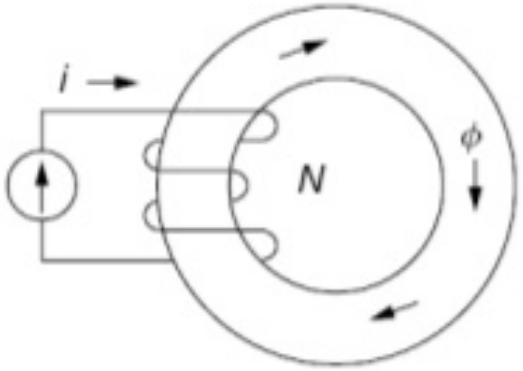
$$B = \mu H$$

Electrical	Magnetic	Magnetic Units
Voltage v	Magnetomotive force $\mathcal{F} = Ni$	Amp-turns
Current i	Magnetic flux ϕ	Webers Wb
Resistance R	Reluctance $\mathcal{R}$	Amp-turns/Wb
Conductivity $1/\rho$	Permeability μ	Wb/A-t-m
Current density J	Magnetic flux density B	$\text{Wb}/\text{m}^2 = \text{teslas T}$
Electric field E	Magnetic field intensity H	Amp-turn/m

CIRCUIT DIAGRAMS

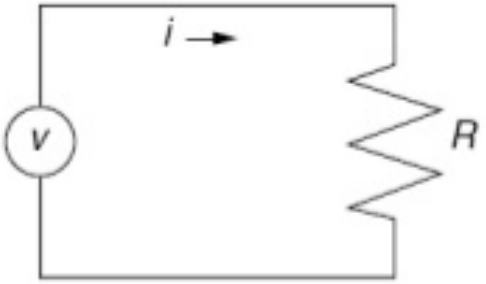


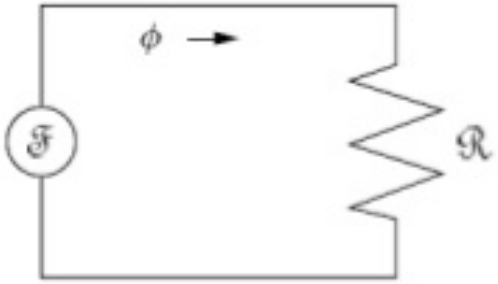
Electrical



Magnetic

EQUIVALENT CIRCUITS





Sr. No.	Electric Circuit	Magnetic Circuit
1.	Path traced by the current is called electric circuit.	Path traced by the magnetic flux is defined as magnetic circuit.
2.	E.M.F. is the driving force in electric circuit, the unit is volts.	M.M.F. is the driving force in the magnetic circuit , the unit of which is ampere turns.
3.	There is current I in the electric circuit measured in amperes.	There is flux ϕ in the magnetic circuit measured in webers.
4.	The flow of electrons decides the current in conductor.	The number of magnetic lines of force decides the flux.
5.	Resistance oppose the flow of the current. Unit is ohm.	Reluctance is opposed by magnetic path to the flux. Unit is ampere turn/weber.

6.	$R = \rho \frac{l}{a}$. Directly proportional to l. Inversely proportional to 'a'. Depends on nature of material.	$S = \frac{l}{\mu_0 \mu_r a}$. Directly proportional to l. Inversely proportional to $\mu = \mu_0 \mu_r$. Inversely proportional to area 'a'.
7.	The current $I = \frac{\text{e.m.f.}}{\text{resistance}}$	The flux $\phi = \frac{\text{m.m.f.}}{\text{reluctance}}$
8.	The current density $\delta = \frac{I}{a}$ A/m^2	The flux density $B = \frac{\phi}{a}$ Wb/m^2
9.	Conductivity is reciprocal of the resistivity. Conductance = $\frac{1}{R}$	Permeance is reciprocal of the reluctance. Permeance = $\frac{1}{S}$
10.	Kirchhoff's current and voltage law is applicable to the electric circuit.	Kirchhoff's m.m.f. law and flux law is applicable to the magnetic circuit.

- Faraday's Laws:\

First law: EMF is induced in a coil whenever magnetic field linking that coil is changed.

