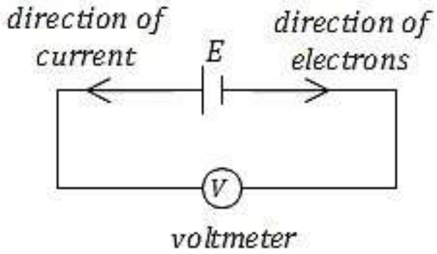
NTARE SCHOOL
S.4 A, B, C, D and G
CURRENT ELECTRICITY

This deals with the flow of electric charges in a conductor from one point to another when they are at different potentials.

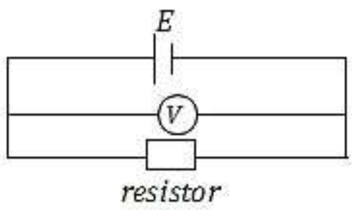
Potential difference (p.d): The p.d between two points is the work done when one coulomb of charge moves from one point to another in a circuit.
P.d is measured in the laboratory by *voltmeter.* S.I units of p.d are *volts* (V).
A volt is a work done of one joule when one coulomb of electricity is passing in a conductor from one point to another.

Electromotive force (e.m.f, E): it is the total work done to transfer a charge in circuit in which the source is connected.
E.m.f of a cell is regarded as the potential difference across terminals of a cell in an open circuit i.e when it is not producing current in a circuit.
Terminal p.d of a cell is the potential difference across its terminals in a closed circuit.



(a) open circuit

Voltmeter reads e.m.f of the cell



(b) closed circuit

Voltmeter reads terminal p.d of the cell lower than e.m.f

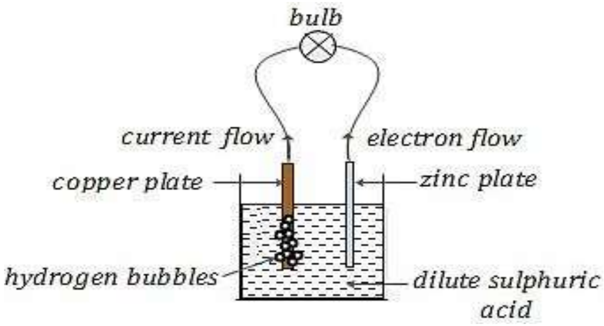
ELECTRIC CELLS
A cell converts chemical energy to electric energy.
A cell has twos terminals – positive terminal at higher potential and negative terminal at lower potential. Because of this potential difference, an electric current flows when a cell is connected in a complete circuit. There are two types of cells – primary and secondary cells.

(A) Primary cells

The chemical reactions in the cells are irreversible i.e they can't be charged when they run down.
Examples include; simple cell and dry cell (Leclanché cell).

1. Simple cell

This has an e.m.f of 1V.



When copper and zinc plates are dipped in dilute Sulphuric acid;

- a bulb lights up showing that current I flows in the wires
- light goes off after a short time indicating that the cell is no longer producing current.

Action:

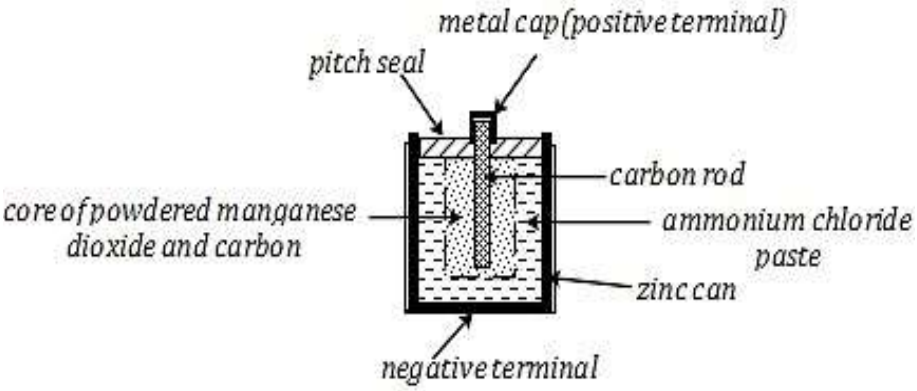
If a zinc rod (more reactive than copper) is placed in a dilute solution of Sulphuric acid, it oxidizes and loses electrons.
The electrons flow around the circuit to the copper plate, where they will be taken up by the positive hydrogen ions of the dilute acid producing bubbles of hydrogen gas.

Defects of a simple cell

(a) Polarisation: this is the formation of hydrogen bubbles on a copper plate that form an insulating layer which increases internal resistance of the cell.
It is minimised by
- blushing off hydrogen bubbles
- use of a depolariser (oxidizing agent) such as manganese iv oxide or potassium dichromate.

(b) Local action: The impurities in zinc result in zinc being eaten up even when no current is supplied.
It is minimised by cleaning the zinc plate in Sulphuric acid and smear it with mercury.

2. Dry cell; It is a dry cell because it has no liquid in it. It has an e.m.f of 1.5V when fresh.



The chemical reaction between zinc and ammonium chloride results into production of hydrogen which collects at the carbon rod that polarizes it. Manganese dioxide in the mixture minimises polarisation making the cell last longer and maintain the e.m.f constant.
The carbon in the mixture reduces the internal resistance of the cell making the cell supply a steady current.
Local action which can not entirely be prevented slowly deteriorates the cell.

Advantages

- It is compact and portable
- It does not contain any liquid which can spill
- It is cheap to buy

Disadvantages

- It is subject to polarization
- It produces only intermittent currents

(B) Secondary cells (accumulators)

These are types of cells that can be recharged when they run down.
They maintain a large current for a long period without polarisation.
Types of secondary cells; lead – acid accumulators and alkaline accumulators

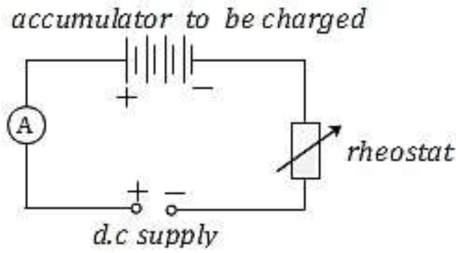
1. Lead – acid accumulators:

A lead-acid storage consists of a group of cells connected together in series. Each cell consists of a lead plate (negative electrode), a lead oxide plate (positive electrode), and an electrolytic solution of Sulphuric acid. Each cell has e.m.f of about 2.2V and falls to 1.8V at a full discharge.

Charging an accumulator

A lead-acid storage is recharged by forcing current through the battery in the direction opposite to the direction the current flows when the battery is fully charged.

The supply voltage must be a d.c of greater e.m.f than the accumulator to be charged.



During charging

- smaller currents regulated by the rheostat are required to allow reverse chemical reactions take place.
- lids of the cells be removed or loosened to allow gassing.

Advantages

- They deliver a strong current of electricity for starting an engine; because of low internal resistance
- They can be recharged by passing current in opposite direction

Disadvantages

- They are heavy to carry
- They run down quickly
- They are damaged by careless use
- They are expensive to buy

Care and maintenance of lead – acid accumulator

- Liquid level should be maintained by using distilled water so that electrodes are not exposed
- It should be recharged regularly
- Avoid short – circuiting its terminals (this draws too much current from the cells thus destroying them)
- Avoid keeping it in cold as this lowers its e.m.f
- Its terminals should be cleaned and greased with Vaseline to ensure good electrical connections.
- Avoid spilling of acid on its top as this causes corrosion of the terminals.

