Chapter Six

DESCRIPTION AND PROPERTY OF FIELDS

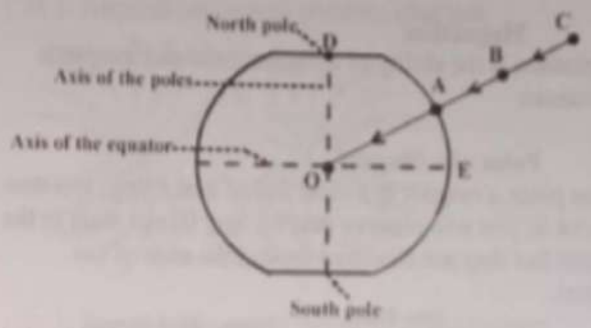
A field is a region or space under the influence of some physical agency such as gravitation, magnetism and electricity. It is the same as force-field. We have two classes of fields namely: scalar fields and vector fields.
A scalar field is the one that has only magnitude but no direction e.g heat, work and pressure.
A vector field is the one that has both magnitude and direction e.g gravitational field, magnetic field and electric field. There are many types of fields but at this stage we shall concern ourselves with only two namely: gravitational field and magnetic field.

Gravitational field

Gravitational field is a region or space around a mass in which the gravitational force of the mass can be felt.
Objects on or around the surface of the earth are always attracted (pulled) towards the centre of the earth by the earth's gravitational force. For this reason, the following observations are common.

i. If you release an object in your hand, it falls towards the earth.
ii. If you throw an object upward, it will move up to a point (its highest point), it will stop momentarily and fall back to the earth.
iii. If you are lifting a bucket of water you feel that a force is pulling it toward the earth.
iv. There is a limit of height to which we can jump.

When you are lifting a load the force that pulls it toward the earth is the weight of the load. The weight of an object is a measure of the earth's gravitational force on that object.
This gravitational force causes a change in velocity of the objects under its influence, meaning that it accelerates such objects.
The acceleration of objects due to the earth's gravitational force of attraction is called acceleration due to gravity. It is represented by the symbol g and it has an average value of $9.81ms^{-2}$. However for simplicity of calculations we usually adopt an approximate value of $10ms^{-2}$.
The acceleration due to gravity is uniform for a given location and is the same for all bodies within the same location irrespective of their masses. It however varies from place to place on or around the earth surface. It decreases with the distance of the object from the centre of the earth. That is, the closer the distance of an object to the centre of the earth, the more the value of its acceleration due to gravity and the farther the distance of an object from the center of the earth, the lesser the value of its acceleration due to gravity.
The earth is not a perfect square in the sense that it is flattened at both the north and south poles, thus the axis of the equator is longer than the axis of the poles.



The above is a schematic diagram of the earth showing objects at different locations on and around the earth surface. Considering objects D, A and E on the earth surface. D, at the pole is the closest to the centre O of the earth and has the highest values of g, followed by A while E at the equator is the farthest from the centre O of the earth and has the least value of g.
Also considering objects A, B and C around the surface of the earth and at varying distances from the centre of the earth. A is closest to O with the highest value of g, followed by B and C is the farthest from O with the least value of g.
Acceleration due to gravity can be determined experimentally.
The Weight W of a body is the product of its mass, m, and acceleration due to gravity g

$$W = mg$$

Mass is constant but weight varies from place to place because acceleration due to gravity varies from place to place.

The acceleration due to gravity is also called acceleration of free fall. That is, all objects falling freely, falls with this acceleration.
In the absence of air resistance or friction, all bodies fall with the same acceleration irrespective of their masses. That is, two bodies of different masses released simultaneously from the same height will reach the ground at the same time.

2011/8 Exercise 6.1
In the absence of gravitational force, the weight of a body is
A its mass B zero C its density D its volume

Magnetic Field

Magnetic field is the region or space around a magnet in which the influence of the magnet can be felt. The following are observed around a magnet.

i. Pins or nails placed near a magnet are attracted by it.
ii. The closer the object is to the magnet, the more the force with which it is attracted to the magnet.
iii. Things like wood, plastic, glass, paper etc. are not attracted by a magnet however near they are.