Second law: The magnitude of the induced EMF is proportional to the rate of change of flux linkage.

$$e = -N\frac{d\phi}{dt}$$

Lenz's law: This law states that the induced EMF due to change of flux linkage by a coil will produce a current in the coil in such a direction that it will produce a magnetic field which will oppose the cause, that is the change in flux linkage.

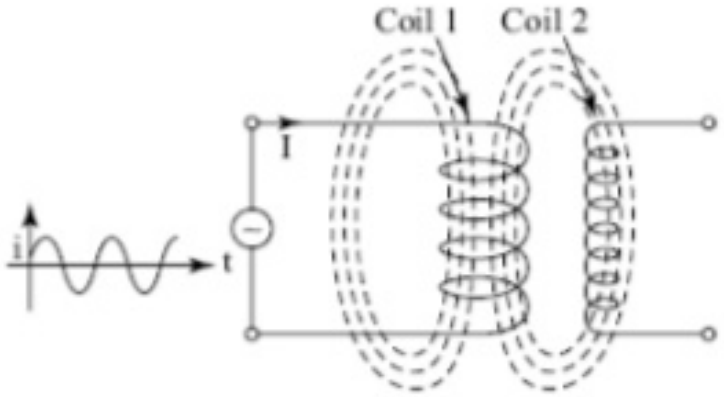
Self-induced EMF and Mutually induced EMF

The EMF induced in a coil due to change in flux linkage when a changing current flows through the coil is called **self-induced EMF.**

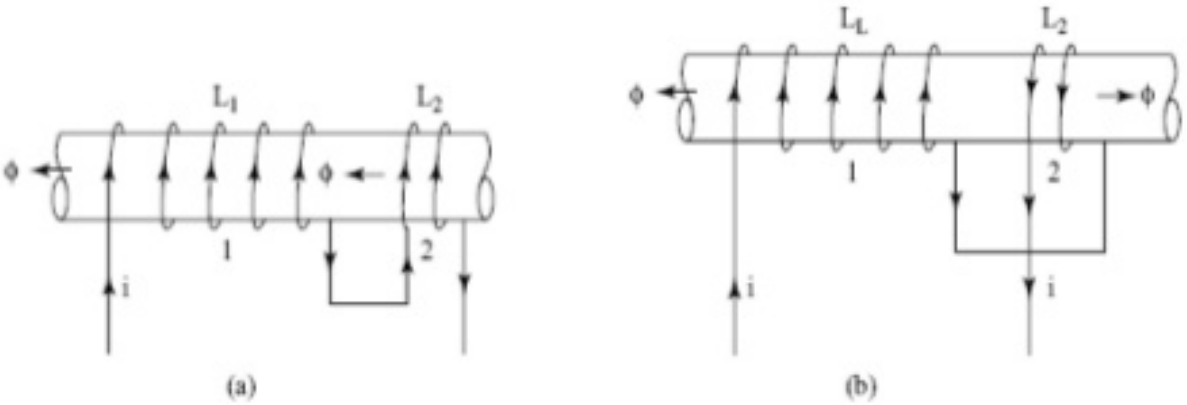
when a second coil is brought near a coil producing changing flux, EMF will be induced in the second coil due to change in current in the first coil. This is called **mutually induced EMF.**

$$e_1 = -N_1 \frac{d\phi}{dt}$$

$$e_2 = -N_2 \frac{d\phi}{dt}$$



Inductance of Coils connected in series having a common core



Coils connected in series in (a) cumulatively (b) differentially

Since the two coils are connected in series, the same current flows through them.

$$e_1 = -L_1 \frac{di}{dt}$$

$$e_2 = -L_2 \frac{di}{dt}$$

Due to mutual inductance, the EMF induced in coil 1 due to change in current in coil 2 and vice versa are expressed as EMF induced in coil 1 due to change in current in coil 2 is

$$e_{12} = -M \frac{di}{dt}$$

Now let the total equivalent inductance of the single circuit coil 1 and coil 2 as they are connected as in be 'Le'

