CURRENT ELECTRICITY

Current electricity is the flow of charged particles from one point to another e.g. electrons.
Electrical devices which use electricity are called electrical appliances.
Sources of electricity/emf include;

- Batteries
- Generators
- Solar panels/solar energy.
- Wind mills

TERMS USED IN ELECTRICITY;

CHARGE(Q):
This is the quantity of electricity which passes any point in a conductor.
The SI unit of charge is a coulomb (**C**).

ELECTRIC CURRENT (I):
Charges move from one point to another in a given time. This rate of flow is called electric current.
Definition:
Electric current is the rate of flow of charge in a conductor.
The SI unit of current is the ampere (**A**).

$$Current\ (\boldsymbol{I}) = \frac{Charge\ (\boldsymbol{Q})}{Time\ (\boldsymbol{t})}$$

$$\boxed{\boldsymbol{I} = \frac{\boldsymbol{Q}}{\boldsymbol{t}}}$$

Note:
- The time should always be in seconds.
- Current is measured by an instrument called an ammeter.

Definition:
An **ampere** is the constant current when a charge of 1C flows in a conductor in one second.
OR
An **ampere** is current which when flowing in two straight parallel wires of infinite length placed one meter apart in a vacuum produce a force of $2 \times 10^{-7} Nm^{-1}$ on each of the wires.

But also $\boldsymbol{Q = It}$ implying that $\boldsymbol{1C = 1A \times 1s}$
Definition:
A **coulomb** is the quantity of charge which passes any point of a conductor in one second when a current of one ampere is flowing in the conductor.

Other units of current include;
$1mA = 1 \times 10^{-3} A$
$1\mu A = 1 \times 10^{-6} A$

Examples:

1. A current of 6A flows for 2 hours in a circuit. Calculate the quantity of electricity that flows in this time.

$$Q = It$$
$$Q = 6 \times 2 \times 3600$$
$$Q = 43200\text{C}$$

2. A charge of 2550C flows past a point in a circuit in 25minutes. Find the current flowing.

$$Q = 2550C, \quad t = 25mins = 25 \times 60 = 1500s$$
$$Q = It$$
$$2550 = \text{I} \times 1500$$
$$\text{I} = \frac{2550}{1500}$$
$$\text{I} = 1.7\text{A}$$

3. A current of 6mA flows for 2 hours in a circuit. Find the quantity of charge.

$$Q = ?, \quad t = 2\ hrs = 2 \times 3600 = 7200s, \quad I = 6mA = \frac{6}{1000} = 0.006A$$
$$Q = It$$
$$Q = 0.006 \times 7200$$
$$Q = 43.2\text{C}$$

4. A charge of 20 kC crosses two sections of a conductor in 1minute. Find the current through the conductor.

$$Q = 20kC = 20 \times 1000 = 20000C, \quad t = 1min = 1 \times 60 = 60s$$
$$Q = It$$
$$20000 = \text{I} \times 60$$
$$\text{I} = \frac{20000}{60}$$
$$\text{I} = 333.3\text{A}$$

POTENTIAL DIFFERENCE (p.d):

This is the work done in joules when one coulomb of charge moves from one point to another in a circuit.

If two points in a conductor are of different electric potentials, then a charge can move from one point to another and work is said to be done. Potential difference is sometimes referred to as **voltage**.

The instrument used to measure potential difference is a voltmeter.

The SI unit of potential difference is the Volt (**V**).

Definition:

A **volt** is the potential difference between two points in a circuit when one joule of work is done to move one coulomb of charge from one point to another.

ELECTROMOTIVE FORCE (emf):

This is the work done in joules when one coulomb of charge moves from one point to another in a circuit in a cell is connected.

The SI unit of emf is the Volt (**V**).

Sources of emf include; cells, generators, solar cells etc.

ELECTRICAL RESISTANCE (R):
This is the opposition to flow of current in a conductor.
The SI unit of resistance is an ohm (**Ω**).
Definition:
An **Ohm** is the resistance of a conductor in which a current of 1A flows when a potential difference of one volt is applied across its ends.

INTERNAL RESISTANCE OF A CELL (r):
This is the opposition to flow of current within the cell.

FACTORS THAT AFFECT RESISTANCE OF A CONDUCTOR:

(i) Length:
The resistance of a conductor is directly proportional to the length of a conductor ($R \propto L$). Resistance of a conductor increases when its length increase. Therefore, the shorter the wire, the lower the resistance and the longer the wire, the higher the resistance.

(ii) Cross-sectional area:
The resistance of a conductor is inversely proportional to its cross-sectional area. ($R \propto \frac{1}{A}$).
Thin wires have a high resistance while thicker wires have a low resistance.

(iii) Temperature:
The resistance of a pure metals like copper increase when their temperatures increase.

(iv) Nature of conductor:
Good conductors like metals have a lower resistance compared to the bad conductors.

Note; The first two factors can be combined as

$$\boldsymbol{R \propto \frac{L}{A}}$$

$$\boldsymbol{R = \rho\frac{L}{A}}$$

$$where\ \boldsymbol{\rho}\ is\ resistivity\ in\ \boldsymbol{\Omega m}$$

Examples:

1. A conductor of length 20m has a cross sectional area of $2 \times 10^{-4}m^2$. Its resistance is 0.6Ω. Find the resistivity of the conductor.

$$\boldsymbol{R = \rho\frac{L}{A}}$$

$$\boldsymbol{0.6 = \rho \times \frac{20}{2 \times 10^{-4}}}$$

$$\boldsymbol{\rho = \frac{0.6 \times 2 \times 10^{-4}}{20}}$$

$$\boldsymbol{\rho = 6 \times 10^{-4}\Omega m}$$

2. A wire of cross-sectional area of $0.002m^2$ and length 2m has its resistivity as $1.0\ x10^{-7}\ \Omega m$. What is its resistance?

$$\boldsymbol{R = \rho\frac{L}{A}}$$

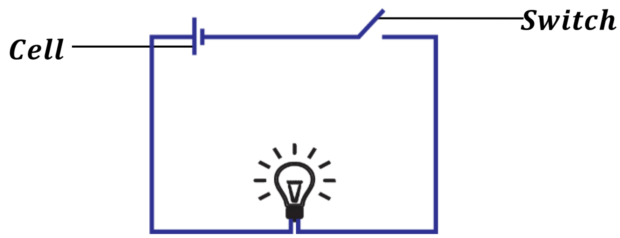
$$\boldsymbol{R = 1.0 \times 10^{-7} \times \frac{2}{0.002} = 0.0001\Omega}$$

ELECTRIC CIRCUIT:

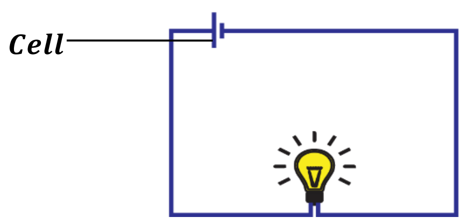
This is the path followed by current.

Types of circuits include;

- **Open circuit**: This a circuit in which current is not flowing to the external circuit.



- **Closed circuit**: This is a circuit in which current is flowing to the external circuit.

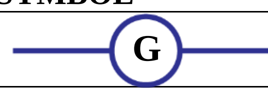
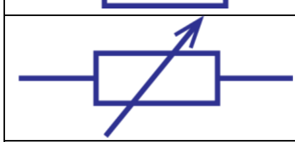
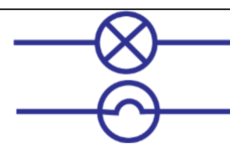
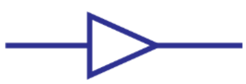
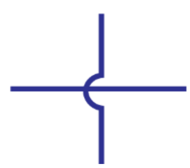
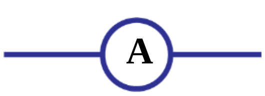
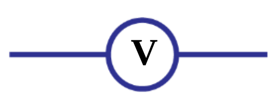


Note:

A **short circuit** is a low resistance path for the flow of current.

It occurs when two points in a circuit are directly connected so that current flows through a shorter distance. This increases the flow of current hence damaging the circuit.

ELECTRICAL SYMBOLS IN ELECTRICAL CIRCUITS.

SYMBOL	NAME	SYMBOL	NAME
	**Standard resistor**		**Galvanometer**
	**Variable resistor (Rheostat)**		**Alternating current supply**
	**Switch**		**Bulbs/lamps**
	**Cell**		**Capacitor**
	**Diode**		**Crossing wires**
	**Battery/accumulator**		**Connected wires**
	**Ammeter**		**Voltmeter**

OHM'S LAW

It states that current flowing through a metallic conductor is directly proportional to the potential difference across its ends provided temperature and other physical conditions are remain constant.

$$p.d \propto current$$
$$V \propto I$$
$$V = RI$$
$$\boxed{V = IR}$$

Where **R**-resistance of conductor.
V-potential difference.
I-current.

Examples:

1. Calculate the potential difference across a 10Ω resistor carrying a current of 2A.

$$V = IR$$
$$V = 2 \times 10$$
$$V = 20V$$

2. The voltage across a 2Ω resistor is 4V. What is the current flowing?

$$V = IR$$
$$4 = I \times 2$$
$$I = \frac{4}{2}$$
$$I = 2A$$

3. Find the potential difference across a conductor of resistance 2Ω if the charge of 180C flows for 2 minutes.

$$R = 2\Omega, \quad Q = 180C, \quad t = 2mins = 2 \times 60 = 120s$$

$$\text{But } I = \frac{Q}{t}$$
$$I = \frac{180}{120}$$
$$I = 1.5A$$

$$V = IR$$
$$V = 1.5 \times 2$$
$$V = 3V$$

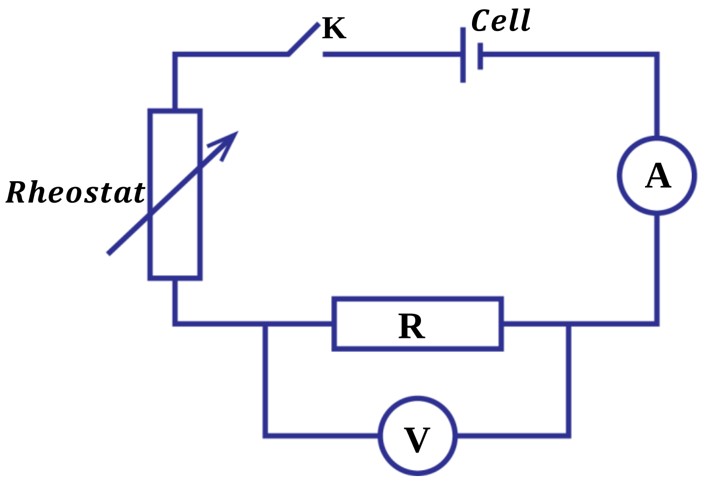
4. What voltage is needed to make a current of 0.4A flow through when the appliance has resistance of 20Ω?

$$V = IR$$
$$V = 0.4 \times 20$$
$$V = 8V$$

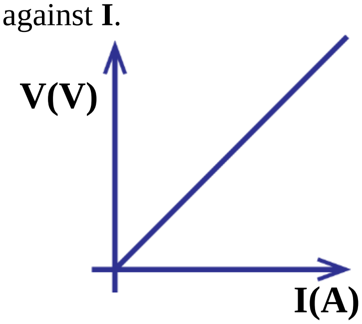
5. A current of 4A flows through an electric kettle when the p.d. across it is 8V. Find the resistance.

$$V = IR$$
$$8 = 4 \times R$$
$$R = \frac{8}{4}$$
$$R = 2\Omega$$

Experiment to verify ohm's law.