Magnetic and Non-magnetic substances

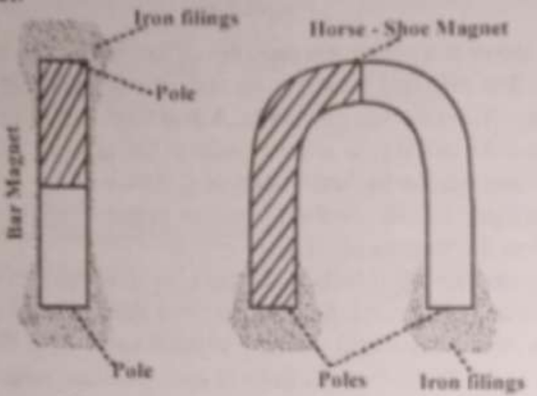
Magnetic substances are those substances that can be attracted by a magnet. Examples are iron, nickel and cobalt. On the other hand, non-magnetic substances are those substances that cannot be attracted by a magnet. Examples are wood, plastic, glass, paper etc.

Magnetism

Magnetism is the ability of a magnet to attract magnetic substances.

Poles of a Magnet

If you place a magnet in a plate full of iron filings and then remove it, you will observe that the iron filings cling to the magnet but they are clustered around the ends of the magnet.



The ends of the magnet where the iron fillings are concentrated are called the poles of the magnet.
The pole of a magnet is defined as the portion of the magnet where its magnetic attraction appears to be strongest. When a bar magnet is suspended about its centre in such a way that it can swing freely, it quickly comes to rest with its axis aligned approximately in the North–South direction. The end of the magnet that points in the northward direction is the North Pole. The other end that points in the southward direction is the South Pole. The North Pole is represented by the symbol N while the South Pole is represented by S.

2018/8 (a) Neco Exercise 6.2

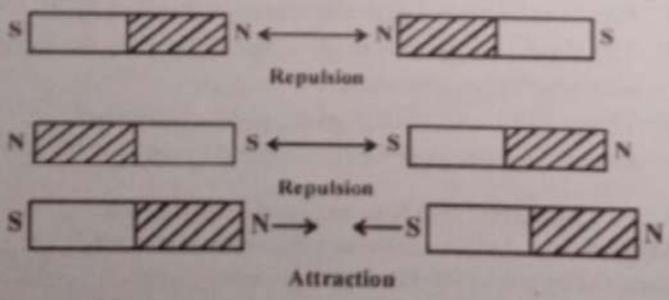
A bar magnet is dipped into iron fillings and removed, state

(i) At what point(s) on the magnet will the fillings be concentrated

(ii) A reason for your answer in (i)

Attraction and Repulsion by poles of magnets

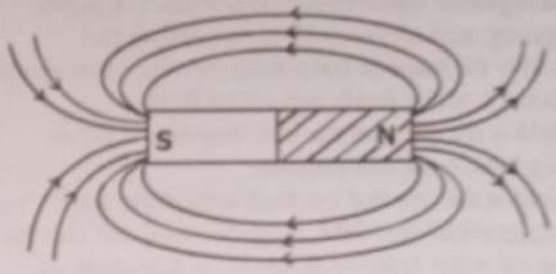
When you bring the North Pole of a particular magnet near the North Pole of another magnet, they are repelled away from each other. The same effect (repulsion) is observed when the South Pole of one magnet is brought near the South Pole of another magnet.
On the other hand, when the South Pole of one magnet is brought near the North Pole of another magnet, they are attracted to each other.



Thus we can conclude that like or similar poles of magnets repel one another while unlike or dissimilar poles attract one another.