2. Alkaline accumulators

These are nickel – iron (NiFe) accumulators or nickel – cadmium (NiCd) accumulators.

NiFe accumulators have electrodes of Nickel hydroxide (+) and iron (–) dipped in potassium hydroxide as the electrolyte. It produces about 1.15 V, and its useful lifetime is about 30 to 40 years.

Uses of alkaline accumulators

- They are used for "load leveling," to compensate for momentary system load fluctuations.
- They are used in ships, hospitals and public buildings to provide emergency lighting.
- Because of high discharge rates they are used to power electronic application such as welding and heavy workshop equipment
- Their long lifetime makes them relevant to electric farming equipment.

Advantages of alkaline over lead – acid accumulators

- Large currents can be drawn from them without damage
- They can be left discharged for longer time without damaging them.
- They are lighter and portable
- They have a very much longer life
- They have low operation cost, low self-discharge and environmental-friendly.
- They can withstand wide temperature variations, mechanical & electrical abuses
- They require no special maintenance when out of use for extended period

Disadvantages of alkaline accumulators

- Their e.m.f falls continuously on discharge
- They have small e.m.f of about 1.2V
- They give off hydrogen gas during charging.

ELECTRIC CURRENT AND RESISTANCE

Electric current (I): This is the quantity of charge flowing through each point of a conductor in one second. $I = \frac{Q}{t} \Rightarrow Q = It$

Current is measured in the laboratory by *ammeter.* S.I units of current are amperes (A). Other units of current are milliampere $(mA) = 1 \times 10^{-3} A$ S.I units of charge are *coulombs* (C).

A coulomb is a quantity of charge conveyed in one second by a steady current of one ampere through a circuit.

Example: A charge of 180C flows through a lamp for 2 minutes. Find the electric current flowing through the lamp. $I = \frac{Q}{t} = \frac{180}{2 \times 60} = \frac{180}{120} = 1.5A$

Electrical resistance (R): This is the opposition to the flow of electric current by a conductor. Good conductors have low resistance and poor conductors have high resistance

Resistors are of two types – fixed (standard) resistors and variable resistors such as a rheostat.
S.I units of resistance are ohms (Ω)

An ohm is a resistance of a conductor such that when a potential difference of one volt is connected across its ends, a current of one ampere flows through it.

Factors affecting resistance of a conductor

- Nature of a conductor: a good conductor has low resistance
- Length of a conductor (l): a long conductor has high resistance
- Cross – sectional area (A): a small conductor has high resistance

Thick copper wires of large cross-sectional areas hence low resistance are used for cookers to allow much electric current to flow in them.

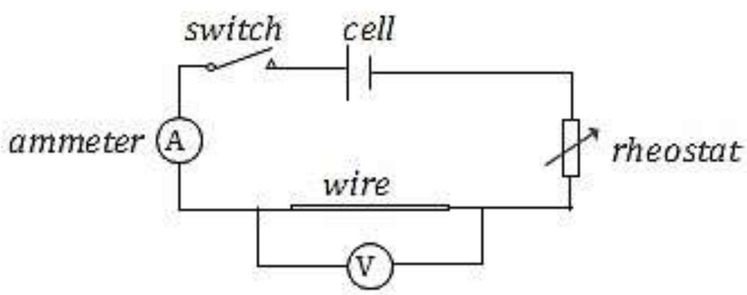
- Temperature: resistance of a conductor increases with temperature

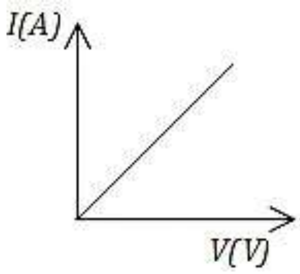
Mechanism of electrical conduction in metals

Atoms in metals are closely and regularly packed vibrating about their mean positions. When a p.d is applied across a metal, the electric field forces free electrons to move from one end to another. Consequently, current flows.

Ohm's law: Current I passing through a conductor at constant temperature is proportional to the potential difference, V, across its ends. $I \propto V \Rightarrow V = IR$ where R is a constant called resistance of a conductor.

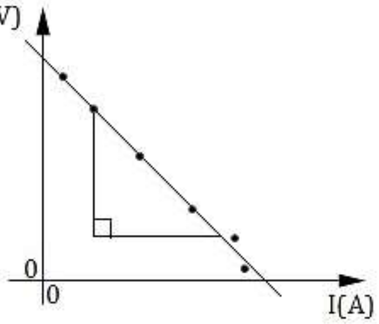
Experiment to verify Ohm's law





- The ammeter, voltmeter, switch, dry cell, rheostat and a wire under test are connected as in the figure.
- The rheostat is adjusted to its maximum (to prevent currents that would destroy other apparatus).
- Switch is closed. Ammeter and voltmeter readings I and V are read and recorded. - Adjusting the rheostat, different values of I and V are obtained - A graph of I against V is drawn.
- A straight line obtained shows that current I through a conductor is proportional to the p.d, V. Hence Ohm's law.

Note: A graph of V against I can be drawn.

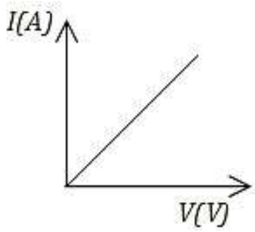


Limitations of Ohm's law

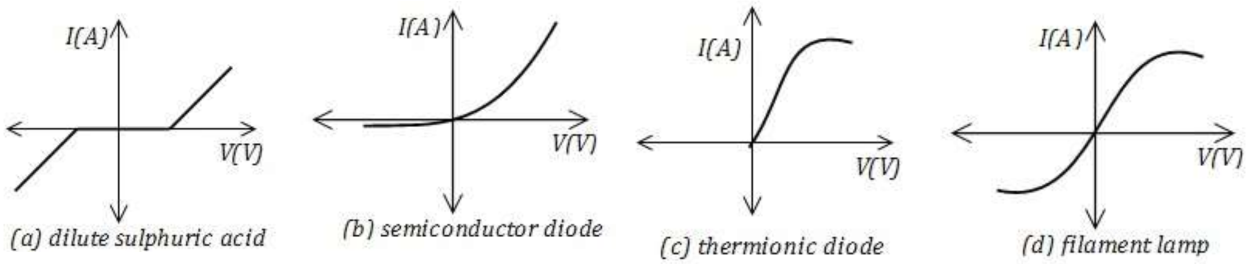
1. Ohm's law only applies to metals and some alloys. Such materials that obey Ohm's law are called ohmic conductors and those that do not obey are called non – ohmic conductors. E.g filament lamp, dilute Sulphuric acid, semiconductor diode and thermionic diode
2. The law holds when all the physical conditions remain constant.

