TOPIC: ELECTRCITY II

General Objective: The learner should be able to use the knowledge of series and parallel connection to relate resistance to the flow of current.

SUB-TOPIC: Introduction to electricity (Part 2).

SPECIFIC OBJECTIVES: The learner should be able to;

- Draw and connect electric circuits.
- Describe the effects of a resistor in an electric circuit.
- Connect a voltmeter and an ammeter in a circuit accurately.
- Investigate and draw 1V characteristics for some components in a circuit.
- Connect components in series and parallel.

ELECTRCITY II

ELECTRIC POTENTIAL, POTENTIAL DIFFERENCE AND ELECTROMOTIVE FORCE:

Electric potential.

The word **potential** refers to the ability to perform work.

If work has to be done to move charge from one point to another, the points are said to be at different **potential.**

The earth's potential is taken to be zero. The potential of any given point is equal to the work done to move a small positive charge from earth up to that point.

$$\textbf{potential} = \frac{\textbf{work done}}{\textbf{charge moved}}$$

In symbols: $\mathbf{V = \frac{W}{Q}}$

S.I unit of Electric potential is volts (V).

Definition: A volt is the work done in moving one coulomb of charge from one point to another.

DEFINITION:

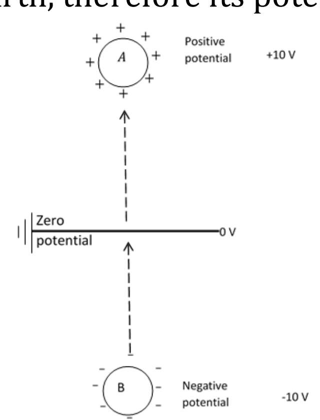
The potential in volts at any point is the work done per coulomb in bringing positive charge from earth to that point.

POSITIVE AND NEGATIVE POTENTIAL:

In the figure below, work must be done to move positive charge from earth to conductor A. Conductor A is at a higher potential than the earth, and its potential is taken as positive.

On the other hand, work must be done to move a positive charge from point B to earth.

B is at a lower potential than the earth, therefore its potential is negative.

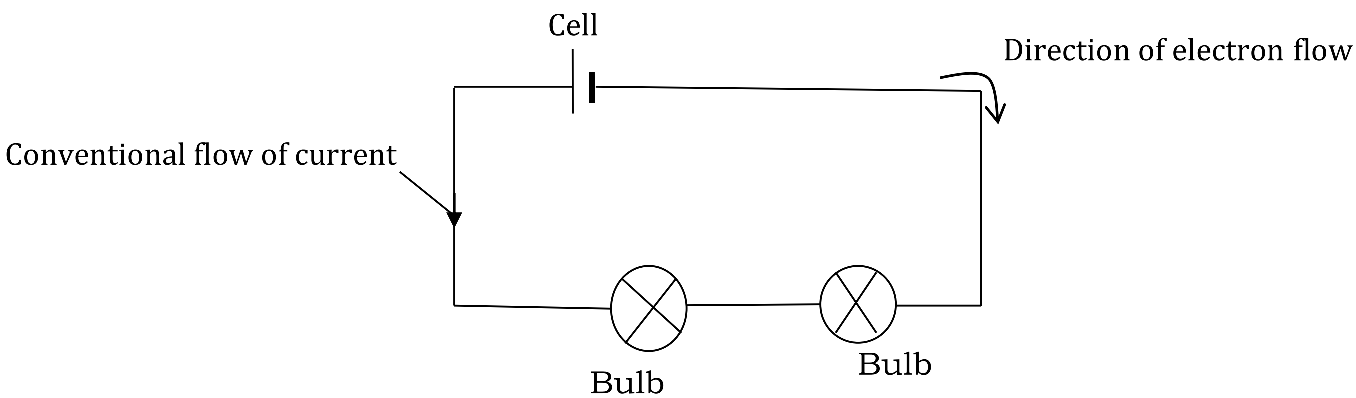


Potential difference and electron flow:
If two conductors are at different potential, there is a potential difference, or p.d between them. **Electrons** always flow **from lower to higher potential**. i.e towards the more positive potential.