- The circuit is connected as shown above.
- Switch **K** is closed and the current flows through the circuit.
- Read and record the ammeter and voltmeter readings I and V respectively.
- The rheostat is adjusted to obtain several values of I and V and the results are tabulated.
- Plot a graph of **V** against **I**.



- A straight line is obtained showing that potential difference, V is directly proportional to current, I.

Limitations of ohm's law:
- The law only applies when the physical conditions of a conductor are constant e.g. temperature.
- The law doesn't apply to semiconductors e.g. diodes and electrolytes.

OHMIC AND NON OHMIC CONDUCTORS

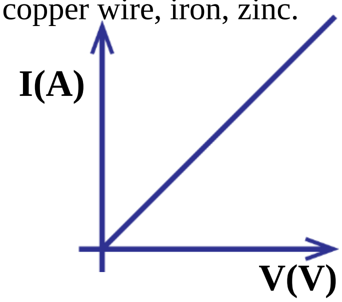
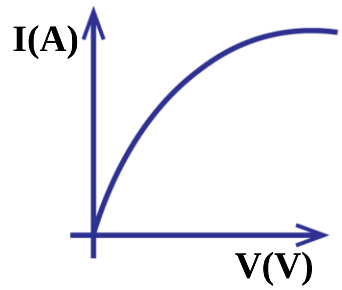
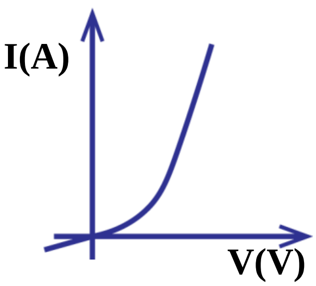
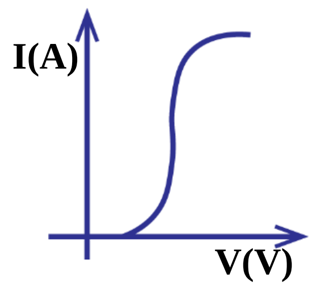
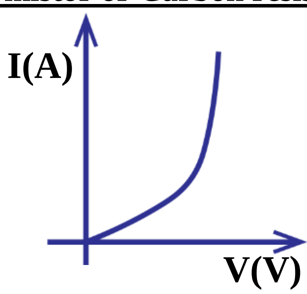
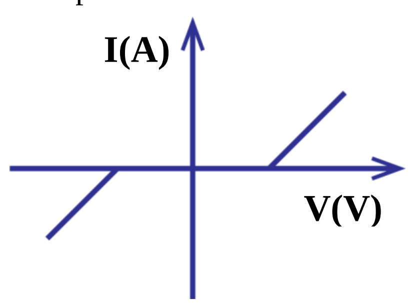
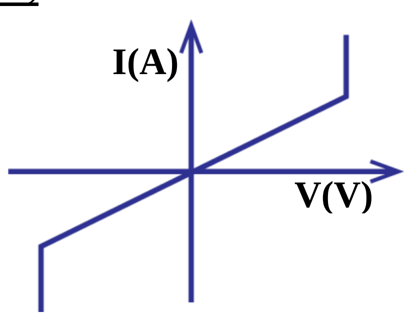
Ohmic conductors:

These are conductors which obey ohm's law.
They include; metals e.g. copper, iron. Zinc etc.
When a graph of I against V is plotted, a straight line is obtained.

Non-ohmic conductors:

These are conductors which do not obey ohm's law.
They include; filament lamps, diodes, neon gas etc.
When a graph of I against V is plotted, a non-straight line is obtained.

Graphs of current against voltage for different conductors (characteristic curves):

<table>
<tr>
<td><u>Ohmic conductor</u>;
e.g. copper wire, iron, zinc.
</td>
<td><u>Filament lamp</u>;
</td>
</tr>
<tr>
<td><u>Semi-conductor diode</u>;
</td>
<td><u>Vacuum or Thermionic diode</u>;
</td>
</tr>
<tr>
<td><u>Thermistor or Carbon resistor</u>;
</td>
<td rowspan="2"><u>Electrolyte</u>;
e.g. dilute sulphuric acid
</td>
</tr>
<tr>
<td><u>Neon gas;</u>
</td>
</tr>
</table>

CIRCUITS CONNECTION

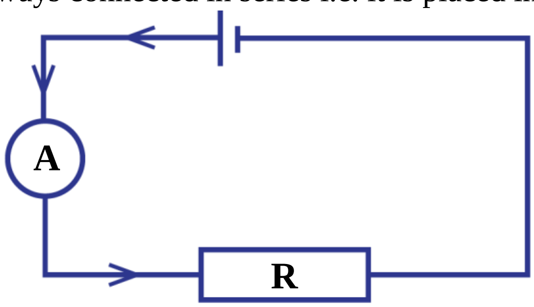
Ammeter:

This is an electrical device used to measure current in a physics laboratory.
An ammeter has a very low resistance i.e. **0**Ω

QN: Why is an ammeter constructed with a low resistance.

To allow all the current to be accurately measured without being affected by the resistance. The low resistance ensures that all the current to be measured passes through the ammeter without being opposed/resisted.

The ammeter is always connected in series i.e. it is placed in the path of current.



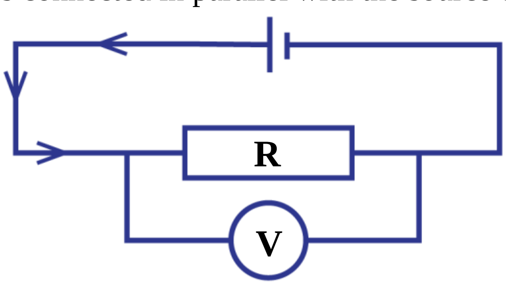
Ammeter:

This is an electrical device used to measure potential difference or voltage in a physics laboratory.
A voltmeter has a very high resistance.

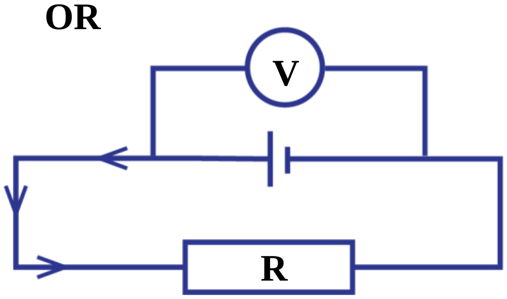
QN: Why is a voltmeter constructed with a very high resistance.

It has a very high resistance so as to draw a very low current from the source thus not affecting the total current in the circuit.

The voltmeter is always connected in parallel with the source of current.



OR



RESISTORS

A **resistor** is a device which opposes the flow of current in a circuit.
In a circuit, resistors are either arranged in series or in parallel.

Types of resistors:

(i) **Standard resistors:**

These are resistors whose resistances are known e.g. $2\Omega, 5\Omega, 10\Omega$ etc.

(ii) **Variable resistors/Rheostats:**

These are resistors whose resistances can be varied by moving a slider.
The amount of current in the circuit can be varied by adjusting the rheostat.

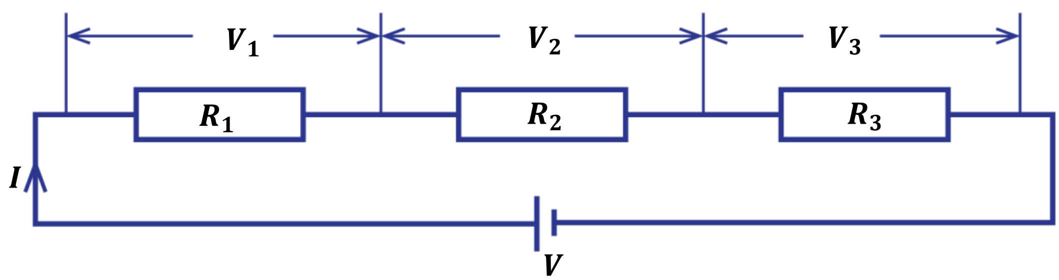
Series arrangement of resistors:

Resistors are said to be in series if they are connected end to end so that the same current passes through them.

Note: In series;

- The same amount of current flows through each resistor.
- P.d or voltage across each resistor is different.
- Total voltage is equal to sum of individual voltages across each resistor.

Consider three resistors $\boldsymbol{R_1, R_2}$ *and* $\boldsymbol{R_3}$ connected in series across a potential difference, **V.**



$$V = V_1 + V_2 + V_3$$

$$from\ ohm's\ law\ V = IR \quad i.e. V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$$

$$IR = IR_1 + IR_2 + IR_3$$

$$IR = I(R_1 + R_2 + R_3)$$

$$\frac{IR}{I} = \frac{I(R_1 + R_2 + R_3)}{I}$$

$$\boxed{\mathrm{R} = \mathrm{R_1} + \mathrm{R_2} + \mathrm{R_3}}$$ **Effective resistance**

Note:

All electrical appliances e.g. lamps, bulbs etc. connected in series have the same amount of current flowing through them.

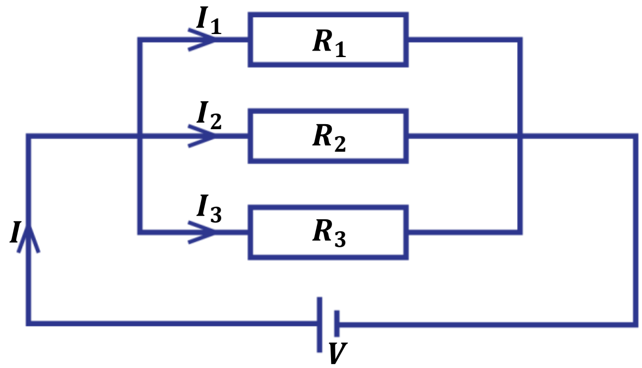
Parallel arrangement of resistors:

Resistors are said to be in parallel if they are connected side by side with their adjacent ends joined together at a common point.