I – V characteristics for

(a) ohmic conductors

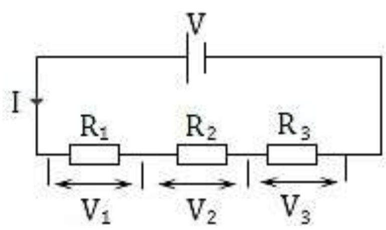


(b) non – ohmic conductors



ELECTRIC CIRCUITS

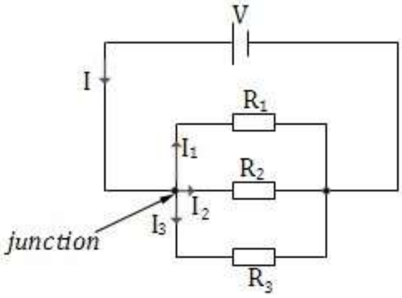
(a) Series arrangement



There are several characteristics of series circuits:

1. There is a single path through the circuit. If the current is interrupted at any point then all current will stop following.
2. Current in each resistor is equal to the total current in the circuit i.e (I_{same})
3. The voltage drop across each resistor is equal to the current times its resistance. $V_1 = IR_1, V_2 = IR_2$ and $V_3 = IR_3$
4. The total voltage across the circuit is equal to the sum of the voltage drops across each resistor.
   i.e total p.d $V = V_1 + V_2 + V_3$
   $\Rightarrow IR = IR_1 + IR_2 + IR_3$
   Dividing through by I; $\Rightarrow R = R_1 + R_2 + R_3$ Total resistance in the circuit $R = R_1 + R_2 + R_3$
   Thus total equivalent resistance of the circuit is the sum of the individual resistances.

(b) Parallel arrangement



There are several characteristics of parallel circuits:

1. There is a junction between them so the voltage across each resistor is the same. (V_{same})
2. The amount of current in each resistor is inversely proportional to its resistance $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$
3. The total current in the circuit is equal to the sum of the currents through each resistor
   i.e total current at a junction $I = I_1 + I_2 + I_3$
   $\Rightarrow \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$
   $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
   As the number of parallel branches increases, the total resistance of the circuit decreases. The total resistance will be less than the resistance of any individual resistor.
   Note: For only two resistors in parallel, total resistance $R = \frac{product}{sum}$

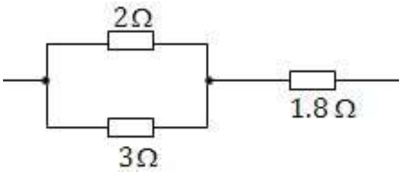
Questions

1. Calculate the effective resistance when a 3Ω and 2Ω resistors are connected in series and in parallel.

   In series, total resistance $R = 3 + 2 = 5\,\Omega$

   In parallel, total resistance $R = \frac{2\times3}{3+2} = \frac{6}{5} = 1.2\,\Omega$

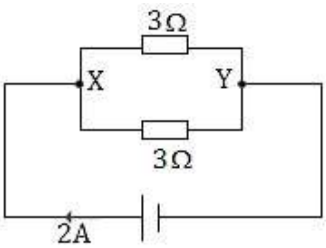
2. Calculate the resistance from the circuit below



   In parallel, total resistance $= \frac{2\times3}{3+2} = \frac{6}{5} = 1.2\,\Omega$

   In series, total resistance $R = 1.2 + 1.8 = 3\,\Omega$

3. Find the p.d across points X and Y from the figure below

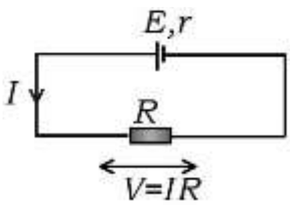


   In parallel, total resistance $= \frac{3\times3}{3+3} = \frac{9}{6} = 1.5\,\Omega$

   P.d across parallel combination $= 1.5 \times 2 = 3V$

Internal resistance r of a cell

This is the opposition offered to the flow of electric current by a cell due to its chemical composition.



In a closed circuit above (when external resistor R is drawing current from the dry cell), terminal p.d V is less than the e.m.f (E) of a cell by lost p.d across internal resistance r.

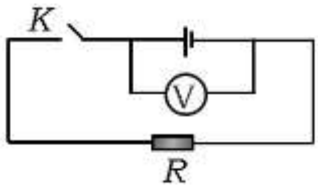
i.e E.m.f useful p.d across R(IR) =lost p.d across r (Ir)

$$E - IR = Ir$$

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

Experiment to determine internal resistance of a cell

- A standard resistor R, dry cell and the voltmeter are connected as in the figure below.



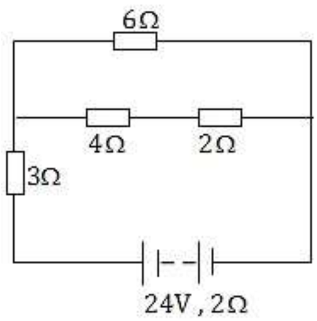
- With the switch K open, the voltmeter reading E is recorded. - The switch K closed and voltmeter reading V is recorded.
- The internal resistance r of the cell is calculated from $r = \frac{R(E-V)}{V}$

Alternatively

- Experiment is repeated for different values of R.
- A graph of $\frac{E}{V}$ against $\frac{1}{R}$ is drawn
- Gradient S of the line gives internal resistance of the cell.

Questions

1. From the figure below, calculate the current through a 6Ω resistor



Series arrangement 4Ω *and* 2Ω *;* $R = 4 + 2 = 6\Omega$ *Parallel arrangement* 6Ω *and* 6Ω *;*

$R = \frac{6\times6}{6+6} = \frac{36}{12} = 3\Omega$

Series arrangement 3Ω *and* 3Ω*;*

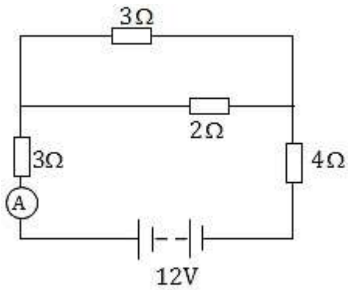
$R_T = 3 + 3 + 2 = 8\Omega$

Current supplied by battery, $I = \frac{24}{8} = 3A$

P.d across 3Ω*, (parallel arrangement)* $V = IR = 3 \times 3 = 9V$ *This is the same p.d across* 6Ω *resistor.*

Thus current through a 6Ω *resistor is* $I = \frac{9}{6} = 1.5A$.

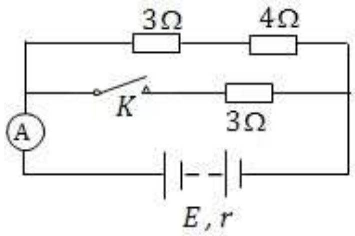
2. Find the reading of the ammeter and the p.d across the parallel combination of resistors in the figure below



Series arrangement 4Ω *and* 3Ω ; $R = 4 + 3 = 7\Omega$
Parallel arrangement 2Ω *and* 3Ω;
$R = \frac{3\times2}{2+3} = \frac{6}{5} = 1.2\Omega$
Series arrangement 7Ω *and* 1.2Ω ;
$R = 7 + 1.2 = 8.2\Omega$

Current supplied by battery, $I = \frac{12}{8.2} = 1.46A$
P.d across 1.2Ω, *(parallel arrangement)* $V = IR = 1.46 \times 1.2 = 1.75V$

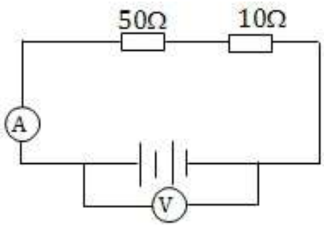
3. In the circuit below, when switch K is open, ammeter reads 4A and reads 5A when K is closed.