The EMF induced in the whole circuit will, therefore, be

$$e = -L_e \frac{di}{dt}$$

Electric Current

Current is the rate of flow of electrons/charge

- It is abbreviated as I
- It is measured in amperes
- One ampere is defined as one coulomb of electrons flowing past a point each second (Q/s)

VOLTAGE

- Voltage is a force that pushes/drives the electrons/ charge
    - It is also referred to as electromotive force or difference in potential.
    - It is abbreviated as E or EMF
    - Voltage is measured in **volts** (v)

    Voltage source will have a polarity (negative and positive side)

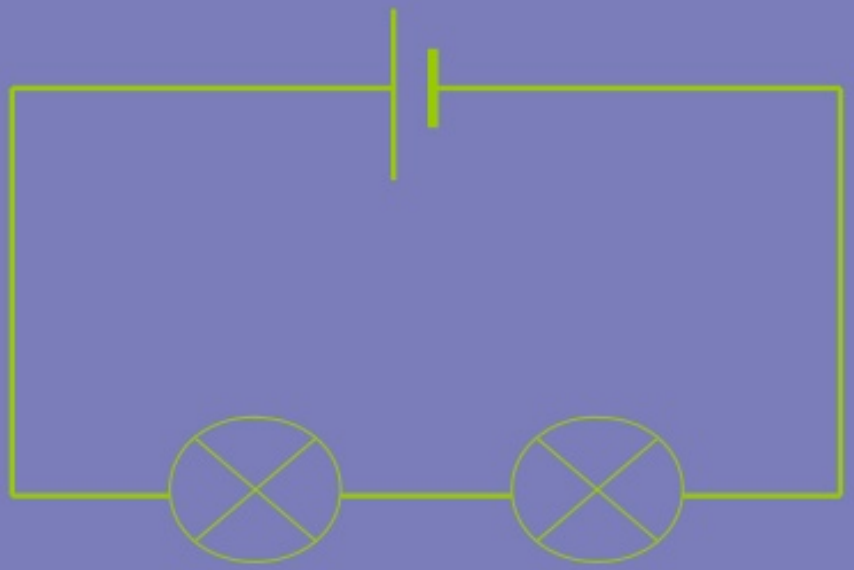
    Current flows from negative to positive (changing conventions)

    AC/DC: Alternating current (polarity of source reverses) or Direct current (polarity is constant)

RESISTANCE

Resistances are the barriers to the flow of charge
It is abbreviated as R
It is measured in ohms

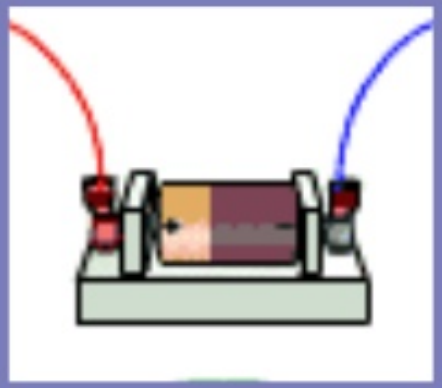
ELECTRICAL CIRCUITS



S.MORRIS 2006

The CELL

The cell stores **chemical energy** and transfers it to electrical energy when a circuit is connected.

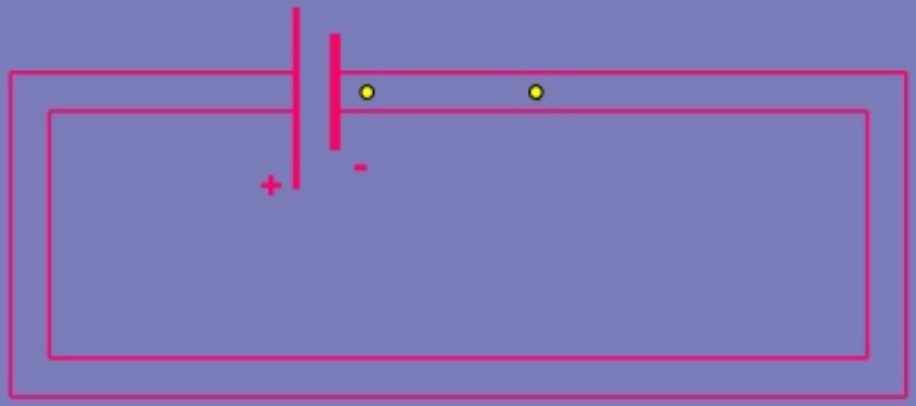


When two or more cells are connected together we call this a **Battery**.