Electric current flows in the **direction opposite to that of electron flow.**

Definition:
The **potential difference** between two points in an electric field or circuit is the work done in moving one coulomb of charge from one point to the other.

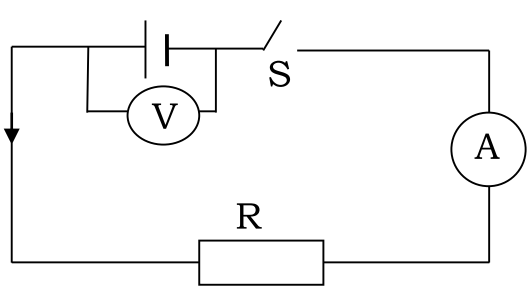
ELECTRIC CURRENT:
In a closed circuit below, charged particles called electrons move from the negative terminal of the cell to the bulb and back to the cell through the positive terminal.



The movement of electrons constitutes an electric current.

ELECTROMOTIVE FORCE (e.m.f)
The e.m.f of a cell is the potential difference between the terminals of a cell.
It is the energy the cell provides to each coulomb of charge in the circuit.
e.g a cell labelled 1.5 V gives 1.5 joules of potential difference to each coulomb of charge in the circuit. This energy is then converted to other forms of energy e.g light and heat in the lamp.

Definitions of emf
- The e.m.f of a cell is the potential difference across the terminals of a cell in an open circuit.
- The. e.m.f of a cell is the total energy per coulomb of charge available from the cell.
- The e.m.f of a cell is the total potential difference across all external devices to which the cell is supplying current in the circuit including the p.d required to drive current through the cell itself.



N.B.
The p.d across the terminals of the cell when the switch S is open is called electromotive force (e.m.f), E of the cell.
The p.d across the terminals of the cell when switch S is closed is called terminal p.d, V

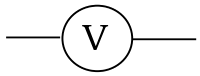
The difference between E and V i.e $E - V$ is the p.d required to drive current through the cell itself in a closed circuit. (This is p.d across the internal resistance of the cell.)

MEASUREMENT OF POTENTIAL DIFFERENCE (p.d) AND CURRENT IN CIRCUITS.

The Voltmeter.

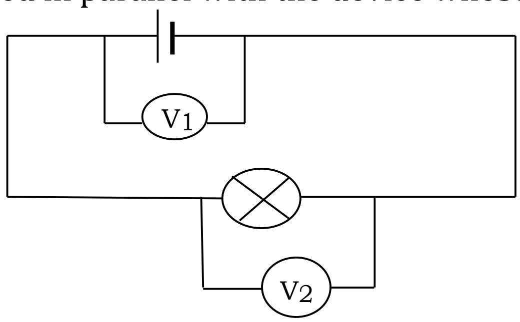
The **voltmeter** is an instrument used to measure the **potential difference** between two points. The SI unit of potential difference is the volt (V).

Symbol of a voltmeter:



Connecting a voltmeter in an electric circuit:

The Voltmeter is connected in parallel with the device whose potential difference is to be measured.



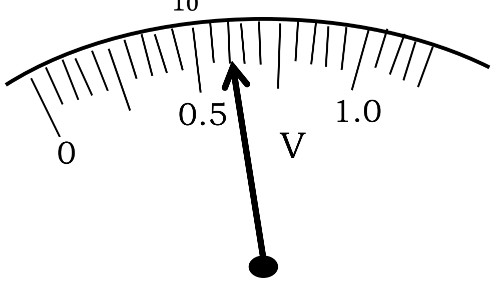
Voltmeter V_1 measures the p.d between the terminals of the cell, while V_2 measures the p.d across the bulb.

N.B. The **positive** terminal (**red in colour**) of the voltmeter is always directly or indirectly connected the positive terminal of the cell/battery, and its **negative** terminal (**black in colour**) to the negative terminal of the cell/battery.

Reading a Voltmeter.

The Voltmeters used in the laboratory have a range from 0 V - 3.0 V. There are 10 divisions between 0 V and 0.5 V.

Therefore each division represents $\frac{0.5}{10} = 0.05$ V.



The illustration above shows a voltmeter reading $= (12 \times 0.05) = 0.60$ V.