Calculate the
(i) Internal resistance of the cells (ii)
E.m.f of the cells.

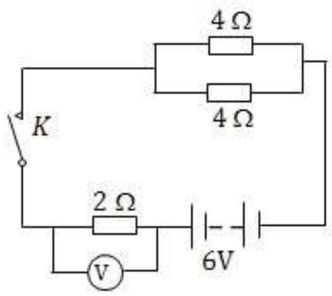
With switch open, Series arrangement 4Ω , 3Ω *and* r;
$R = 4 + 3 + r = (7 + r)\Omega$ *Using*
$V = IR \Rightarrow E = 4(7 + r) = 28 + 4r \quad \Rightarrow E = 28 + 4r \ldots\ldots\ldots\ldots (i)$
With switch closed, Series arrangement 4Ω *and* $3\ \Omega$; $R = 4 + 3 = 7\ \Omega$
Parallel arrangement 3Ω *and* 7Ω; $R = \frac{3\times7}{7+3} = \frac{21}{10} = 2.1\ \Omega$
Series arrangement 2.1Ω *and* r ; $R = (2.1 + r)\ \Omega$
Using $V = IR \Rightarrow E = 5(2.1 + r) = 10.5 + 5r \quad \Rightarrow E = 10.5 + 5r \ldots\ldots\ldots\ldots (ii)$
Solving (i) and (ii) simultaneously, $\Rightarrow r = 17.5\Omega$ *and* $E = 98V$
Internal resistance is 17.5Ω *and the e.m.f is* $98V$
$Lost\ p.d = Ir = 5 \times 17.5 = 87.5V$

4. If the ammeter reads 0.2A, what is the reading of the voltmeter in the figure below?



Series arrangement 50Ω *and* 10Ω ; $R = 60\Omega$
Using $V = IR \Rightarrow V = 0.2 \times 60 = 12V$
Reading of the voltmeter is $12V$.

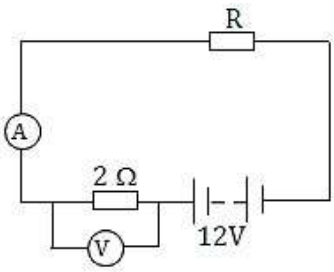
5.



In the figure above, find the
(i) effective resistance in the circuit.
(ii) what is the reading of voltmeter when switch K is closed?

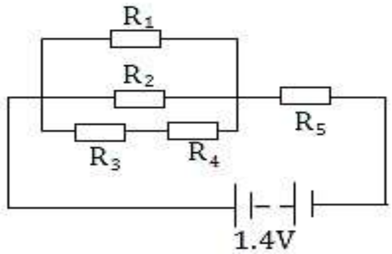
(i) *Parallel arrangement* 4Ω *and* 4Ω;
$R = \frac{4\times4}{4+4} = \frac{16}{8} = 2\Omega$
Series arrangement 2Ω *and* 2Ω ; $R = 2 + 2 = 4\Omega$
(ii) When switch is closed, current supplied $I = \frac{6}{4} = 1.5A$
P.d across 2Ω, $V = 1.5 \times 2 = 3V$.

6. In the figure below, the voltmeter reads 4V. Find the value of resistance R



Current through 2Ω *resistor* $I = \frac{4}{2} = 2A$
In series, P.d across $2\Omega +$ *pd across* $R = 12$,
i.e $4 + V = 12 \Rightarrow V = 12 - 4 = 8V$
Using $V = IR, 8 = 2R \Rightarrow R = 4\Omega$

7. In the figure below, $R_1 = R_2 = R_3 = R_4 = R_5 = 1\Omega$.



Find

(i) the equivalent resistance of the circuit

(ii) current flowing through R_3

(iii) current through R_4

(i) Series arrangement R_3 *and* R_4 ; $R = 1 + 1 = 2\Omega$

Parallel arrangement 2Ω, R_1 *and* R_2 ; $\frac{1}{R} = \frac{1}{2} + \frac{1}{1} + \frac{1}{1} \Rightarrow R = 0.4\Omega$

Series arrangement 0.4Ω *and* R_5 ; $R = 0.4 + 1 = 1.4\Omega$

(ii) Current supplied by battery, $I = \frac{1.4}{1.4} = 1.0A$

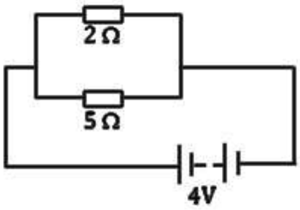
P.d across 0.4Ω, *(parallel arrangement)* $V = IR = 0.4 \times 1.0 = 0.4V$ *This is the same p.d across* R_3

Using $V = IR \Rightarrow 0.4 = I \times 1.0 \Rightarrow I = 0.4A$

(iii) P.d across R_3 *and* R_4 , $V = 0.4V$. $R = 1 + 1 = 2\Omega$

Current through R_4 , $I = \frac{0.4}{2} = 0.2A$

8. Calculate the current flowing through a 2Ω resistor in the figure below.



P.d across 2Ω *and* 5Ω,

$V = 4V$ *(Parallel arrangement)*

Using $V = IR \Rightarrow 4 = I \times 2 \Rightarrow I = 2A$

9. An ammeter connected in series with a cell and a 2Ω resistor reads 0.5A. When a 2Ω resistor is replaced with a 5Ω resistor, the ammeter reading drops to 0.25A. Calculate the

(i) internal resistance of the cell

(ii) e.m.f of the cell

Let r be the internal resistance and E the e.m.f of the cell

In series arrangement, total resistance $R = 2 + r$

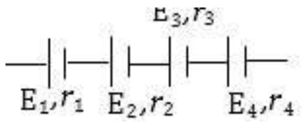
Using $V = IR, \Rightarrow E = 0.5(2 + r) = 1 + 0.5r \ldots\ldots\ldots (i)$

Similarly, $E = 0.25(5 + r) = 1.25 + 0.25r \ldots\ldots\ldots (ii)$

On solving, $r = 1\Omega$ *and* $E = 1.5V$

ARRANGEMENT OF CELLS

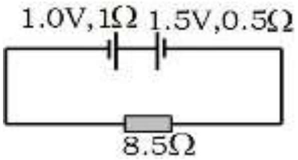
(a) Series arrangement



Total e.m.f $E = E_1 + E_2 + E_3$ and total internal resistance $r = r_1 + r_2 + r_3$

Note: If terminals of two cells are oppositely connected, total e.m.f $E = E_1 - E_2$ when $E_1 > E_2$.

Example: Find the current flowing through the circuit below.