The cells chemical energy is used up pushing a current round a circuit.

What is an electric current?

An electric current is a flow of microscopic particles called **electrons** flowing through wires and components.

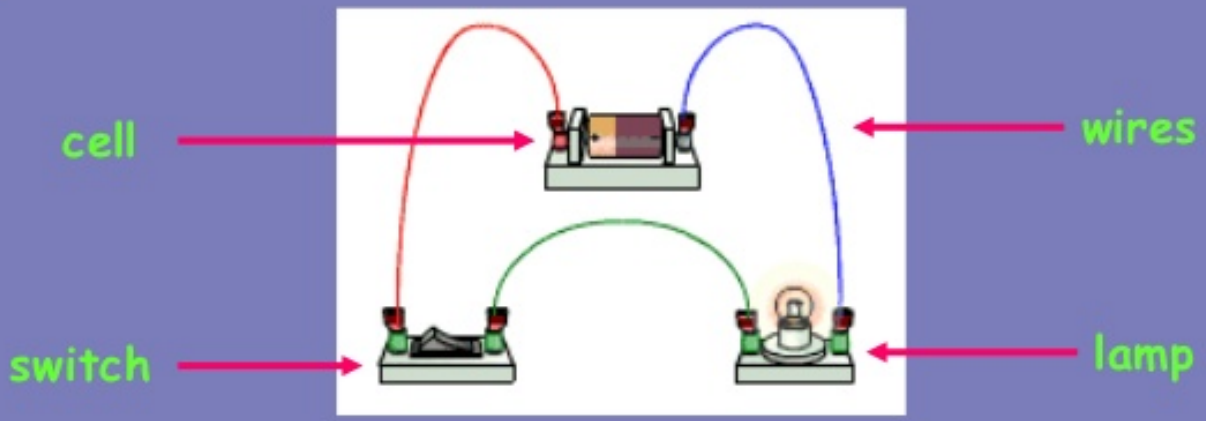


In which direction does the current flow?

from the **Negative** terminal **to** the **Positive** terminal of a cell.

simple circuits

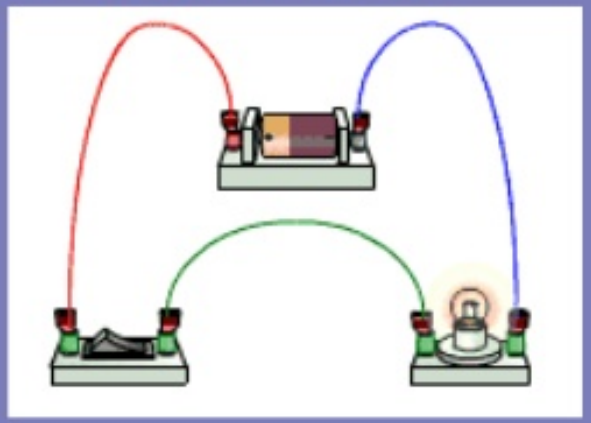
Here is a simple electric circuit. It has a cell, a lamp and a switch.



To make the circuit, these components are connected together with metal connecting wires.

simple circuits

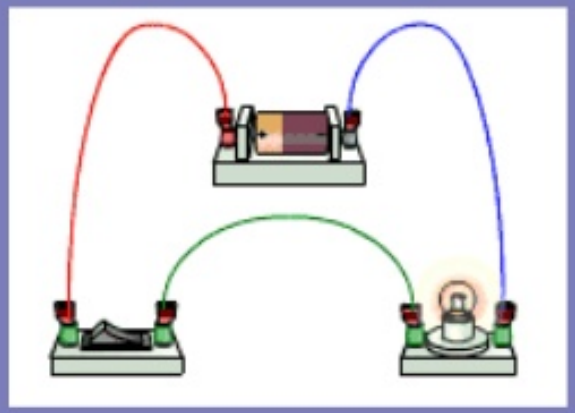
When the switch is closed, the lamp lights up. This is because there is a continuous path of metal for the **electric current** to flow around.