Field Pattern Round a Magnet

Magnetic field is a force-field and a vector field. By means of a compass needle, we can demonstrate and map out the pattern and direction of the magnetic field of a bar magnet. The diagram below gives the pattern of magnetic field round a bar magnet, plotted using a compass needle.



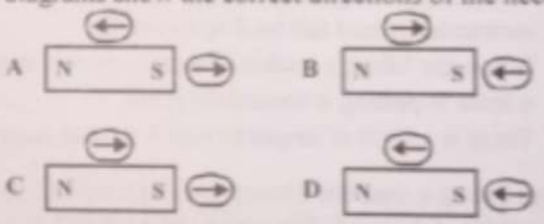
These emergent lines are called magnetic field lines, magnetic lines of force or magnetic flux. The magnetic line of force of a magnet is defined as the line along which a free North-pole would tend to move if placed in the field.

Properties of magnetic field lines

i. They begin on a North pole and end on a south pole.
ii. They do not cross each other, otherwise the magnetic field would have two possible directions at the point of intersection.

2018/45

A student uses two compass needles to investigate the magnetic field around a bar magnet. Which of the following diagrams show the correct directions of the needles?



Patterns of magnetic field (magnetic field lines) are plotted using a compass needle. The direction of the compass needle at the point where it is placed, indicates the direction of the field at that point.
A magnetic field line always begin on a north pole and ends on a south pole. That is, it always leaves a north pole and enters a south pole. A careful look at the options shows that only option B fits/agrees with the characteristic of magnetic field lines stated above. (B)

2014/36 Exercise 6.3

The region around a magnet in which magnetic force can be experienced is known as

A declination B flux density C field D flux

Chapter Seven

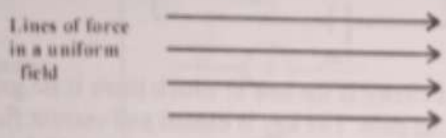
ELECTRIC FIELD

Electric field is a region or space where a charged body experiences an electric force. Electric field is a vector field. It has both magnitude and direction.
The direction of an electric field at any point is given by the direction of the force acting on a small positive charge placed at that point.
Electric field is represented by electric lines of force.

Types of Electric fields

There are two types of electric field namely: Uniform field and variable field.

i. Uniform Field: A uniform field is that in which the field lines are straight, parallel and evenly spaced.



ii. Variable field: A variable field is the one in which the field lines are curved. The direction of the filed varies from point to point and is tangential to the lines of force at any point.

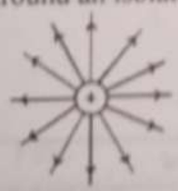
The direction of the field at the points A, B and C is given by the tangents to the curve at those points.

Electric line of force

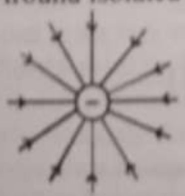
Electric line of force is the path which an isolated small positive charge would follow if placed in the field.
It is an imaginary line drawn in an electric field such that the direction at any point gives the direction of the electric field at that point.
Lines of force are also called electric flux.