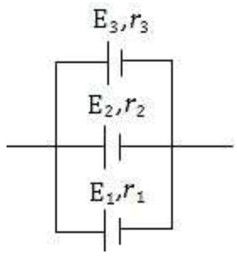


$Total\ e.m.f\ E = 1.5 - 1.0 = 0.5\ V$

$Total\ resistance\ R = 1 + 0.5 + 8.5 = 10\Omega$

$Current\ flowing\ I = \frac{0.5}{10} = 0.05\ A$

(b) Parallel arrangement



E.m.f $E = E_1 = E_2 = E_3$ and

Total internal resistance r is calculated from $\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$

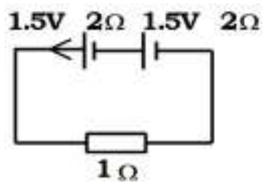
Question

1. Two cells each of e.m.f 1.5V and internal resistance of 2Ω are connected in
   (a) series and (b)
   parallel
   Find the current in each case when the cells are connected to a 1Ω resistor.

   (a) $In\ series\ total\ e.m.f\ E = 1.5 + 1.5 = 3.0V$ $Total\ resistance$ $R = 2 + 2 + 1 = 5\Omega$

   $Current\ supplied\ by\ the\ cells\ I = \frac{3.0}{5} = 0.6A$

   $Current\ supplied\ by\ each\ cell\ \ I = 0.6A\ since\ current\ is\ same\ in\ series.$



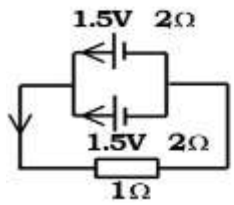
(b) In parallel e.m.f $E = 1.5V$

Total internal resistance $\frac{1}{r} = \frac{1}{2} + \frac{1}{2} \Rightarrow r = 1\Omega$

Total resistance $R = 1 + 1 = 2\Omega$

Current supplied by the cells $I = \frac{1.5}{2} = 0.75A$

Current supplied by each cell $I = \frac{0.75}{2} = 0.375A$



Advantage of connecting cells in parallel over series

There is less drain on the cells since they share the total current whereas with series, the same main current is supplied by each cell.

Disadvantage of connecting cells in parallel over series

Cells become exhausted if they have different e.m.f since current circulates in the parallel circuit. This is not the case in series.

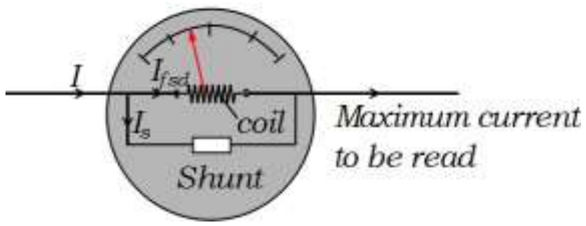
ELECTRIC METERS

The moving coil galvanometer (M.C.G)

It is a current sensitive instrument and gives a full scale deflection (f.s.d) i.e its pointer moves across the scale for a small current called *full scale deflection current*, I_{fsd}

(a) *Ammeter*

By construction, an ammeter is a galvanometer with a coil of low resistance called *shunt*, connected in parallel with the galvanometer. In this case the galvanometer reads a large current.



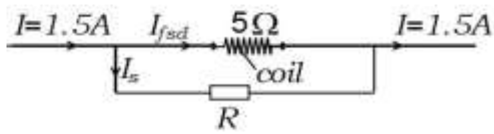
At a junction; $I = I_{fsd} + I_s$ *and p.d across the shunt = p.d across the coil*

Example

A moving coil galvanometer has a coil of resistance 5 Ω and gives a full scale deflection when a current of 15 mA passes through it. Calculate the value of the resistance required to convert it to an ammeter which reads 1.5 A at a full scale deflection.

$I_{fsd} = 15\ mA = \frac{15}{1000} = 0.015\ A$

Solution: Let I_s *be the current that passes through a resistor R.*



At a junction; $I = I_{fsd} + I_s$

$\Rightarrow 1.5 = 0.015 + I_s \Rightarrow I_s = 1.485\ A$

Using $V = IR$;

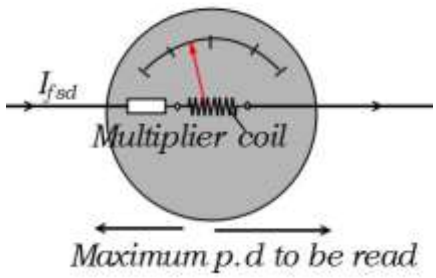
P.d across a 5Ω *resistor* = *p.d across* $R\ \Omega$ *resistor*

$\Rightarrow 0.015 \times 5 = 1.485\ R$ $\quad \Rightarrow R = \frac{0.075}{1.485} = 0.0505\ \Omega$

Therefore the resistance required is $0.0505\ \Omega$

(b) *Voltmeter*

By construction, a voltmeter is an M.C.G with a coil of high resistance called *multiplier,* connected in series with the galvanometer. In this case the galvanometer reads a large voltage.



Total p.d = *p.d across the coil* + *p.d across the multiplier*

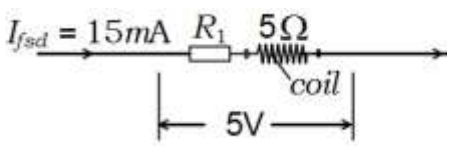
Example

A moving coil galvanometer has a coil of resistance 5 Ω and gives a full scale deflection when a current of 15 mA passes through it. Calculate the value of the resistance required to convert it to a voltmeter which reads up to 5 V at a full scale deflection.

Solution: Let resistance required be R_1.

In series;

Total p.d = *p.d across the coil* + *p.d across the multiplier*



$\Rightarrow 5 = 0.015 \times 5 + 0.015R_1$

Resistance required is $328.3\ \Omega$

Note: Sensitivity of the electric metres is increases by -
increasing area of the coil.

- increasing strength of the permanent magnet - increasing number of turns of the coil
- using a spring of small constant.

Differences between ammeter and voltmeter

Ammeter	Voltmeter
- It measures current - It is connected in series in a circuit - It is a galvanometer with a shunt connected in parallel to its coil.	- It measures p.d - It is connected across the load whose p.d is required - It is a galvanometer with a multiplier connected in series with its coil

HEATING EFFECT OF AN ELECTRIC CURRENT

When an electric current passes round a circuit, electrical energy is converted to heat energy wherever there is resistance.

Question: Explain what happens to a person seated near a coil carrying current.

An electric current flowing in a coil sets up a potential difference across ends of a coil. Electrons are set in motion by electric forces and acquire energy. Moving electrons collide with atoms giving up their kinetic energy to the atoms leading to increased temperature of the coil. Thus a person seated near the coil feels sensation of heat acquired by radiation.

Electric work done: If a p.d V is applied across the conductor of resistance R and quantity of charge flows Q in time t, the electrical work done $W = QV$.

Where $Q = It \quad \Rightarrow W = ItV$

Or from $V = IR, \Rightarrow W = I^2Rt = \frac{V^2}{R}t$ Thus $W = IVt = I^2Rt = \frac{V^2}{R}t$

Electric power, P: is the rate of dissipation of electric energy in a conductor when a p.d is connected across it.