Note: In parallel;

- P.d across each resistor is the same.
- Current flow in the circuit splits and therefore, current through each resistor is different.
- Total current is equal to sum of individual currents through each resistor.

Consider three resistors $\boldsymbol{R_1}, \boldsymbol{R_2}$ *and* $\boldsymbol{R_3}$ connected in parallel across a potential difference, **V.**



$$I = I_1 + I_2 + I_3$$

$$\text{from ohm's law } V = IR \quad i.e.\, I = \frac{V}{R}, I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

dividing through by $\boldsymbol{V}$ *on both sides*

$$\boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$ Where **R** is **Effective resistance**

Note:

For two resistors connected in parallel;

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\boxed{R = \frac{R_1 R_2}{R_1 + R_2}}$$

Therefore, effective resistance,

$$R = \frac{Product}{Sum}$$

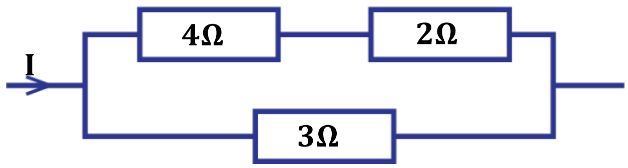
Examples:

Find the effective resistance in the following diagrams.

(i)

$$R = R_1 + R_2$$
$$R = 10 + 11$$
$$R = 21\Omega$$

(ii)



$for\ series\ connection;$

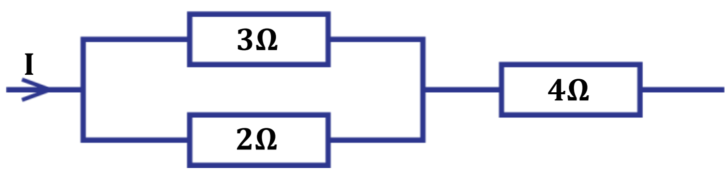
$$R_s = R_1 + R_2$$
$$R_s = 4 + 2$$
$$R_s = 6\Omega$$

$for\ parallel\ connection;$

$$\frac{1}{R} = \frac{1}{R_s} + \frac{1}{R_3}$$
$$\frac{1}{R} = \frac{1}{6} + \frac{1}{3}$$
$$\frac{1}{R} = \frac{3}{6}, \qquad R = \frac{6}{3}$$

$effective\ resistance, R = 2\Omega$

(iii)



$for\ parallel\ connection;$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{2}$$
$$\frac{1}{R_p} = \frac{5}{6}, \qquad R_p = \frac{6}{5}$$
$$R_p = 1.2\Omega$$

$for\ series\ connection;$

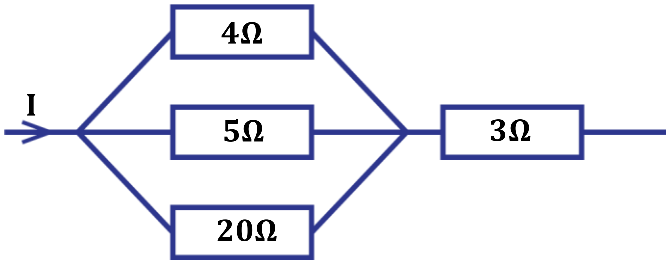
$$R = R_p + R_3$$
$$R = 1.2 + 4$$

$effective\ resistance, R = 5.2\Omega$

OR

$$effective\ resistance, R = \frac{R_1 R_2}{R_1 + R_2} + R_3$$
$$R = \frac{3 \times 2}{3 + 2} + 4$$
$$R = 1.2 + 4$$
$$R = 5.2\Omega$$

(iv)



for parallel connection;

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

$$\frac{1}{R_p}=\frac{1}{4}+\frac{1}{5}+\frac{1}{20}$$

$$\frac{1}{R_p}=\frac{10}{20},\qquad R_p=\frac{20}{10}$$

$$R_p=2\Omega$$

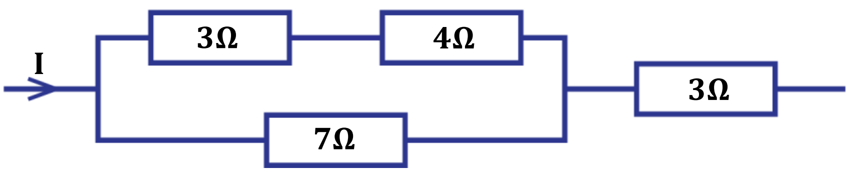
for series connection;

$$R=R_p+R_3$$

$$R=2+3$$

$$effective\ resistance, R=5\Omega$$

(v)



for series connection;

$$R_s=R_1+R_2$$

$$R_s=3+4$$

$$R_s=7\Omega$$

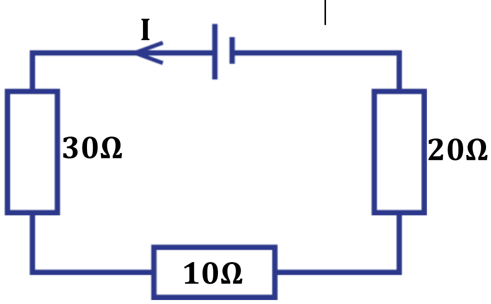
$$then\ R=\frac{R_sR_2}{R_s+R_2}+R_3$$

$$R=\frac{7\times 7}{7+7}+3$$

$$R=3.5+3$$

$$R=6.5\Omega$$

(vi)

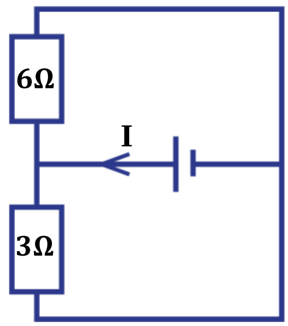


$$R=R_1+R_2+R_3$$

$$R=30+10+20$$

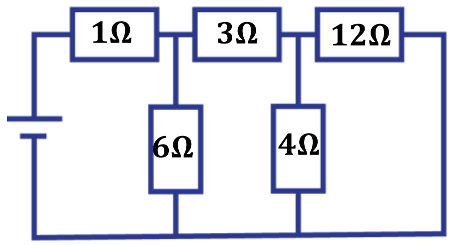
$$R=60\Omega$$

(vii)



$$R = \frac{R_1R_2}{R_1 + R_2}$$
$$R = \frac{6 \times 3}{6 + 3}$$
$$R = 2\Omega$$

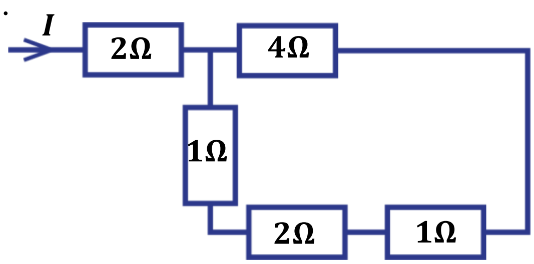
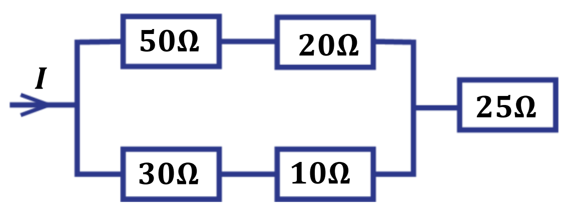
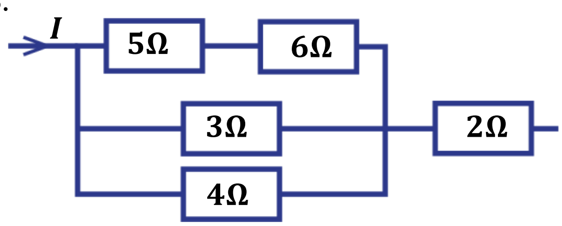
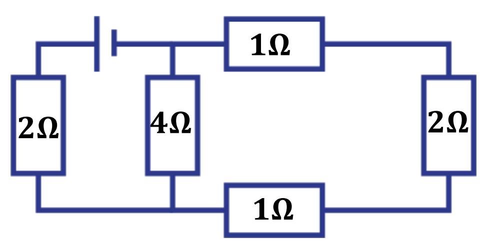
(viii)



$$R = R_1 + \frac{R_2R_3}{R_2 + R_3} + \frac{R_4R_5}{R_4 + R_5}$$
$$R = 1 + \frac{3 \times 6}{3 + 6} + \frac{4 \times 12}{4 + 12}$$
$$R = 1 + 2 + 3$$
$$R = 6\Omega$$

<u>EXERCISE</u>:

Find the effective resistance in the following diagrams.

1. 	2. 
3. 	4. 

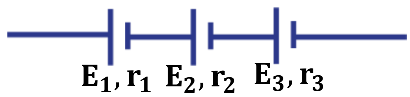
CONNECTION OF CELLS:

Cells provide us with emfs and these emfs can be arranged in series or in parallel.

Series arrangement of cells:

Cells are said to be in series if the positive terminal of one cell is connected to negative terminal of another cell.
The total emf of the cells is equal to the sum of individual emfs.

Consider three cells each of emf, **E** and internal resistance, **r** connected in series as shown below.

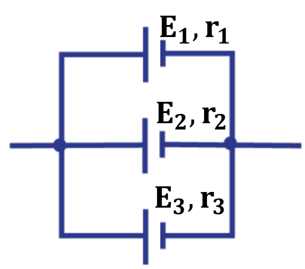


$$Total\ emf,\quad E = E_1 + E_2 + E_3$$
$$Total\ internal\ resistance,\quad r = r_1 + r_2 + r_3$$

Parallel arrangement of cells:

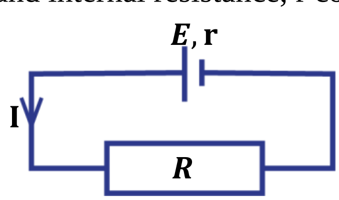
Cells are said to be in parallel if the positive terminals of the cells are connected to one point and the negative terminals of cells are connected to another point.
The total emf is equal to one of the emfs of the cell.