Patterns of electric field

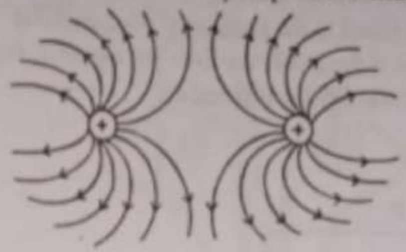
(i) Around an isolated positive charge



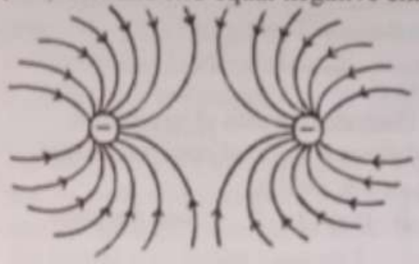
(ii) Around isolated negative charge



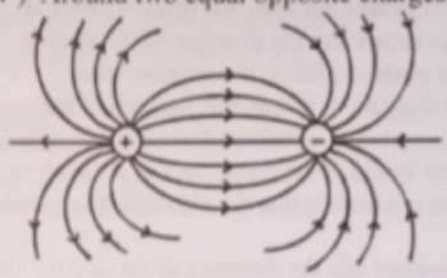
(iii) Around two equal positive charges



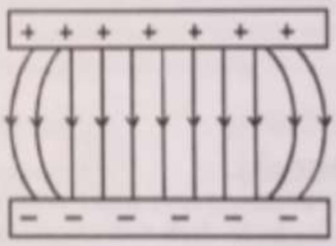
(iv) Around two equal negative charges.



(v) Around two equal opposite charges



(vi) Between a pair of parallel conducting plates.



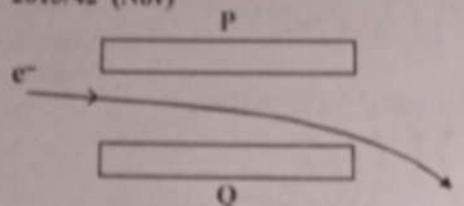
Properties of field lines

The properties of electric lines of force can be summarized as follows:

1 Lines of force are imaginary.
2 Lines of force begin only on positive charges and end only on negative charges. The number of field lines starting or ending is proportional to the magnitude of the charge.
3 They repel each other sideways. That is, they do not cross each other. If they cross it means the field would point in different direction at the same point, which does not make sense.
4 Lines of force in a uniform field are straight parallel and evenly spaced.
5 Lines of force indicate the direction of the electric field. The direction of the field at any point is given by the direction of the tangent to the field at that point.
6 Lines of force are continuous in any region with free charges.

7 The lines are such that the electric field in a given region is proportional to the number of lines crossing that region. That is the closer the lines are together, the stronger the electric field in that region.

2013/42 (Nov)



The diagram above illustrates the path of an electron between two parallel plates P and Q of opposite charges. The direction of the electric field is

A from P to Q B from Q to P C into the paper
D into space

Solution

The electric field pattern between two parallel plates of opposite charges shows that the direction of the electric field is from the positive plate to the negative plate. From the given diagram, it is seen that the path of the electron (negative charge) is deflected towards the plate Q. Since an electron would be attracted towards positive charges, then we can deduce that the plate Q is the positive place.

This implies therefore that the direction of the electric field is from Q to P. (B)

Current Electricity

Static electricity (electrostatics) deals with electric charges at rest while current electricity deals with electric charges in motion.

Electric current

Electric current is the time rate of flow of electric charge along a conductor such as a wire.

$$Electric\ current = \frac{Quantity\ of\ charge}{time}$$

Given that electric current = I
Quantity of charge = Q and Time = t, then

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

$$Q = It$$

Q is in coulomb (C), t in second (s) and I is in amperes (A).
The S.I. unit of current is ampere A.
However there are smaller units of current such as:

Milliampere (mA) = 10^{-3}A and
Microampere (μ A) = 10^{-6}A

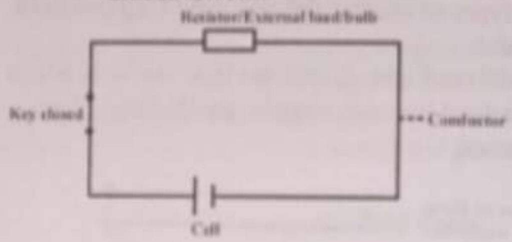
These kind of low currents are common in transistor radios and electric calculators: The instrument used for measuring current is called Ammeter. Smaller currents are measured using Milliammeters while very small currents are detected by sensitive instruments called Galvanometers.