Electric power $P = \frac{electric\ energy}{time} = \frac{IVt}{t} = \frac{I^2Rt}{t} = \frac{\frac{V^2}{R}t}{t}$

$\Rightarrow P = IV = I^2R = \frac{V^2}{R}$ Electrical energy $E = Pt$

Example

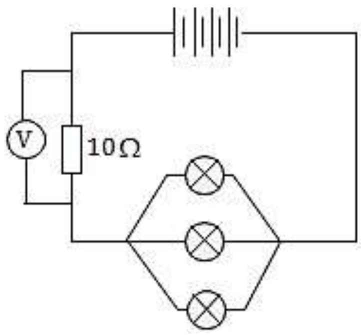
1. An electric lamp uses energy at a rate of 48 W on a 12 V supply. Calculate
   (i) current
   (ii) resistance of the filament lamp
   $(i) P = IV \Rightarrow 48 = 12I \Rightarrow I = 4\ A \quad (ii)\ V = IR \Rightarrow 12 = 4R \Rightarrow R = 3\ \Omega$
2. A block of metal of mass 1.5 kg which is insulated is heated from 30 ℃ to 50 ℃ in 8 minutes and 20 seconds by an electric heater coil rated 54 W. Find:
   (a) the quantity of heat supplied by the heater.
   (b) the heat capacity of the block.
   (c) its specific heat capacity.
   $(a) Quantity\ of\ heat\ supplied = power \times time = 54 \times 500 = 27000\ J$

(b) Heat capacity $C = \frac{Q}{\Delta\theta} = \frac{27000}{50-30} = 1350\, JK^{-1}$
(c) Heat capacity $C = m\,c$
Specific heat capacity, $c = \frac{1350}{1.5} = 900\, Jkg^{-1}K^{-1}$

3. Find the final temperature of water if a heater source rated 42 W heats 50 g water from 20 °C in five minutes.
(Specific heat capacity of water is 4200 $Jkg^{-1}K^{-1}$)
Electrical energy supplied by the heater = Heat gained by the water.
$power \times time = mc\Delta\theta$ $42 \times 5 \times 60 = \frac{50}{1000} \times 4200 \times (\theta - 20)$ $\theta = 80°C$
Final temperature of water is 80°C

4. A refrigerator extracts 0.7 kW of heat. How long will it take to convert 500 g of water at 20°C into ice?
[Specific heat capacity of water is 4200 $Jkg^{-1}K^{-1}$ and specific latent heat of fusion of ice is $3.36 \times 10^5\, Jkg^{-1}$]
Energy lost by the water in forming ice
$Q = Power \times t = mc\ (20-0)\ + ml$
$\Rightarrow 0.7 \times 1000\, t = \frac{500}{1000} \times 4200(20-0) + \frac{500}{1000} \times 3.36 \times 10^5$
$\Rightarrow t = 300\ s$ *It will take* 300 *s.*

5. The figure below shows four identical cells each of internal resistance 0.2 Ω connected to form a battery.
Three identical lamps each marked 3W and a 10 Ω resistor are connected in the figure.
If the current through each lamp is 0.5A, find the
(i) resistance of each lamp
(ii) current supplied by the cells
(iii) reading of the voltmeter
(iv) effective resistance in the circuit
(v) energy delivered by the battery per second



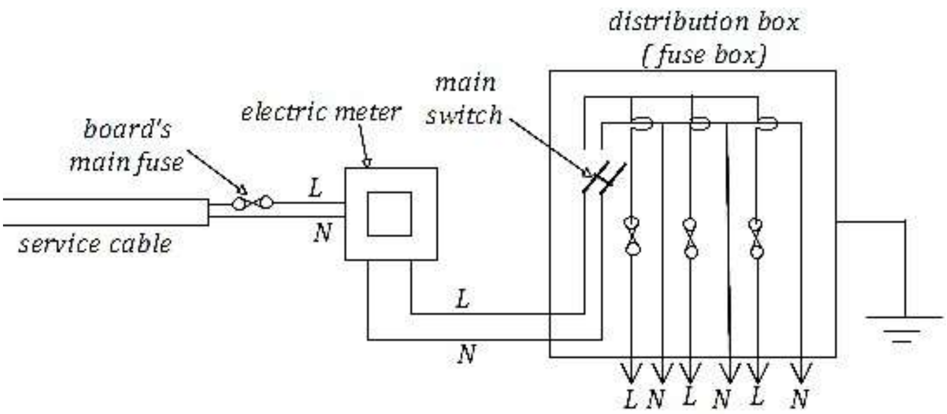
Solution
(i) $P = I^2R \Rightarrow 3 = (0.5)^2R \Rightarrow R = 12\ \Omega$ *Resistance of each lamp is* 12 Ω
(ii) *Current supplied by the cells* $I = 0.5 + 0.5 + 0.5 = 1.5\ A$ *since the lamps are in parallel*
(iii) $I = 1.5\ A$ *P.d across a* 10 Ω *resistor,* $V = 10 \times 1.5 = 15\ V$. *Reading of the voltmeter is* 15V
(iv) *Total internal resistance* $r = 0.2 + 0.2 + 0.2 + 0.2 = 0.8\ \Omega$
Total resistance in series $R_1 = 10 + 0.8 = 10.8\ \Omega$
Total resistance in parallel $\frac{1}{R_2} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} \Rightarrow R_2 = 4\ \Omega$
Total resistance in the circuit $= 10.8 + 4 = 14.8\ \Omega$
(v) $P = I^2R = (1.5)^2 \times 14.8 = 33.3W$

Hazards of Using Electricity

1. Electricity is dangerous and can harm people if it is not used properly.

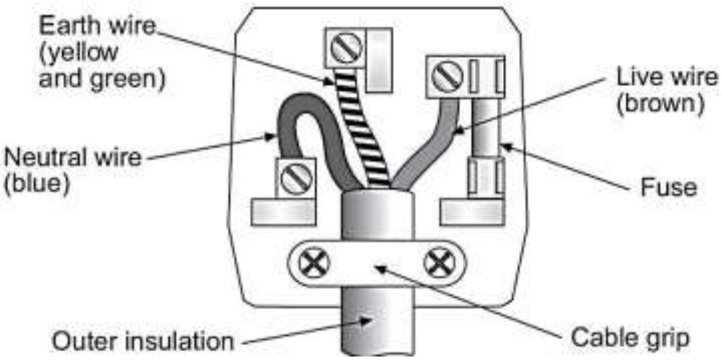
2. Some of the common dangers involved are:
   (a) Handling electrical appliances with wet hands can lead to electric shock.
   (b) Overheated cables can lead to fire.
   e.g. Plugging many appliances to one power point using multi plugs.
   (c) Electrical cables with damaged insulation, especially the live wire, can lead to an electric shock.

DOMESTIC ELECTRICITY SUPPLY



The service cable supplying the mains electricity supply into a house contains two wires – the live (L) and the neutral (N). The neutral wire is always earthed at a local substation and so it is at a zero potential. The supply is alternating current (A.C) and the live wire is alternately positive and negative.

<u>Safe Use of Electricity in the House</u>
The three-pin plug



1. There are three wires in the household electric cable: live (L), neutral (N) and earth (E).
   (a) All appliances need at least 2 wires (live and neutral) to form a complete circuit.
   (b) The live (L) wire (brown) delivers the current at high voltage from the supply to the appliance. It is the most dangerous, thus switches, fuses and circuit breakers are connected to it.