Consider three cells each of emf, **E** and internal resistance, **r** connected in series as shown below.



$$Total\ emf,\quad E = E_1 = E_2 = E_3$$
$$Total\ internal\ resistance,\quad \frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

Note:
Consider a cell of emf, E and internal resistance, r connected in series to a standard resistor, R.



$$total/effective\ resistance = (R + r)$$
$$from\ ohm's\ law\quad V = IR$$
$$therefore\quad E = I(R + r)$$
$$E = IR + Ir$$

$$\boxed{E = IR + Ir}$$

Terminal p.d **lost p.d due to internal resistance**

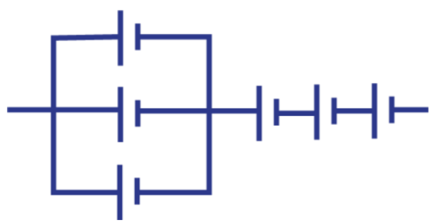
Definition:
Terminal p.d is the voltage across the terminals of a cell when current is being delivered to an external circuit.
QN: Explain why terminal p.d is less than the actual emf of a cell.
Terminal p.d is always less than the emf because of the opposition to flow of current within a cell i.e. internal resistance.

EXAMPLES:
1. Find the total emf and total internal resistance in the following circuits if each cell has an emf of 1.5V and internal resistance of 1Ω

(i) 

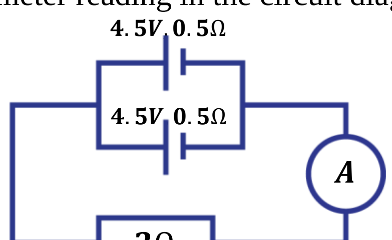
Total emf,	Total internal resistance,
$E = E_1 + E_2 + E_3$	$r = r_1 + r_2 + r_3 + r_4$
$E = 1.5 + 1.5 + 1.5 + 1.5$	$r = 1 + 1 + 1 + 1$
$E = 6V$	$r = 4\Omega$

(ii)



Total emf,	Total internal resistance,
$E = 1.5 + 1.5 + 1.5 + 1.5$	$r = \left[\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}\right] + r_4 + r_5 + r_6$
$E = 6V$	$r = \left[\frac{1}{1} + \frac{1}{1} + \frac{1}{1}\right] + 1 + 1 + 1$
	$r = 6\Omega$

2. Find the ammeter reading in the circuit diagram below.



$total\ emf, E = 4.5V$

$total\ internal\ resistance, r = \frac{0.5 \times 0.5}{0.5 + 0.5}$

$r = 0.25\Omega$

$effective\ resistance, R = 2\Omega$

$E = I(R + r)$

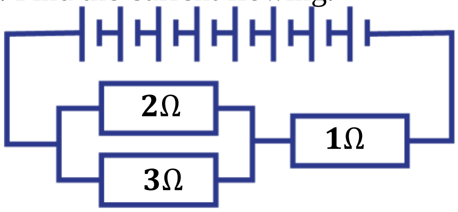
$4.5 = I(2 + 0.25)$

$4.5 = I(2.25)$

$I = \frac{4.5}{2.25}$

$Ammeter\ reading\ I = 2A$

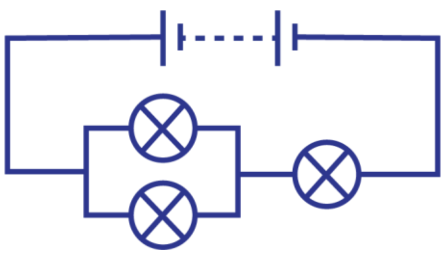
3. Eight identical cells each of emf 1.5V and internal resistance 0.1Ω are connected in a circuit as shown below. Find the current flowing.



$$total\ emf, \boldsymbol{E = 1.5 \times 8 = 12V}$$
$$total\ internal\ resistance, \boldsymbol{r = 0.1 \times 8}$$
$$\boldsymbol{r = 0.8\Omega}$$
$$effective\ resistance, \boldsymbol{R = \frac{R_1R_2}{R_1 + R_2} + R_3}$$
$$\boldsymbol{R = \frac{2 \times 3}{2 + 3} + 1}$$
$$\boldsymbol{R = 1.2 + 1}$$
$$\boldsymbol{R = 2.2\Omega}$$

$$\boldsymbol{E = I(R + r)}$$
$$\boldsymbol{12 = I(2.2 + 0.8)}$$
$$\boldsymbol{12 = I(3)}$$
$$\boldsymbol{I = \frac{12}{3}}$$
$$current\ \boldsymbol{I = 4A}$$

4. A battery of 4 cells each of emf 1.5V and negligible internal resistance are connected in the circuit with 3 bulbs each of resistance 0.8Ω. Calculate the current flowing in the circuit.



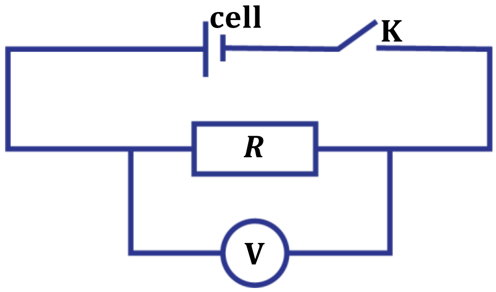
$$total\ emf, \boldsymbol{E = 1.5 \times 4 = 6V}$$
$$total\ internal\ resistance, \boldsymbol{r = 0\Omega}$$
$$effective\ resistance, \boldsymbol{R = \frac{R_1R_2}{R_1 + R_2} + R_3}$$
$$\boldsymbol{R = \frac{0.8 \times 0.8}{0.8 + 0.8} + 0.8}$$
$$\boldsymbol{R = 0.4 + 0.8}$$
$$\boldsymbol{R = 1.2\Omega}$$

$$\boldsymbol{E = I(R + r)}$$
$$\boldsymbol{6 = I(1.2 + 0)}$$
$$\boldsymbol{6 = I(1.2)}$$
$$\boldsymbol{I = \frac{6}{1.2}}$$
$$current\ \boldsymbol{I = 5A}$$

EXPERIMENT TO DETERMINE INTERNAL RESISTANCE OF A CELL

Method 1: Using a voltmeter and standard resistor

- Measure the emf, E of the cell by connecting the terminals of the cell to the voltmeter.
- Connect a cell in series with a switch, K and a standard resistor, R.
- Connect a voltmeter across the standard resistor as shown below.

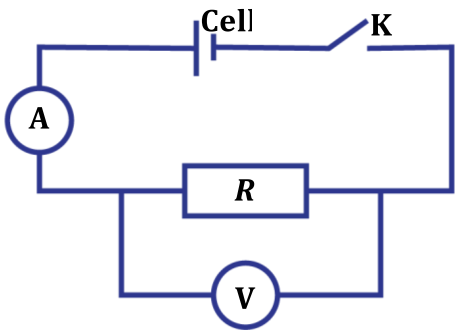


- Switch, K is then closed and the voltmeter reading V is noted and recorded.
- The internal resistance, r is got from $\boldsymbol{r} = \frac{\boldsymbol{R(E-V)}}{\boldsymbol{V}}$

$\boldsymbol{E = IR + Ir}$
$from\ Ohm's, law$
$\boldsymbol{V = IR}\ and\ \boldsymbol{I} = \frac{\boldsymbol{V}}{\boldsymbol{R}}$
$then\ \boldsymbol{E = V} + \frac{\boldsymbol{V}}{\boldsymbol{R}}\boldsymbol{r}$
$therefore, \boldsymbol{r} = \frac{\boldsymbol{R(E-V)}}{\boldsymbol{V}}$

Method 2: Using a voltmeter, ammeter and standard resistor

- Measure the emf, E of the cell by connecting the terminals of the cell to the voltmeter.
- Connect a cell in series with a switch, K, an ammeter, A and a standard resistor, R.
- Connect a voltmeter across the standard resistor as shown below.



- Switch, K is then closed and the ammeter and voltmeter readings **I** and **V** are noted and recorded.
- The internal resistance, **r** is got from $\boldsymbol{r} = \frac{\boldsymbol{E-V}}{\boldsymbol{I}}$

$\boldsymbol{E = IR + Ir}$
$from\ Ohm's, law$
$\boldsymbol{V = IR}$
$then\ \boldsymbol{E = V + Ir}$
$therefore, \boldsymbol{r} = \frac{\boldsymbol{E-V}}{\boldsymbol{I}}$

ELECTRICAL ENERGY AND POWER

ELECTRICAL ENERGY:

Electrical energy is the work done in moving an electric charge by an electric force.
The SI unit of electrical energy is the Joule (**J**)
This electrical energy is accompanied with a rise in temperature so this energy may be given out as heat energy.
This explains why wires become hot when electricity passes through them.

QN: Explain electrical wires (metals) heat up when electricity passes through them.

As current is switched on, electrons start moving through the wire. Due to resistance of the wire, the electrons are opposed from moving and they collide with the molecules of the wire. They lose some of their kinetic energy to the molecules of the wire which causes a rise in temperature (heat energy).

Simple derivations for work done

$$Work\ done = potential\ difference \times charge$$
$$W = QV$$
$$but\ Q = \text{It}$$
$$\boxed{\boldsymbol{W = VIt}} \text{ - - - - - - - - - (1)}$$

$$But\ from\ Ohm's\ law\ V = IR\ (substitute\ in\ equation\ 1)$$
$$then\ \ W = IR \times I \times t$$
$$\boxed{\boldsymbol{W = I^2Rt}}$$

$$But\ from\ Ohm's\ law\ V = IR\ \implies I = \frac{V}{R}\ \ (substitute\ in\ equation\ 1)$$
$$thus\ \ W = V \times \frac{V}{R} \times t$$
$$\boxed{\boldsymbol{W = \frac{V^2}{R}t}}$$

ELECTRICAL POWER:

This is the rate of doing work on a charged particle.
Th SI unit of electrical power is the Watt (**W**).

$$Power = \frac{Work\ done}{Time}$$
$$but\ work\ done, W = VIt$$
$$P = \frac{VIt}{t}$$
$$\boxed{\boldsymbol{P = IV}} \quad \text{(2)}$$
$$but\ from\ Ohm's\ law\ V = IR\ (substitute\ in\ equation\ 2)$$
$$P = I \times IR$$
$$\boxed{\boldsymbol{P = I^2R}}$$
$$But\ from\ Ohm's\ law\ V = IR\ \Rightarrow I = \frac{V}{R}\ \ (substitute\ in\ equation\ 2)$$
$$P = \frac{V}{R} \times V$$
$$\boxed{\boldsymbol{P = \frac{V^2}{R}}}$$

EXAMPLES:

1. How much energy is consumed by a 0.5kW electrical kettle in 30 minutes?

$$P = 0.5kW = 0.5 \times 1000$$
$$\boldsymbol{P = 500W}$$
$$t = 30\ mins = 30 \times 60$$
$$\boldsymbol{t = 1800s}$$

$$\boldsymbol{W = VIt}$$
$$\boldsymbol{but\ P = IV = 500W}$$
$$\boldsymbol{W = 500 \times 1800}$$
$$\boldsymbol{W = 900{,}000J}$$

2. How much energy is consumed by a 60W lamp in 10 hours?

$$\boldsymbol{P = 60W}$$
$$t = 10\ hours = 10 \times 3600$$
$$\boldsymbol{t = 36000s}$$

$$\boldsymbol{W = VIt}$$
$$\boldsymbol{but\ P = IV = 60W}$$
$$\boldsymbol{W = 60 \times 36000}$$
$$\boldsymbol{W = 2{,}160{,}000J}$$

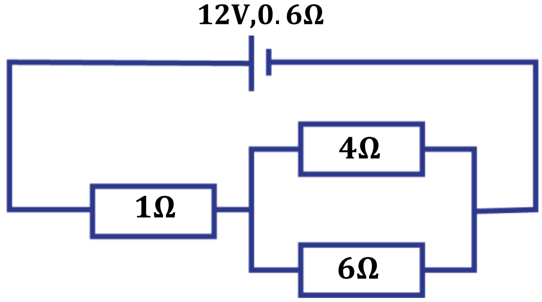
CALCULATIONS IN ELECTRICAL CIRCUITS

Steps and tips taken;

- Find the total or effective resistance in the circuit.
- When finding current through a resistor in parallel, first find the potential difference (voltage) across the parallel connection.
- Power dissipated in any resistor is $\boldsymbol{P = I^2R}$
- Power expended in the whole circuit is $\boldsymbol{P = I^2(R + r)}$ $where\ \boldsymbol{R}\ is\ effective\ resistance.$

EXAMPLES:

1. In the diagram below, a battery of emf 12V and internal resistance 0.6Ω is connected to 3 resistors.



Calculate;

(i) Current through the circuit.
(ii) Current through the 4Ω and 6Ω resistor.
(iii) Power dissipated in the 4Ω resistor.
(iv) Power expended in the circuit.

$\boldsymbol{E = 12V \quad r = 0.6\Omega}$

$\underline{\textit{effective resistance}}$

$$\text{In parallel}, \boldsymbol{R_p = \frac{R_1R_2}{R_1 + R_2}}$$

$$\boldsymbol{R_p = \frac{4 \times 6}{4 + 6}}$$

$$\boldsymbol{R_p = 2.4\Omega}$$

$$\text{thus } \boldsymbol{R = 1 + R_p}$$

$$\boldsymbol{R = 1 + 2.4}$$

$$\boldsymbol{R = 3.4\Omega}$$

(i)

$\underline{\textit{current through the circuit}}$

$\boldsymbol{E = I(R + r)}$

$\boldsymbol{12 = I(3.4 + 0.6)}$

$\boldsymbol{12 = I \times 4}$

$\boldsymbol{I = \frac{12}{4}}$

$\boldsymbol{I = 3A}$

(ii)

$\underline{\textit{p.d acoss parallel connection}}$

$$\boldsymbol{V = IR_p}$$

$$\boldsymbol{V = 3 \times 2.4}$$

$$\boldsymbol{V = 7.2V}$$

$\underline{\textit{current through } 4\Omega \textit{ resistor}}$

$\text{from } \boldsymbol{V = IR}$

$\boldsymbol{7.2 = I \times 4}$

$\boldsymbol{I = \frac{7.2}{4}}$

$\boldsymbol{I = 1.8A}$

$\underline{\textit{current through } 6\Omega \textit{ resistor}}$

$\text{from } \boldsymbol{V = IR}$

$\boldsymbol{7.2 = I \times 6}$

$\boldsymbol{I = \frac{7.2}{6}}$

$\boldsymbol{I = 1.2A}$

(iii)

$\underline{\textit{power dissipated in } 4\Omega \textit{ resistor}}$

$\boldsymbol{P = I^2R}$

$\boldsymbol{P = 1.8^2 \times 4}$

$\boldsymbol{P = 12.96W}$

(iv)

$\underline{\textit{power dissipated in } 4\Omega \textit{ resistor}}$

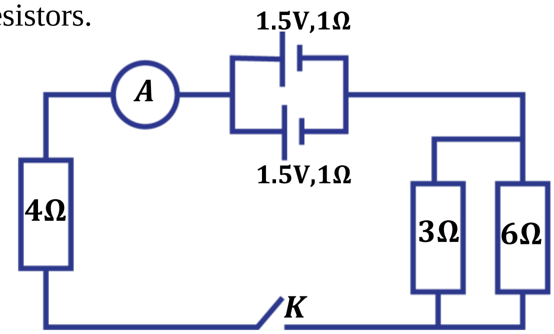
$\boldsymbol{P = I^2(R + r)}$

$\boldsymbol{P = 3^2 \times (3.4 + 0.6)}$

$\boldsymbol{P = 9 \times 4}$

$\boldsymbol{P = 36W}$

2. In the diagram below, two cells of emf 1.5V and internal resistance of 1Ω each are connected to a network of resistors.



(i) What will be the ammeter reading when switch K is closed?
(ii) Calculate the current through the 3Ω resistor.
(iii) Calculate power dissipated in 3Ω resistor.
(iv) Calculate power developed in 4Ω resistor.

$total\ emf, \boldsymbol{E = 1.5V}\ (cells\ in\ parallel)$

$total\ internal\ resistance, \boldsymbol{r} = \dfrac{\boldsymbol{r_1 r_2}}{\boldsymbol{r_1 + r_2}}$

$$\boldsymbol{r = \frac{1 \times 1}{1 + 1} = 0.5\Omega}$$

$\underline{effective\ resistance}$

$$In\ parallel, \boldsymbol{R_p = \frac{R_1 R_2}{R_1 + R_2}}$$

$$\boldsymbol{R_p = \frac{3 \times 6}{3 + 6}}$$

$$\boldsymbol{R_p = 2\Omega}$$

$$thus\ \boldsymbol{R = 4 + R_p}$$

$$\boldsymbol{R = 4 + 2}$$

$$\boldsymbol{R = 6\Omega}$$

(i)

$\underline{current\ through\ the\ circuit}$

$\boldsymbol{E = I(R + r)}$

$\boldsymbol{1.5 = I(6 + 0.5)}$

$\boldsymbol{1.5 = I \times 6.5}$

$\boldsymbol{I = \frac{1.5}{6.5}}$

$\boldsymbol{I = 0.23A}$

The ammeter reading will be **0.23A.**

(ii)

$\underline{p.d\ acoss\ parallel\ connection}$

$$\boldsymbol{V = IR_p}$$

$$\boldsymbol{V = 0.23 \times 2}$$

$$\boldsymbol{V = 0.46V}$$

$\underline{current\ through\ 3\Omega\ resistor}$

$from\ \boldsymbol{V = IR}$

$\boldsymbol{0.46 = I \times 3}$

$\boldsymbol{I = \frac{0.46}{3}}$

$\boldsymbol{I = 0.15A}$

(iii)

$\underline{power\ dissipated\ in\ 3\Omega\ resistor}$

$\boldsymbol{P = I^2 R}$

$\boldsymbol{P = 0.15^2 \times 3}$

$\boldsymbol{P = 0.068W}$

(iv)

$\underline{power\ developed\ in\ 4\Omega\ resistor}$

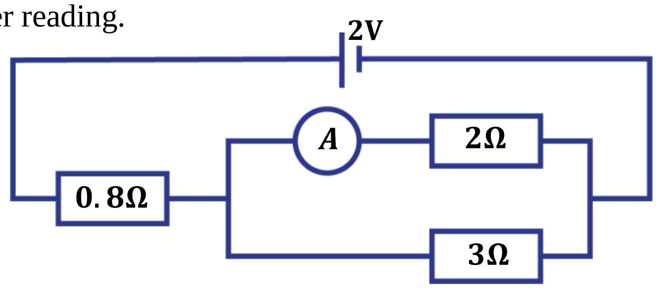
Since it is in series, the current passing through it is the current through the whole circuit.

$\boldsymbol{P = I^2 R}$

$\boldsymbol{P = 0.23^2 \times 4}$

$\boldsymbol{P = 0.212W}$

3. A battery of emf 2V and negligible internal resistance is connected as shown below. Find the ammeter reading.



$\boldsymbol{E = 2V \quad r = 0\Omega}$

$\underline{effective\ resistance}$

$$In\ parallel, \boldsymbol{R_p = \frac{R_1R_2}{R_1 + R_2}}$$

$$\boldsymbol{R_p = \frac{2 \times 3}{2 + 3}}$$

$$\boldsymbol{R_p = 1.2\Omega}$$

$$thus\ \boldsymbol{R = 0.8 + R_p}$$

$$\boldsymbol{R = 0.8 + 1.2}$$

$$\boldsymbol{R = 2\Omega}$$

$\underline{current\ through\ the\ circuit}$

$\boldsymbol{E = I(R + r)}$

$\boldsymbol{2 = I(2 + 0)}$

$\boldsymbol{2 = I \times 2}$

$\boldsymbol{I = \frac{2}{2}}$

$\boldsymbol{I = 1A}$

The ammeter is reading the current through the 2Ω.

$\underline{p.d\ acoss\ parallel\ connection}$

$$\boldsymbol{V = IR_p}$$

$$\boldsymbol{V = 1 \times 1.2}$$

$$\boldsymbol{V = 1.2V}$$

$\underline{current\ through\ 2\Omega\ resistor}$

$from\ \boldsymbol{V = IR}$

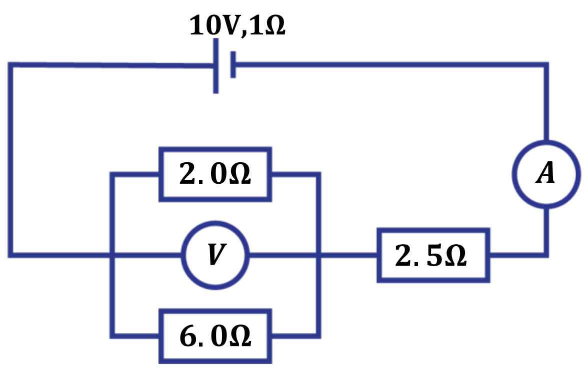
$\boldsymbol{1.2 = I \times 2}$

$\boldsymbol{I = \frac{1.2}{2}}$

$\boldsymbol{I = 0.6A}$

The ammeter reading is $\boldsymbol{0.6A}$

4. A battery of emf 10V and internal resistance 1.0Ω is connected to a system of resistors as shown below.



(i) Calculate the ammeter and voltmeter readings.
(ii) Find the current through the 2Ω resistor.
(iii) Find the power dissipated in 2Ω resistor.
(iv) Find also the total power expended in the circuit.