Voltmeter readings are written up to 2 decimal places and occur in multiples of 5.

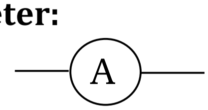
The Ammeter.

An Ammeter is an instrument used to measure the current flowing in an electric circuit.

The SI unit of current is the Ampere (A).

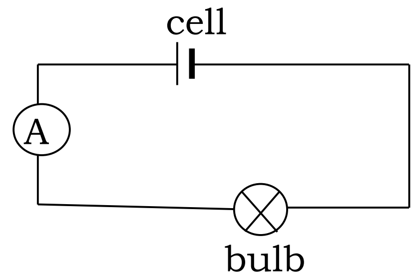
Therefore, the ammeter measures current in Amperes and it is labeled with letter A.

Symbol for the Ammeter:



Connecting an Ammeter in an electric circuit:

The ammeter is **connected in series** with the device through which current is to pass.



This ensures that the current that passes through the device is the same current that passes through the ammeter.

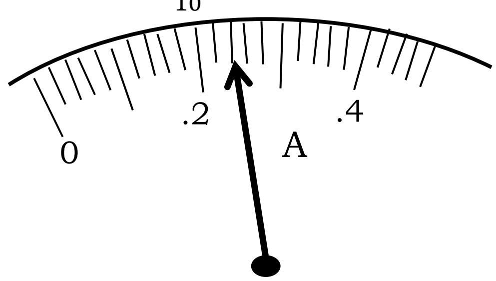
N.B. The positive terminal of the Ammeter is always directly or indirectly connected the positive terminal of the cell/battery, and its negative terminal to the negative terminal of the cell/battery.

Reading the ammeter.

The Ammeters used in the laboratory have a range from 0 A- 1.0 A.

There are 10 divisions between 0 A and 0.2 A.

Therefore each division represents $\frac{0.2}{10} = 0.02$ A.



The illustration above shows an ammeter reading $= (12 \times 0.02) = 0.24$ A.

Ammeter readings are written up to 2 decimal places and occur in multiples of 2.

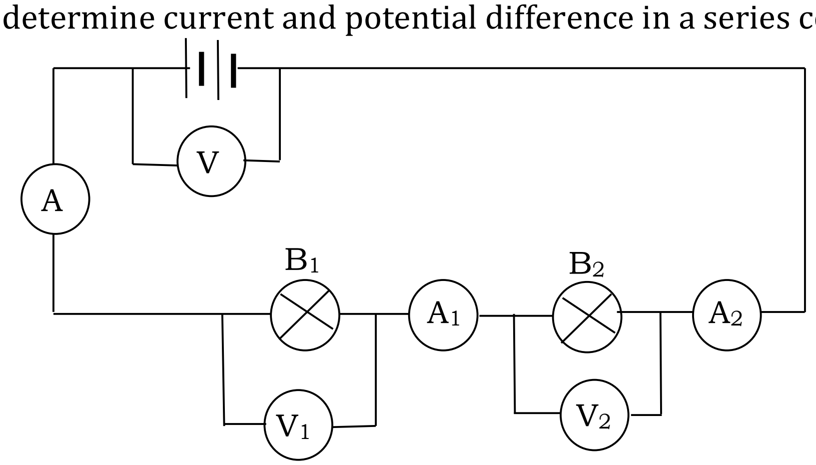
TYPES OF ELECTRIC CONNECTIONS.

There are two ways of connecting electric devices in an electric circuit.

(a) **Series connection.**

(b) Parallel connection.

Experiment: To determine current and potential difference in a series connection.



Bulbs B_1 and B_2 are connected in the circuit as shown above.

Ammeter, A measures the current in the circuit while ammeters A_1 and A_2 measure current through bulbs B_1 and B_2 respectively. Voltmeter V measures the p.d across the battery (source of e.m.f) while voltmeters V_1 and V_2 measure the p.d's across bulbs B_1 and B_2 respectively.