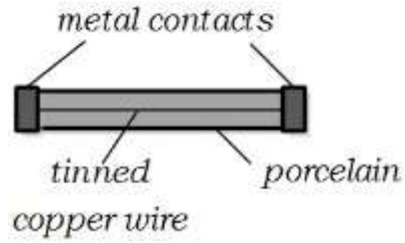
(c) The neutral (N) wire (blue) completes the circuit by forming a path for the current back to the supply. It is usually at zero potential.
(d) The earth (E) wire (yellow and green) is a low-resistance wire, usually connected to the metal casing of the appliance.
(e) Earthing (use of earth wire) protects the user from an electric shock if the metal casing should accidentally become live.
Earthing is a safety measure to prevent electric shocks by providing a path of low resistance between an appliance and the earth.
(f)The large current that flows from the loose live wire through the metal casing and the earth wire will blow the circuit fuse and cut off the supply to the appliance.

2. Fuse

A fuse is a safety device that is connected to the live wire of an electrical circuit to protect the equipment against any excessive current flow.
A fuse is a protective device used to protect circuits from short circuiting and overloading.

- *Short circuiting refers to when wires leading to an appliance come in contact resulting into current bypassing the appliance.*
- *Overloading the circuit refers to a situation when too many appliances drawing current from the circuit are connected to the circuit at the same time.*

A fuse is made of a thin tinned copper metal wire which has a low melting point.



Common fuse ratings: 1 A, 2 A, 5 A, 10 A and 13 A.
Fuse rating in a device must be slightly higher than the current through the device.

Action of a fuse

When current is too large exceeding a certain marked value, the fuse becomes hot and melts (blown fuse), thus cutting off the current flow from the live wire to the device.

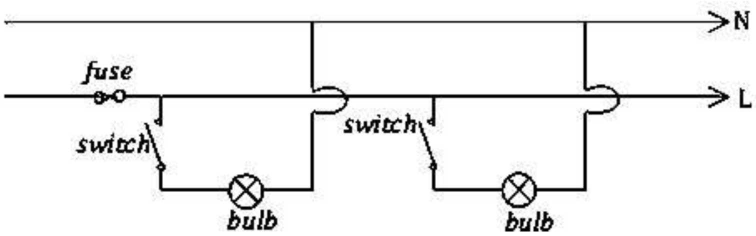
3. Switches are connected on the live wire to control the flow of current by closing and opening the circuit.

House circuits

Every electrical appliance is connected in parallel with the supply i.e across live and neutral wires so that it receives full mains p.d of 240V. The house is wired with several circuits such as lighting circuit, ring circuits (for sockets) such that if one circuit is faulty, the whole supply of the house is not cut off/disconnected.

Lighting circuits

In a lighting circuit, cables of small cross-sectional area are used so that little current flows in the cables.



Parallel circuits are more appropriate for domestic lighting since

- bulbs connected in parallel have low net resistance, have same potential difference and thus glow brighter.
- if one lamp blows, other lamps will continue to glow. ▯ light is individually controlled.

Note: In sockets, thick cables of large cross-sectional area are used to allow more electric current to flow.

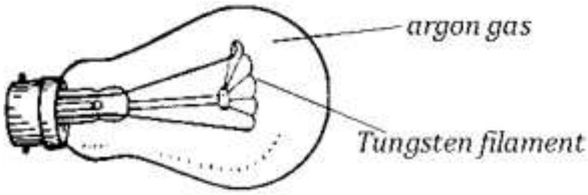
Safety precautions in wiring a house

- Wires must be properly insulated
- Switches and fuses should be connected to live wires to control the flow of electricity into the circuit
- Electrical appliances should be earthed to prevent electric shocks - Right color codes should be used.

ELECTRIC LAMPS

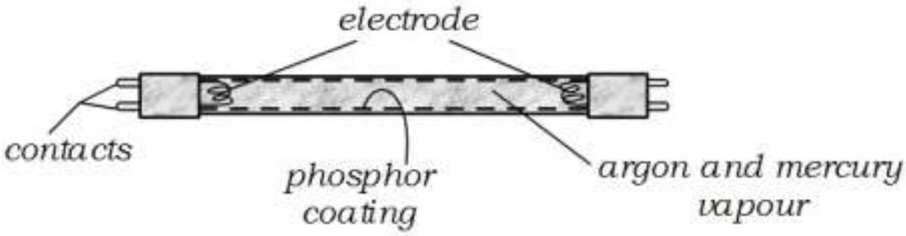
These are the filament, discharge and fluorescent lamps. These lamps convert electric energy to light and heat energy.

(i) Filament lamp



Tungsten filament has a high resistance and high melting point. Current in the high resistance filament produces a great deal of heat making it hot enough to glow white hot and give out light.
The argon gas prevents hot filament from oxidation at high temperatures.

(ii) Fluorescent lamp



The electrodes when heated, supply electrons that ionize the argon gas.
Excited mercury atoms emit red, green, blue, and ultraviolet light which strike phosphor coating that converts the ultraviolet light into other visible colors.

(iii) Discharge lamps
These are gas filled tubes fitted with metal electrodes. The gas glows with a characteristic color when a high voltage is applied at the electrodes. Examples include mercury vapour lamps used for street lighting.

Advantages of fluorescent lamps over filament lamps

- They are cheaper to run. They convert about 10% of electrical energy supplied - They produce softer light
- They more efficient and provide about three times as much as filament lamps of the same wattage.
- They last longer

Disadvantages of fluorescent lamps over filament lamps

- They are more expensive to buy
- They delay to start
- They flicker a lot and cause eye strain
- They are destroyed by switching on and off

Labeling of electrical appliances

Every appliance has a label stating the potential difference (p.d) for which it is designed and the power it converts when working at that p.d. E.g. A bulb marked 240V, 75W. What does it mean?

This means that when this bulb is connected to a 240V supply, it converts 75W of the electrical power into heat energy and light energy.

COST OF ELECTRICITY

The amount of depends on the

- power of the appliances
- time which they are switched on.

Units of electricity used (electric energy used)=total power of appliances (kW)× time they are switched on (hours)

Its units are kWh. Where $1kW = 1000W$

A kilowatt hour is the electrical energy used by one kilowatt appliance in one hour.

Cost of electricity =units×cost per unit

Thus cost of electricity=total power (kW)×time (hours)×cost per unit

Questions

1. Calculate the cost of running an electric fire for $2\frac{1}{2}$ hours if it takes 13 A on a 100V supply. Each unit costs Ush.500.

   $Power = 13 \times 100 = 1300W = \frac{1300}{1000} = 1.3\ kW$

   $Cost\ of\ electricity = 1.3 \times 2\frac{1}{2} \times 500 = Sh. 1{,}625$

2. Four bulbs each rated 75W operate for 120 hours. If the cost of electricity is sh.600, what is the total cost?

   $Total\ power = 75 \times 4 = 300W = \frac{300}{1000} = 0.3\ kW$

   $Cost\ of\ electricity = 0.3 \times 120 \times 600 = Sh. 21{,}600$

3. A house has one 100W, two 75W bulbs and five 40W bulbs. Find the cost of having all these bulbs switched on for 2 hours every day for 30 days at a cost of sh.500 per unit.