$E = 10V \quad r = 1\Omega$

effective resistance

$$In\ parallel, R_p = \frac{R_1R_2}{R_1 + R_2}$$

$$R_p = \frac{2 \times 6}{2 + 6}$$

$$R_p = 1.5\Omega$$

$$thus\ R = 2.5 + R_p$$

$$R = 2.5 + 1.5$$

$$R = 4\Omega$$

(i)

current through the circuit

Since the ammeter is in series with the battery, it reads the total current through the whole circuit.

$E = I(R + r)$

$10 = I(4 + 1)$

$10 = I \times 5$

$I = \frac{10}{5}$

$I = 2A$

The ammeter reading is 2A

p.d acoss parallel connection

Since the voltmeter is connected across the resistors in parallel, it is reading the p.d across the parallel connection.

$$V = IR_p$$

$$V = 2 \times 1.5$$

$$V = 3V$$

The voltmeter reading is 3V.

(ii)

current through 2Ω resistor

$from\ V = IR$

$3 = I \times 2$

$I = \frac{3}{2}$

$I = 1.5A$

(iii)

power dissipated in 2Ω resistor

$P = I^2R$

$P = 1.5^2 \times 3$

$P = 4.5W$

(iv)

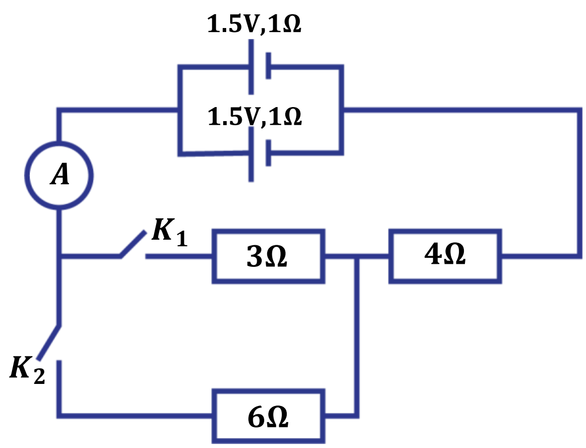
total power expended in circuit

$P = I^2(R + r)$

$P = 2^2 \times (4 + 1)$

$P = 20W$

5. Three resistors are connected as shown in the circuit diagram below.



Calculate;

(i) The ammeter reading when K_1 and K_2 are closed.

(ii) The ammeter reading only if K_1 is closed.

$total\ emf, \boldsymbol{E} = \mathbf{1.5}\boldsymbol{V}\ (cells\ in\ parallel)$

$total\ internal\ resistance, \boldsymbol{r} = \dfrac{\boldsymbol{r_1 r_2}}{\boldsymbol{r_1 + r_2}}$

$$\boldsymbol{r} = \frac{\mathbf{1 \times 1}}{\mathbf{1 + 1}} = \mathbf{0.5}\Omega$$

(i)

$when\ switches\ \boldsymbol{K_1}\ and\ \boldsymbol{K_2} are\ closed,$
$current\ flows\ through\ all\ the\ resistors$

$\underline{effective\ resistance}$

$$In\ parallel, \boldsymbol{R_p} = \frac{\boldsymbol{R_1 R_2}}{\boldsymbol{R_1 + R_2}}$$

$$\boldsymbol{R_p} = \frac{\mathbf{3 \times 6}}{\mathbf{3 + 6}}$$

$$\boldsymbol{R_p} = \mathbf{2}\Omega$$

$$thus\ \boldsymbol{R} = \mathbf{4} + \boldsymbol{R_p}$$

$$\boldsymbol{R} = \mathbf{4 + 2}$$

$$\boldsymbol{R} = \mathbf{6}\Omega$$

$\underline{current\ through\ the\ circuit}$

$\boldsymbol{E} = \boldsymbol{I}(\boldsymbol{R} + \boldsymbol{r})$

$\mathbf{1.5} = \boldsymbol{I}(\mathbf{6 + 0.5})$

$\mathbf{1.5} = \boldsymbol{I} \times \mathbf{6.5}$

$\boldsymbol{I} = \dfrac{\mathbf{1.5}}{\mathbf{6.5}}$

$\boldsymbol{I} = \mathbf{0.23}\boldsymbol{A}$

The ammeter reads **0.23A.**

(ii)

$when\ only\ switch$ only $\boldsymbol{K_1}$ is closed, current only flows through the 3Ω and 2Ω resistors

$\underline{effective\ resistance}$

$$\boldsymbol{R} = \mathbf{3 + 4}$$

$$\boldsymbol{R} = \mathbf{7}\Omega$$

$\underline{current\ through\ the\ circuit}$

$\boldsymbol{E} = \boldsymbol{I}(\boldsymbol{R} + \boldsymbol{r})$

$\mathbf{1.5} = \boldsymbol{I}(\mathbf{7 + 0.5})$

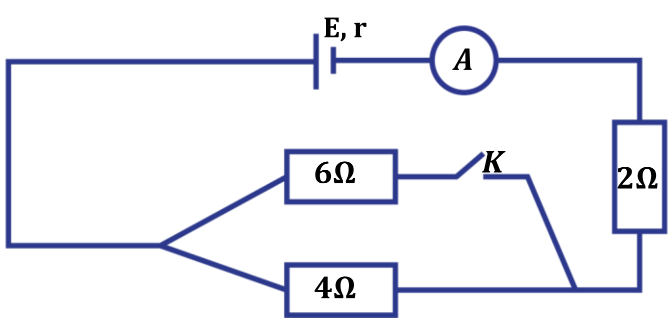
$\mathbf{1.5} = \boldsymbol{I} \times \mathbf{7.5}$

$\boldsymbol{I} = \dfrac{\mathbf{1.5}}{\mathbf{7.5}}$

$\boldsymbol{I} = \mathbf{0.2}\boldsymbol{A}$

The ammeter reads **0.2A.**

6.



In the diagram above, when the switch is open the ammeter reads 2A and when its closed, the ammeter reads 2.64A. Calculate;

(i) Explain what happens when the switch is left open and then closed.
(ii) The emf E and internal resistance of the battery.
(iii) Rate at which electrical energy is converted to when the switch is open.
(iv) Lost voltage (potential drop) when the switch is open.

(i)

When the switch is left open, current from the battery flows only through the 4Ω and 2Ω resistors and the 6Ω resistor is left out since its circuit is not complete.
When the switch is closed, current flows through all the resistors.

(ii)

when the switch is open

Current only flows through 4Ω and 2Ω resistors and they are in series

$I = 2A$

effective resistance

$R = 4 + 2$

$R = 6\Omega$

current through the circuit

$E = I(R + r)$

$E = 2(6 + r)$

$E = 12 + 2r$

$E - 2r = 12$ ------ (1)

when the switch is closed

Current only flows through all the resistors and

$I = 2.64A$

effective resistance

$$R = \frac{R_1R_2}{R_1 + R_2} + R_3$$

$$R = \frac{6 \times 4}{6 + 4} + 2$$

$R = 2.4 + 2$

$R = 4.4\Omega$

current through the circuit

$E = I(R + r)$

$E = 2.64(4.4 + r)$

$E = 11.616 + 2.64r$

$E - 2.64r = 11.616$ ------ (2)

Solving equations 1 and 2 simultaneously.

$$\begin{array}{r} E - 2r = 12 \\ -\ \underline{E - 2.64r = 11.616} \\ 0 + 0.64r = 0.384 \end{array}$$

$$r = \frac{0.384}{0.64}$$

$r = o.6\Omega$

from equation 1, $E - 2r = 12$

$E = 12 + 2r$

$E = 12 + 2 \times 0.6$

$E = 12 + 1.2$

$E = 13.2V$

(iii)

total power or rate at which work is done

$P = I^2(R + r)$

$P = 2^2 \times (6 + 0.6)$

$P = 26.4W$

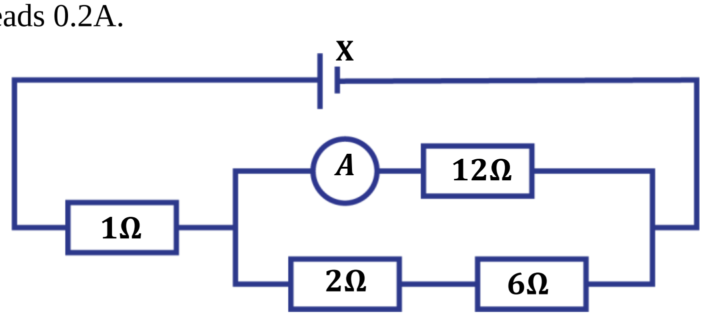
(iv)

$voltage\ drop = Ir$

$voltage\ drop = 2 \times 0.6$

$voltage\ drop = 1.2V$

7. The battery **X** has an internal resistance of 0.2Ω. When its connected in the circuit below, the ammeter reads 0.2A.



Calculate;

(i) Current through 2Ω resistor.

(ii) Emf X of the battery.