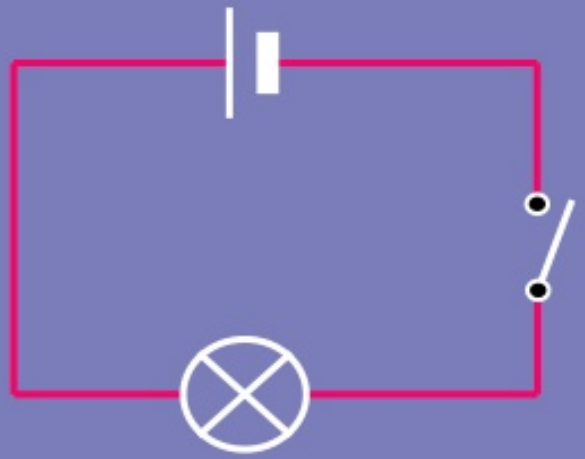


If there were any breaks in the circuit, the current could not flow.

circuit diagram

Scientists usually draw electric circuits using symbols;





cell

lamp

switch

wires

circuit diagrams

In circuit diagrams components are represented by the following symbols;


cell


battery


switch

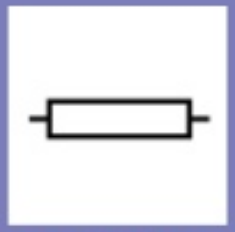

lamp

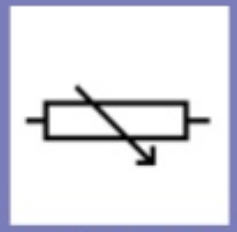

buzzer

ammeter

voltmeter

motor

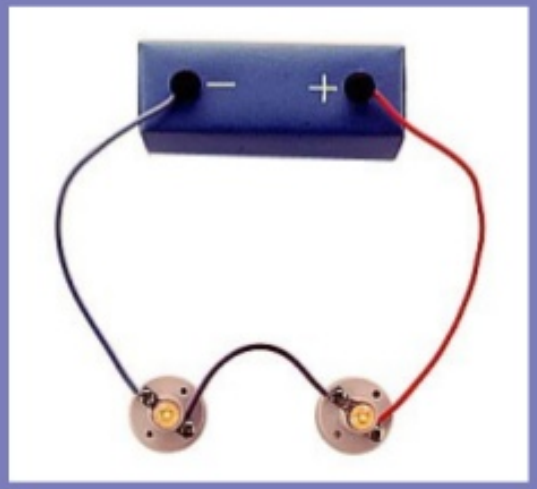

resistor


variable resistor

types of circuit

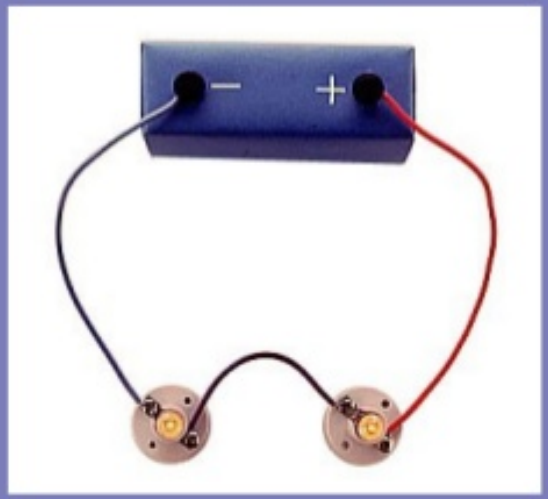
There are two types of electrical circuits;