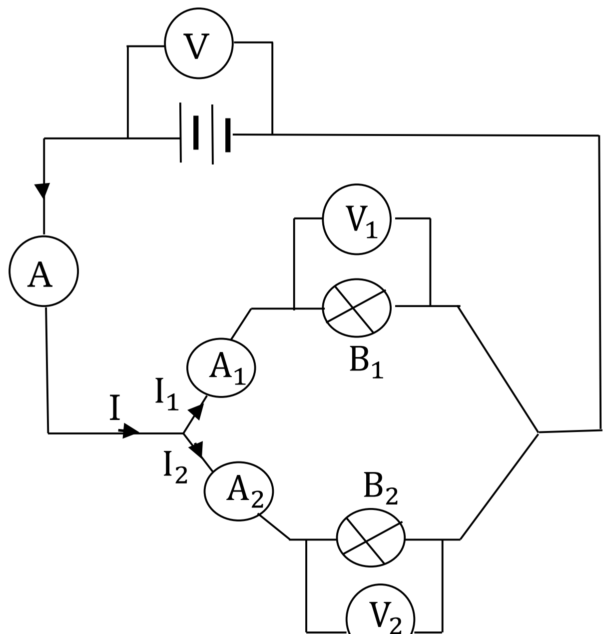
Observations will show that:

The ammeter readings of A, A_1 and A_2 are the same. This shows that the current flowing through the bulbs in series connection is the same as the current flowing through the whole circuit.

The sum of the voltmeter readings V_1 and V_2 is equal to or less than that of voltmeter reading, V. This shows that the sum of the potential differences across bulbs B_1 and B_2 is less than or equal to the total p.d or e.m.f. of the cell/battery.

i.e. $V \geq V_1 + V_2$.

Experiment: To determine current and potential difference in parallel connection.



Bulbs B_1 and B_2 are connected in parallel in the circuit as shown above.

Ammeter A measures the current in the circuit while ammeters A_1 and A_2 measure current through bulbs B_1 and B_2 respectively. Voltmeter V measures the p.d across the battery (source of e.m.f) while voltmeters V_1 and V_2 measure the p.d's across bulbs B_1 and B_2 respectively.

Observations will show that:

The sum of the current I_1 and I_2 through bulbs B_1 and B_2 respectively is the equal to the current I through the cell.

This shows that the sum of current entering a junction is equal to the sum of current leaving the same junction. i.e $I = I_1 + I_2$.

The potential difference, V across the cell/battery is the same as the potential difference V_1 or V_2 across each of the bulbs B_1 or B_2 respectively.

This shows that the potential difference across two or more components that are placed in a parallel connection is the same. i.e. $V = V_1 = V_2$.

Arrangement of Resistors.

Resistors can be arranged either in series, or in parallel.

Series connection of resistors

When the two bulbs (resistors) are connected in series, the following observations are made:

The same current flows through the bulbs/resistors.

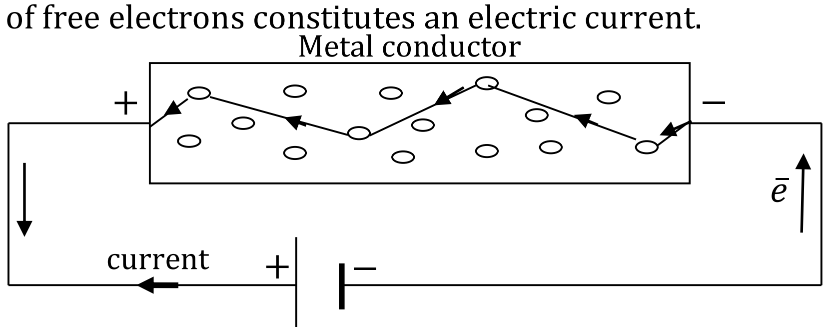
The more bulbs there are in the series connection the less bright they become; meaning that the resistance increases. (The total resistance of the series connection is equal to the sum of the individual resistances)

Parallel connection of resistors

When the two bulbs (resistors) are connected in parallel, the following observations are made:
The bulbs are brighter than those in series connection. This means that the effective resistance of the parallel connection is less than the least resistance than that of the resistor in the parallel connection)
Different amounts of current flow through each individual bulb/resistor.
The potential difference across all the bulbs/resistors is the same.