(i)

<u>*p.d across parallel connection*</u>

This p.d is the same as p.d across the 12Ω resistor.

$$ammeter\ reading\ \boldsymbol{I_1 = 0.2A}$$
$$\boldsymbol{V = I_1R}$$
$$\boldsymbol{V = 0.2 \times 12}$$
$$\boldsymbol{V = 2.4V}$$

<u>*total resistance in series*</u>

$$\boldsymbol{R_s = 2 + 6}$$
$$\boldsymbol{R_s = 8\Omega}$$

<u>*current through 2Ω*</u>

$$\boldsymbol{V = I_1R}$$
$$\boldsymbol{2.4 = I_1 \times 8}$$
$$\boldsymbol{I_1 = \frac{2.4}{8}}$$
$$\boldsymbol{I_1 = 0.3A}$$

(ii)

<u>***total current in the circuit***</u>

$$\boldsymbol{I = I_1 + I_2}$$
$$\boldsymbol{I = 0.2 + 0.3}$$
$$\boldsymbol{I = 0.5A}$$

<u>***effective resistance in the circuit***</u>

$$\boldsymbol{R = \frac{R_s \times R_2}{R_s + R_2} + R_3}$$
$$\boldsymbol{R = \frac{8 \times 12}{8 + 12} + 1}$$
$$\boldsymbol{R = 4.8 + 1}$$
$$\boldsymbol{R = 5.8\Omega}$$

(iii)

$$\boldsymbol{r = 0.2\Omega}$$

$\boldsymbol{E = I(R + r)}$

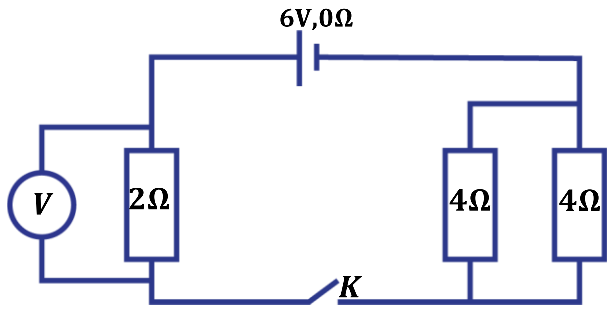
$\boldsymbol{E = 0.5(5.8 + 0.2)}$

$\boldsymbol{E = 0.5 \times 6}$

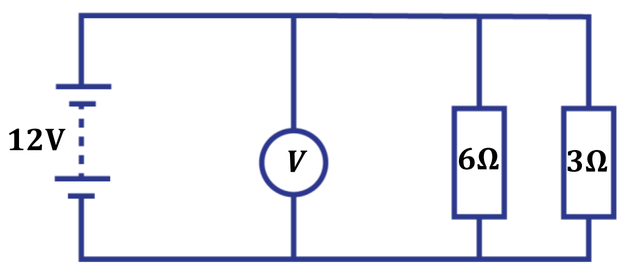
$\boldsymbol{E = 3V}$

EXERCISE:

1. In the diagram below, what will be the voltmeter reading when switch K is closed?



2. In the diagram below, a battery of emf 12V and negligible internal resistance is connected across resistors as shown below.



Calculate;

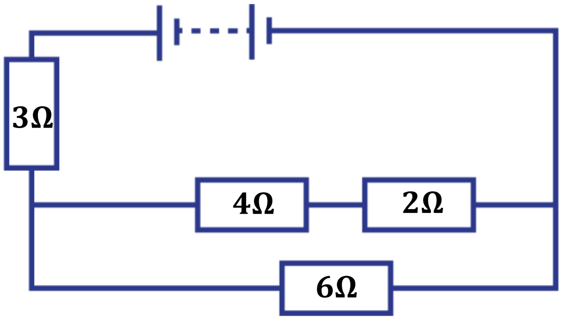
(i). Current through the circuit.

(ii). Voltmeter reading.

(iii). Current through the 6Ω resistor.

(iv). Total power expended in the circuit.

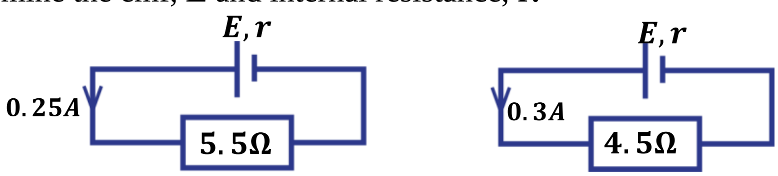
3. An accumulator of 24V and internal resistance 2Ω is connected as shown below.



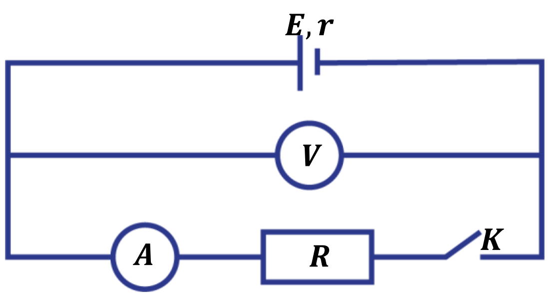
Calculate;

(i). Lost voltage.
(ii). Current through the 6Ω resistor.
(iii). Power dissipated in the 6Ω resistor.
(iv). Total power expended in the circuit

4. A dry cell of emf, **E** and internal resistance, **r** drives a current of 0.25A through a resistor of 5.5Ω and also drives a current of 0.3A through a resistor of 4.5Ω as shown in the figures. Determine the emf, **E** and internal resistance, **r.**



5. A dry cell of emf, E is connected in the circuit as shown below.



When switch **K** is open, the voltmeter reading is **1.4V**. When the switch **K** is closed, the ammeter reading is **1.0A** and the voltmeter reading is **0.9V**.

(i). Write an expression relating **E**, ammeter reading, **I**, voltmeter reading, **V**, and internal resistance, **r** of the cell.
(ii). Calculate the internal resistance of the cell.
(iii). Find the value of the resistance, R.

COMMERCIAL ELECTRICITY

In Uganda, electricity is sold by electricity boards such as UMEME.
They use our meters to estimate the electrical energy consumed
The energy consumed is measured in kilowatt hours (**kWh**).

Definition:

A **kilowatt hour** is the amount of electrical energy consumed by a device of power 1000W in one hour.

$$\mathbf{1kWh = 1kW \times 1hour}$$
$$\mathbf{1kWh = 1000W \times 3600s}$$
$$\mathbf{1kWh = 3{,}600{,}000Ws}$$
$$\mathbf{1kWh = 3{,}600{,}000J}$$

Calculations for cost of electricity:

$$Number\ of\ units\ of\ electricity = Power\ (kilo\ Watts) \times time\ (hours)$$

$$\boxed{Number\ of\ units\ of\ electricity = \boldsymbol{P}\ (kW) \times \boldsymbol{t}\ (hrs)}$$

$$Total\ cost\ of\ electricity = Power\ (kilo\ Watts) \times time\ (hours) \times unit\ cost$$

$$\boxed{Total\ cost\ of\ electricity = \boldsymbol{P}\ (kW) \times \boldsymbol{t}\ (hrs) \times \boldsymbol{unit\ cost}}$$

NOTE:

All electrical appliances are marked (rated) showing the power rating in Watts and voltage in Volts. E.g.

An electrical appliance rated 240V, 60W means that the appliance supplies or consumes 60J every second when connected to a 240V mains supply.

EXAMPLES:

1. How much will it cost to run four bulbs rated at 40W each for 2 days, if the cost of each unit of electricity is shs. 30.?

$$\boldsymbol{P = 4 \times 40 = 160W}$$
$$In\ kW, \boldsymbol{P} = \mathbf{\frac{160}{1000} = 0.16kW}$$
$$\boldsymbol{t} = \mathbf{2}days = \mathbf{2 \times 24 = 48\ hours}$$
$$\boldsymbol{unit\ cost = 30\ shs}$$

$$\boldsymbol{cost\ of\ electricity = Power(kW) \times t(hours) \times unit\ cost}$$
$$\boldsymbol{cost\ of\ electricity = 0.16 \times 48 \times 30}$$
$$\boldsymbol{cost\ of\ electricity = 230.4\ shs}$$

2. Find the cost to run two bulbs rated at 60W each and an electric iron rated at 120W for 35 minutes, if the unit is 415 shs.

$\underline{for\ bulbs}$	$\underline{for\ electric\ iron}$
$\boldsymbol{P = 2 \times 60 = 120W}$	$\boldsymbol{P = 120W}$

$$Total\ power, \boldsymbol{P = 120 + 120 = 240W}$$
$$In\ kW, \boldsymbol{P} = \mathbf{\frac{240}{1000} = 0.24kW}$$
$$\boldsymbol{t = 35\ mins = \frac{35}{60}\ hours}$$

$\boldsymbol{unit\ cost = 415\ shs}$

$\boldsymbol{cost\ of\ electricity = Power(kW) \times t(hours) \times unit\ cost}$

$\boldsymbol{cost\ of\ electricity = 0.24 \times \frac{35}{60} \times 415}$

$\boldsymbol{cost\ of\ electricity = 58.1\ shs}$

3. An electrical heater is rated at 3000W, 240V.
   a) What is meant by the statement.
   b) Calculate;
      (i). Current and resistance of the heater.
      (ii). Total number of units it consumes in $1\frac{1}{2}$ hours.
      (iii). The cost of electricity if each unit costs 9,000 shs after using the heater for 3 hours every day for 10 days.

(a) An electrical heater supplies or consumes 3000J every second when connected to a 240V mains supply.

(b) (i) $Given\ \boldsymbol{P = 3000W,\ V = 240V}$

$\boldsymbol{P = IV}$

$\boldsymbol{3000 = I \times 240}$

$\boldsymbol{I = \frac{3000}{240}}$

$\boldsymbol{I = 12.5A}$

$\boldsymbol{V = IR}$

$\boldsymbol{240 = 12.5 \times R}$

$\boldsymbol{R = \frac{240}{12.5}}$

$\boldsymbol{R = 19.2\Omega}$

OR

$\boldsymbol{P = I^2R}$

$\boldsymbol{3000 = 12.5^2 \times R}$

$\boldsymbol{R = \frac{3000}{12.5^2}}$

$\boldsymbol{R = 19.2\Omega}$

(ii)

$\boldsymbol{number\ of\ units = Power(kW) \times t(hours)}$

$\boldsymbol{number\ of\ units = \frac{3000}{1000} \times 1\frac{1}{2}}$

$\boldsymbol{number\ of\ units = 3 \times \frac{3}{2}}$

$\boldsymbol{number\ of\ units = 4.5kWh}$

(iii)

$\boldsymbol{cost\ of\ electricity = Power(kW) \times t(hours) \times unit\ cost}$

$\boldsymbol{cost\ of\ electricity = (\frac{3000}{1000}) \times (3 \times 10) \times 9000}$

$\boldsymbol{cost\ of\ electricity = 810,000\ shs}$

4. Jane paid an electricity bill of 1800shs after using two identical bulbs for 2 hours every day for 10 days at a cost of 600shs per unit. Determine the power consumption by each of the bulbs.

$\boldsymbol{total\ cost\ of\ electricity = Power(kW) \times t(hours) \times unit\ cost}$

$\boldsymbol{1800 = P(kW) \times (2 \times 10) \times 600}$

$\boldsymbol{1800 = P(kW) \times 12000}$

$\boldsymbol{P(kW) = \frac{1800}{12000}}$

$$P(kW) = 0.15kW$$

$$for\ each\ bulb\ P = \frac{0.15}{2} = 0.075kW = 75W$$

Therefore, each bulb consumes power of **75W**.