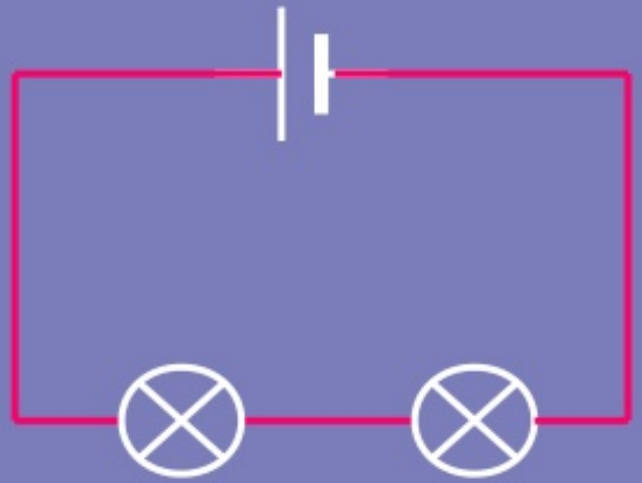
SERIES CIRCUITS



PARALLEL CIRCUITS

SERIES CIRCUITS



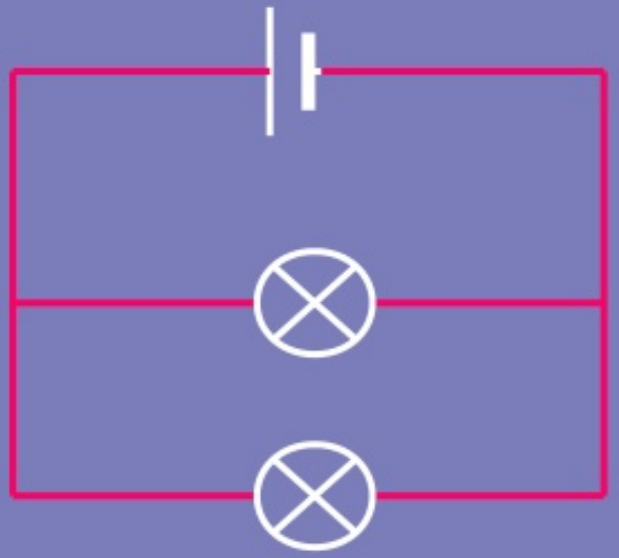


The components are connected end-to-end, one after the other.

They make a simple loop for the current to flow round.

If one bulb 'blows' it breaks the whole circuit and all the bulbs go out.

PARALLEL CIRCUITS



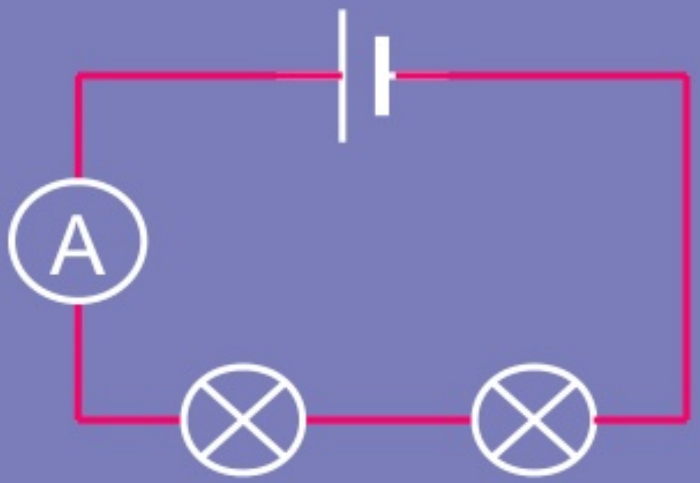
The components are connected side by side.

The current has a choice of routes.