Conduction of electricity in metals:

Metal conductors have free electrons that wander randomly from atom to atom.
When a source of e.m.f is connected across the ends of the metal conductor, an electric field develops. The free electrons experience a force due to the electric field which makes them drift from a region of low potential to that of high potential of the cell.
This movement of free electrons constitutes an electric current.



RESISTANCE AND RESISTORS

The Resistance of a substance is the opposition of the substance to the flow of current through it.
S.I unit of resistance is the ohm (Ω).

Definition of an ohm

An Ohm is the resistance of the conductor which allows a current of one ampere to flow through it when the potential difference between the ends of the conductor is one volt.

A resistor is a conductor which opposes the flow of current through it.

The two common types of resistors are categorized as:

(a) Standard resistor: this is a resistor with a fixed resistance.
(b) Variable resistor (rheostat): this is a resistor whose resistance can be changed or varied.

FACTS ABOUT RESISTORS:

Resistors are used in electrical appliances like; Electric heaters, radios, TV sets, Computers, projectors, e.t.c. in order to:

(i) Limit or divide the current.
(ii) Reduce voltage.
(iii) Protect an electric circuit, or
(iv) Provide large amounts of heat as in heaters or light in bulbs.

EXPLAINING RESISTANCE USING THE KINETIC THEORY.

The atoms of metals are closely and regularly packed. These atoms vibrate to and fro about their mean positions and at constant temperature; the atoms vibrate with the same kinetic energy.
The free electrons in the metal are called conduction electrons.
When a current flows in the circuit, the electrons in motion collide with the vibrating atoms. This causes some obstruction, called resistance, to the flow of the electrons in the circuit.

FACTORS AFFECTING THE RESISTANCE OF A CONDUCTOR:

	FACTOR	EFFECT	EXPLANATION
1	Temperature.	Resistance increases with increase in temperature. i.e. $R \alpha T$	Increasing the temperature increases the rate of vibration of the atoms and their kinetic energy. This increases the collisions between the moving electrons and the atoms, hence increasing the resistance .
2	Length.	Resistance increases with increase in length. i.e. $R \alpha l$	Increasing the length of the conductor means that the moving electrons are going to collide with a great number of vibrating atoms. This in turn will increase the resistance.
3	Cross-sectional Area.	Resistance reduces with cross-sectional area of the conductor. i.e i.e. $R \alpha \frac{1}{A}$	The number of moving electrons increase with increase in the area of the conductor resulting into decrease in resistance.

Applications of resistance:

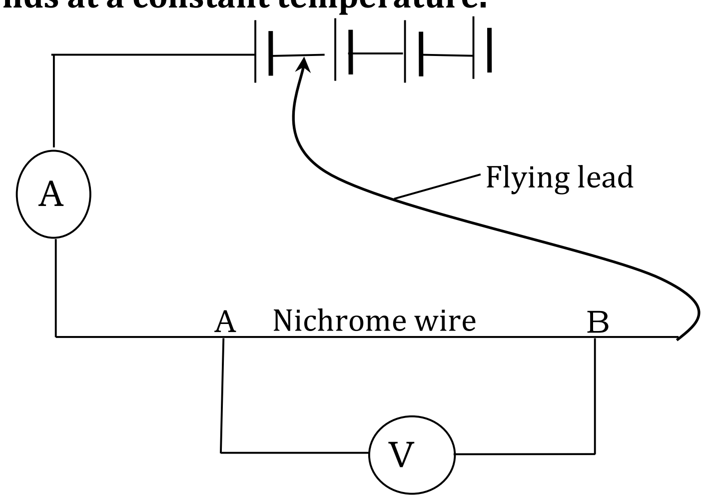
(i) The bulb filaments are made thin and long by coiling to increase their resistance. This increases their temperature resulting in large amounts of heat and light when a current flows through them.

(ii) Fuses are made thin but short to regulate their resistance and amount of current they permit to pass through them.

(iii) Heating coils are made long by coiling to increase their resistance so that they can generate a lot of heat.

I - V Characteristics.

To investigate the relationship between the current through a conduct and the potential difference across its ends at a constant temperature.