EXERCISE:

1. Find the cost of running five 60W lamps and four 100W lamps for 8 hours if the electrical energy costs 5shs per unit.

2. Mr. Ssekwe uses 3 kettles of 800W each, a flat iron of 1000W, 3 bulbs of 60W each and 4 bulbs of 75W each. If they are used for 3hours every day for 30 days and one unit of electricity costs 200shs, find the total cost of running the appliances.

3. A television is rated 240V, 60W.
   (a) What do you understand by the statement above.
   (b) Calculate the current flowing through the TV.
   (c) Calculate the resistance of the television.
   (d) Calculate the cost of running the television for 600 minutes if the unit cost is 60shs.

GENERATION AND TRANSMISSION OF ELECTRICITY

(a) <u>Generation of electricity</u>:

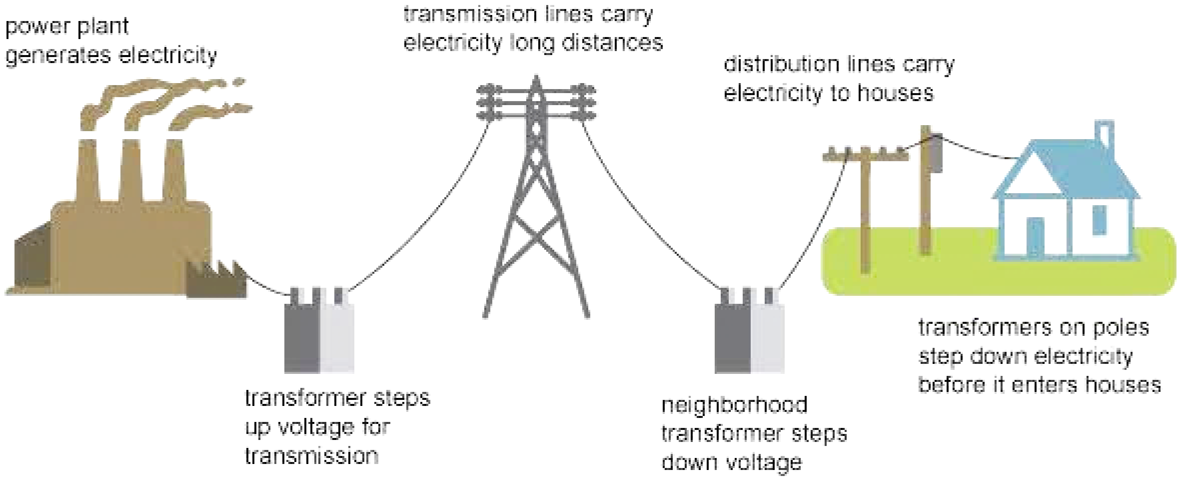
Electricity is generated at power stations by using coal, nuclear reactions, wind, sun, running water etc.

(b) <u>Transmission of electricity</u>:

Electricity generated at power stations is stepped up to higher voltages before transmission using step transformers.

The power transmitted is usually alternating current and it is stepped down as it reaches factories, industries, towns and homes using step down transformers.

Transmission can either be overhead or underground.



How power losses are reduced during transmission of electricity:

- Electricity is transmitted at high voltages to reduce power loss due to the heating effect in the transmission cables.
- The transmission cables are made thick to reduce its resistance hence minimizing power loss.

(c) House wiring (domestic electrical installation):

Electricity is connected in a house by thick cables called the **mains** from the electricity poles to the meter box or fuse box and then to the main distribution box. From here electricity is supplied to the electrical appliances.

The electricity supply cables in a house consist of the following wires.

TYPE OF WIRE	COLOUR	USE
Live wire	Red or brown	It carries current to the appliance.
Neutral wire	Blue or black	It completes the circuit. Thus, it carries current away from the source.
Earth wire	Yellow or green or yellow with green stripes	It is connected to the metal case of an appliance to provide an alternative path for stray current in case the appliance becomes live.

When wiring a house, the following should be included in the circuits.

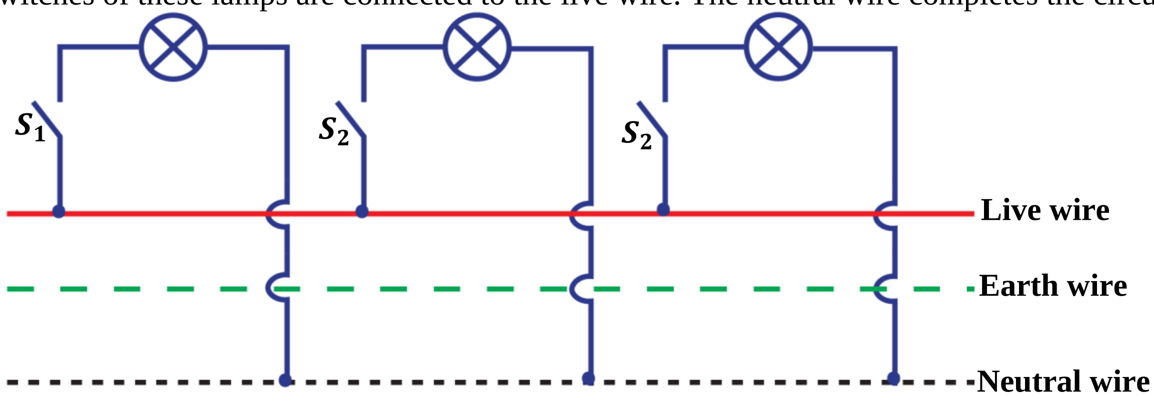
DEVICE NAME	CONNECTION AND USE
(i) Switch 	▪ It controls the flow of current in the circuit. ▪ It I connected to the live wire such that it cut off and switch on current whenever needed.
(ii) Fuse 	▪ It contains a thin wire of a very low melting point. ▪ The thin wire melts whenever current exceeds the rated value. ▪ It is connected to the live wire.
(iii) Sockets 	▪ These are power points usually put on the walls. ▪ They have three holes leading to the live wire, neutral wire and the earth wire.

Precautions taken when wiring a house:

- The right colour codes must be followed i.e. red for live wire, black for neutral wire and yellow for earth wire.
- All switches should be connected to the live wire.
- Wires should be insulated.
- Keep hands dry when dealing with electricity.
- Earthing should always be done to prevent electrical shocks in case an appliance gets a fault.

LIGHT CIRCUITS

Electrical appliances e.g. bulbs and lamps are usually connected in parallel with the mains supply. The switches of these lamps are connected to the live wire. The neutral wire completes the circuit.

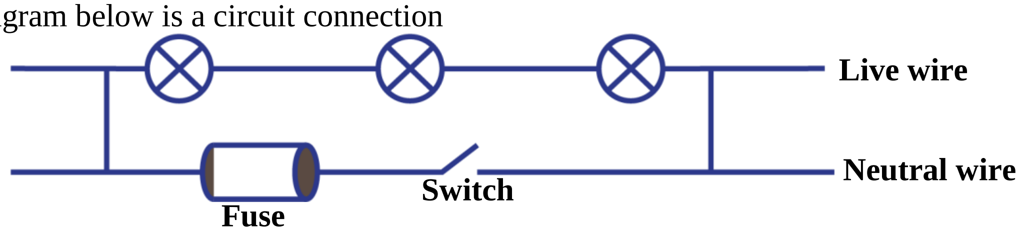


Advantages of connecting lamps in parallel:

- Lamps have the same voltage as the source.
- If one lamp gets a fault, the other lamps continue working.
- It enables switching on and off of the lamps independently (i.e. each lamp can have its own switch.)

Example:

The diagram below is a circuit connection

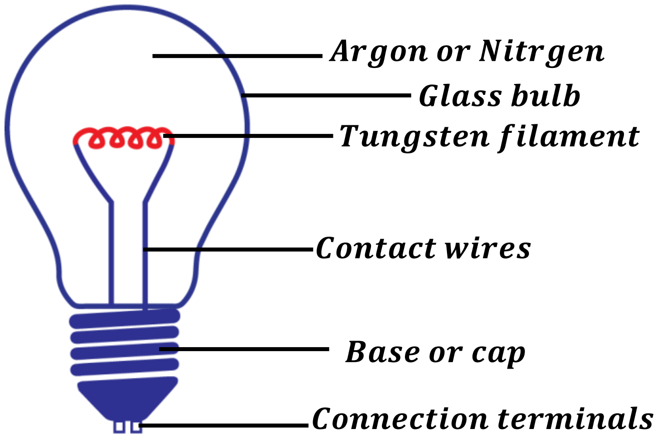


Identify the wrong corrections in the circuit.

- Bulbs were connected in series yet they have to be connected in parallel.
- Fuse was connected to the neutral wire yet it is supposed to be connected on the live wire.
- The switch was connected to the neutral wire yet it is supposed to be connected on the live wire.

FILAMENT LAMPS (INCANDESCENT LAMPS)

These are lamps that produce light by heating a filament to a high temperature.



Mode of operation of a filament lamp:

When switched on, the coiled tungsten filament is heated and it becomes white hot thus emitting light.

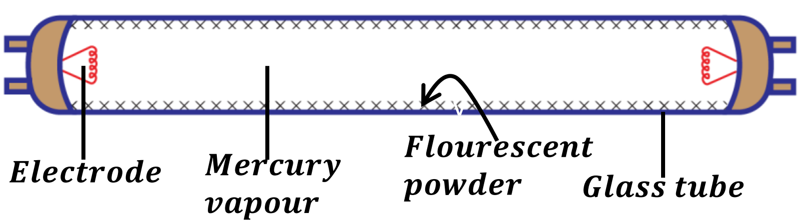
The higher the temperature of the filament, the greater the light given off.

Note:

- The filament is made of tungsten because tungsten has a high melting point. Therefore, it can't melt easily when heated to very high temperatures.
- The filament is coiled to reduce the space it occupies in the glass bulb thus reducing heat through convection.
- The glass bulb contains inert gases (i.e. Argon/Nitrogen) at low pressure to reduce evaporation of the filament otherwise it would condense on the bulb and blacken it.

FLUORESCENT LAMPS (DISCHARGE LAMPS)

Fluorescent tube is a gas discharge lamp that uses electricity to energize or excite mercury vapour. It has electrodes at the ends and the inside wall is coated with fluorescent substance e.g. phosphor.



When switched on, mercury vapour is excited/energized and it emits ultra-violet radiations. The radiations strike the fluorescent substance causing it to produce visible light.

NB: Fluorescent substance is a substance that gives off light when radiations fall on it.

Advantages of fluorescent tubes/lamps over filament lamps:

- They are long lasting.
- They don't produce much heat.
- They consume less power.

Disadvantages of fluorescent lamps:

- They are expensive.
- They require high installation costs.
- They may not start when the supply voltage is low.