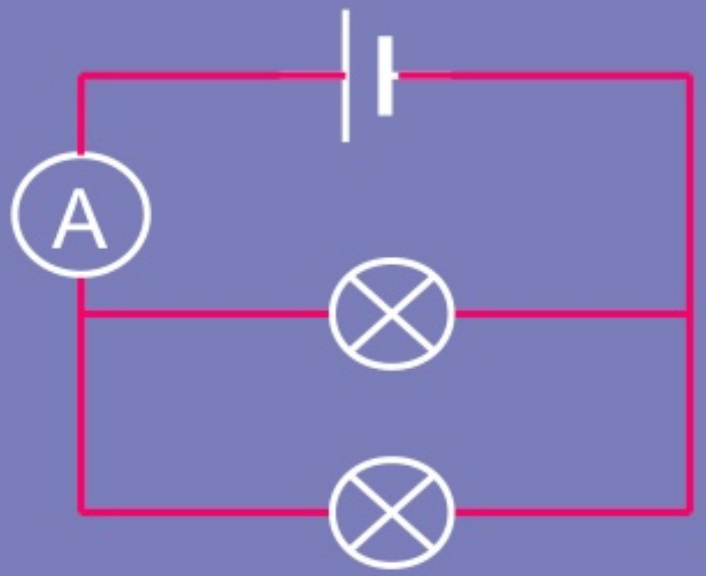
If one bulb 'blows' there is still be a complete circuit to the other bulb so it stays alight.

measuring current

This is how we draw an ammeter in a circuit.



SERIES CIRCUIT



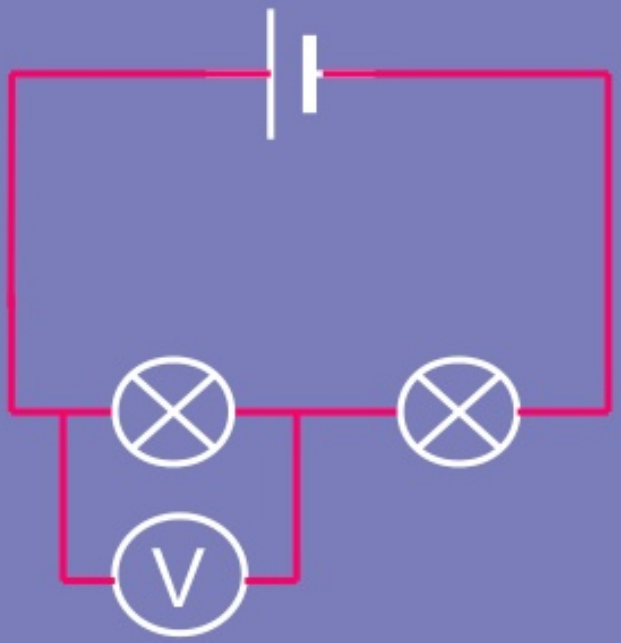
PARALLEL CIRCUIT

measuring voltage

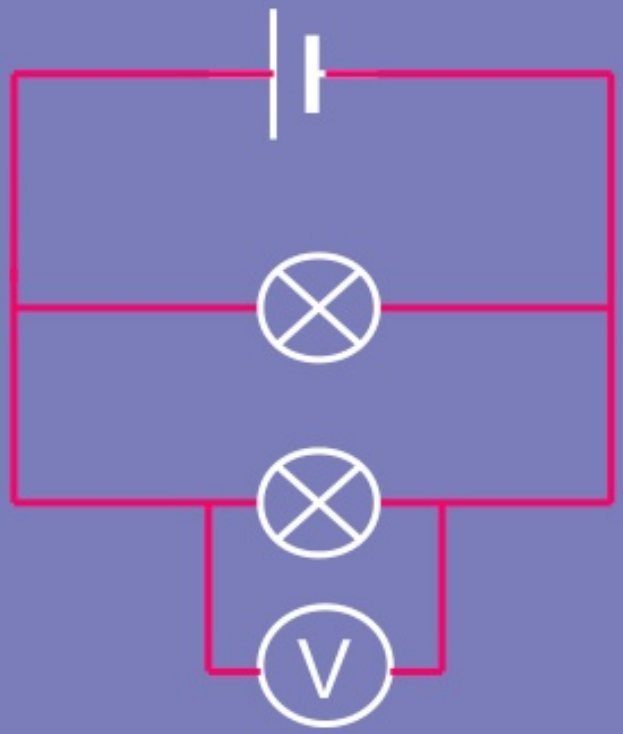
The 'electrical push' which the cell gives to the current is called the voltage. It is measured in **volts** (V) on a **voltmeter**

measuring voltage

This is how we draw a voltmeter in a circuit.



SERIES CIRCUIT



PARALLEL CIRCUIT