   $Total\ power = 100 \times 1 + 75 \times 2 + 40 \times 5 = 450\ W = \frac{450}{1000} = 0.45\ kW$

   $Cost\ of\ electricity = 0.45 \times 2 \times 30 \times 500 = Sh. 13{,}500$

4. How many units of electric energy will be used in a day by a 3 kW?

   $Power = 3kW$

   $Units\ used = total\ power\ (kW) \times time\ (hours)$

$= 3 \times 24 = 72kWh$ **POWER**

TRANSMISSION

Due to the resistance of the wires, power losses $P = I^2R$ occur in overhead cables. Thick wires of low resistance are required to minimize this power loss but it is costly to install such wires.
The economic way to transmit electricity is to use thin wires at high voltages and low currents for long-distance transmission lines. This is achieved by using transformers.

GENERAL QUESTIONS

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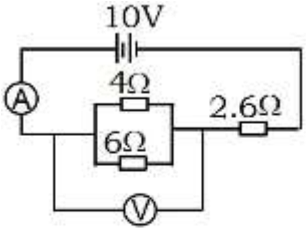
1. (a) What is a volt?
   (b) A lamp is marked 240V, 60W. Explain what this means.
   (c) (i) Use a diagram to show how three identical cells each of e.m.f 1.5 V and internal resistance 0.1 Ω, can be arranged to give minimum e.m.f
   (ii) Calculate the current flowing in the circuit of the arrangement in (c)(i), if two resistors of resistances 4 Ω and 5Ω are included in series in the circuit.
   (d)(i) State two sources of e.m.f
   (ii) With the aid of a labelled diagram, describe how an accumulator can be charged.
2. (a) Give two advantages of connecting the bulbs in parallel to a battery
   (b) (i) State Ohm's law and define the ohm as a unit of resistance
   (ii) Describe an experiment to verify Ohm's law
   (c) Three resistors of $2\Omega, 4\Omega$ and 3Ω are connected in the same circuit.
   (i) Draw a circuit diagram to show how they are connected to give minimum resistance
   (ii)Find the value of the minimum resistance
   (d) Explain why a wire carrying current heats up when electric current is passed through it.
   (e) (i) State how a galvanometer can be used to measure large currents
   (ii) A galvanometer gives a full scale deflection for a current of 0.1A and its resistance is 0.5Ω. Determine the value of the resistance necessary to convert it into a voltmeter which reads up to 100V.
3. (a) Define the following terms
   (i) potential difference
   (ii) electromotive force
   (iii) internal resistance of a cell

(b) A battery of e.m.f 10 V is connected to resistors 2.6 Ω, 4Ω, and 6Ω as shown in the figure below.



(i) Calculate the ammeter and voltmeter readings

(ii) Find the rate at which electrical energy is converted to heat energy in the 6 Ω resistor.

(c) What is meant by a short circuit?

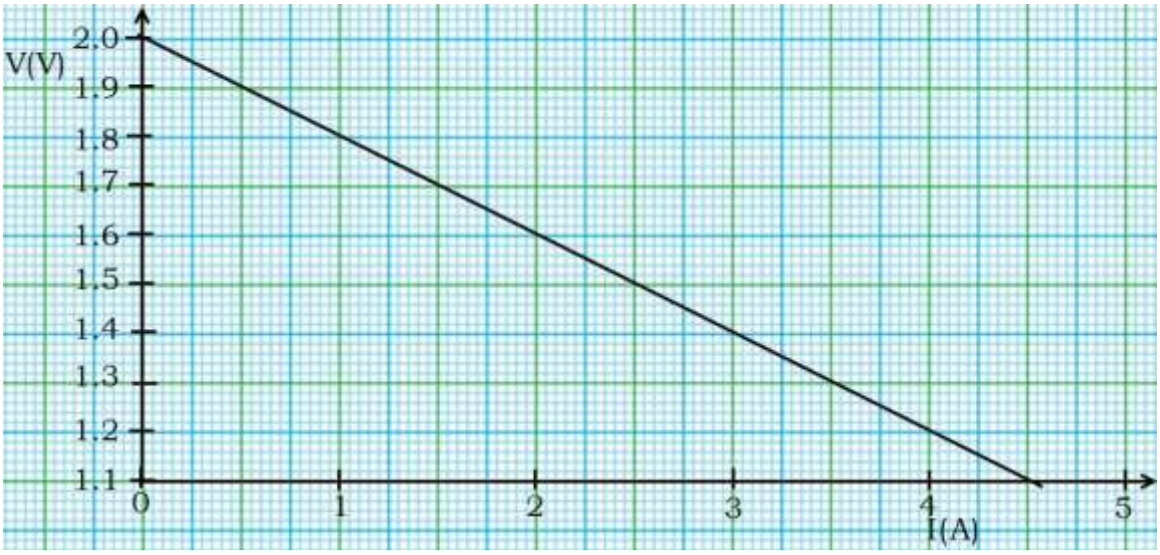
(d) (i) Briefly explain how a milliammeter can be adopted to measure much higher currents

(ii) State two ways of increasing the sensitivity of electrical meters 4. (a) List three precautions necessary to prolong the life of an accumulator (b) State two disadvantages of a NIFE cell over a lead acid cell.

(c) A cell is connected in series with an ammeter and a variable resistor. The potential difference V across the resistor varies with current I supplied through the resistor as shown in the graph below. Use the graph to determine the

(i) e.m.f

(ii) internal resistance, of the cell.



5. (a) Draw sketch graphs of p.d V against current I for the following

(i) a wire

(ii) an electrolyte

(iii) a semi-conductor diode

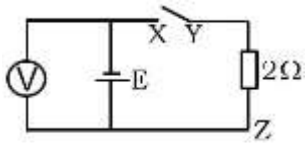
(b) Explain the differences between a voltmeter and an ammeter in terms of their

(i) construction

(ii) use

(c) State three physical properties that affect the resistance of a solid conductor.

(d) A cell of e.m.f E and internal resistance 1.0 Ω is connected in series with a 2.0 Ω resistor and a switch as shown in the figure. The voltmeter reads 1.5 V when the switch is open.



(i) Find the value of E

(ii) What will the voltmeter read when the switch is closed?

(iii) What will the voltmeter read when X is connected to Z. Give reasons for your answer.

(e) Abbot paid an electricity bill of sh. 1800 after using two identical bulbs for 2 hours every day for ten days at a cost of sh.600 per unit. (i) Determine the power consumption by each of the bulbs

(ii) State the energy changes that occur in the bulb

6. (a) (i) Explain what is meant by polarisation as applied to a simple cell (ii) State how polarisation can be minimised in a simple cell.

(b) Explain how the life of a lead-acid accumulator may be prolonged

(c) A bulb is rated 12.0V, 36W when used on a 240.0V mains.

(i) How much current does it draw from the supply?

(ii) What is its resistance?

(d) State three advantages of an alternating current over a direct current in power transmission.

END