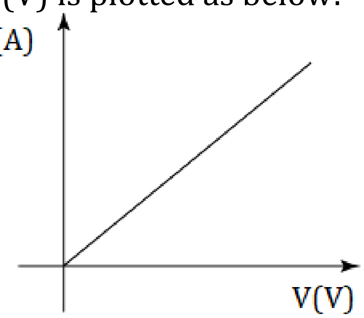


The circuit is connected as shown in the diagram above. The ammeter and voltmeter readings are recorded.
The experiment is repeated by connecting the flying lead to 2, 3 and 4 cells connected in series. The readings are read and recorded in a suitable table.
Precaution. The flying lead is disconnected as soon as each set of readings has been taken. This ensures that the Nichrome wire does not heat up (so that the temperature remains constant)

Table of results:

Number of cells	p.d across the wire (V)	Current (I)
1		
2		
3		
4		

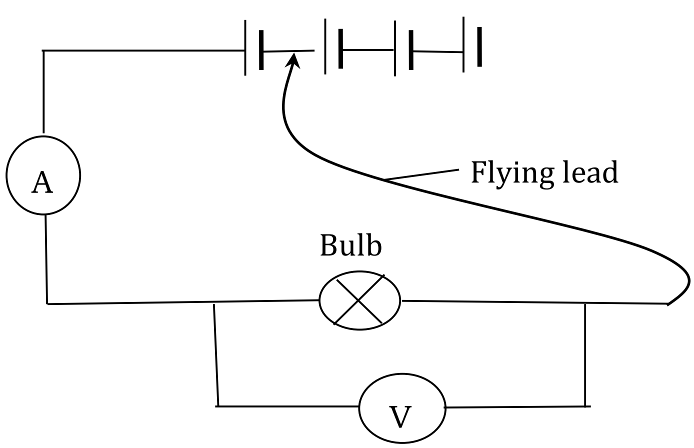
Observation:
The results show that the current increases uniformly with increase in the potential difference across the wire.
A graph of current (I) against the p.d (V) is plotted as below:



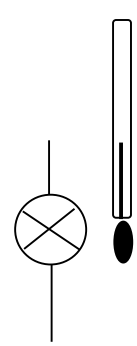
The graph is a straight line passing through the origin.
This shows that *the current is directly proportional to the applied potential differential.*

$$V \alpha I$$

Experiment 2. To investigate the I-V characteristics for a bulb (a filament lamp)
The circuit is connected as shown in the figure below. A blackened bulb of a thermometer is placed near the bulb.



(a) Circuit



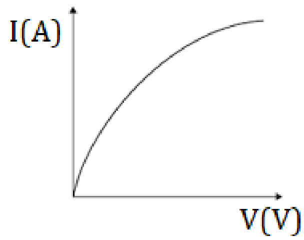
(b) thermometer near bulb

The thermometer will show an increase in temperature. When the thermometer has attained a steady reading then the ammeter reading (I), voltmeter reading (V) and thermometer reading, Θ^{o} C are recorded in a table.
The experiment is repeated by connecting the flying lead to 2, 3 and 4 cells.

Table of results:

Number of cells	p.d V (V)	Current I (A)	Temperature Ɵ (^{0}C)
1			
2			
3			
4			

The results will show that:
as the number of cells increase, the current, potential difference and the temperature all increase.
A graph of current (I) against p.d (V) is plotted as below:



The graph is non-linear (not a straight line). This means that current is not directly proportional to the potential difference in a filament lamp because the temperature does not remain constant.

SUMMARY:
Electric current is due to the movement of charged particles called electrons.
Electric circuit is the path the electrons move.
Electric current in a circuit is due to the potential difference (p.d) created by a cell.
p.d is measured using an instrument called a voltmeter.
A voltmeter is always connected in parallel with the device whose p.d is to be measured.
Electric current is measured using an instrument called the ammeter.
The ammeter is always connected in series with the device through which current is to pass.
In a series circuit, the current is the same at all points, but the p.d is split across the different components in series connection.
In a parallel circuit, the p.d is the same across all components, but the current is split.
In a metallic conductor, the current increases uniformly with the potential difference, if the temperature remains constant.
For a filament lamp, the current increases at a decreasing rate with potential difference, since the temperature of the filament increases.

THE END.

Attempt Revision exercise 5 on pages 113-117 in Longhorn book two.