Electric circuit

An electric circuit is the path provided for the flow of electric current. It consists of the cell/battery which is the source of energy, a conductor (e.g. a wire) through which the cell/battery is connected to a load. The load could be an electric bulb or a resistor. There is a key which serves to close or open the circuit. To close a circuit also means to complete it and to open a circuit also means to break it. There are three types of electric circuit namely:

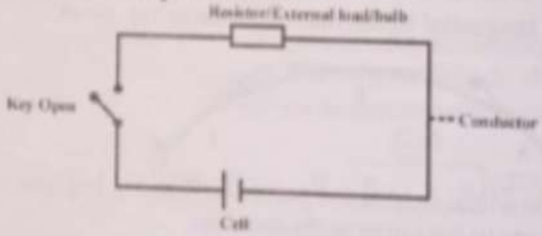
- Closed circuit
- Open circuit
- Short circuit

Closed Circuit



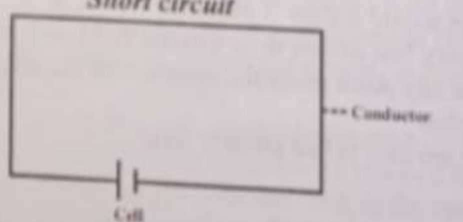
A closed circuit is the one in which there is no gap along the conducting path. The key is closed and current flows through the conductor to the external load. If the external load is a bulb, it lights up.

Open Circuit



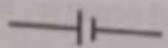
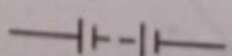
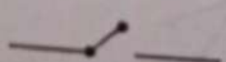
An open circuit is the one in which there is gap along the conducting path. The key is open and current does not flow to the external load and if it is a bulb, it does not light up.

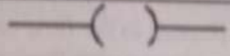
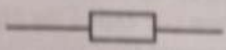
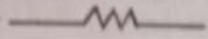
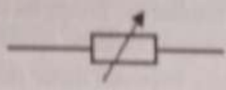
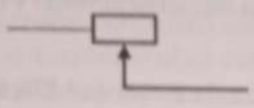
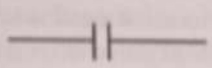
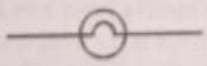
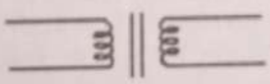
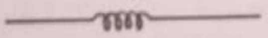
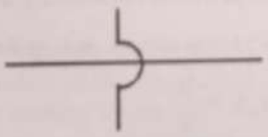
Short circuit



A short circuit is a closed circuit which has no load on it.

Symbols used in Electric Circuits

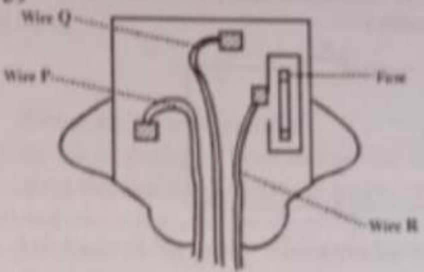
	Name of device	*Symbol used*
1	**Cell**	
2	**Battery**	
3	**Tap key or Switch**	

Name of device	Symbol used
4 Plug key	
5 Resistor	 Or 
6 Resistance box	
7 Rheostat or Variable resistor	
8 Capacitor	
9 Earth Connection	
10 Ammeter	
11 Voltmeter	
12 Galvanometer	 Or 
13 Bulb	 Or 
14 Transformer	
15 Coil of wire	
16 Crossed wires	
17 d.c Source	
18 a.c Source	

Fuse

A fuse is a short length of wire of low melting point, connected to the live wire of an electric circuit so that when a current above a certain level flows in the circuit, the heat developed in the fuse wire, melts it and thus cut the fuse wire, thereby breaking (opening) circuit and current no longer flows to the appliance that the circuit is delivering current to. Thus, the fuse is a safety device for electrical appliances. Fuse rating is the maximum current permitted to flow in a fuse before the fuse breaks.

2018/39



The diagrams above illustrates the wire connections to a three – pin plug. The wires P, Q and R respectively are

A Live, neutral and earth. B Neutral, earth and live.
C Earth, live and neutral. D Earth, neutral and live

Solution

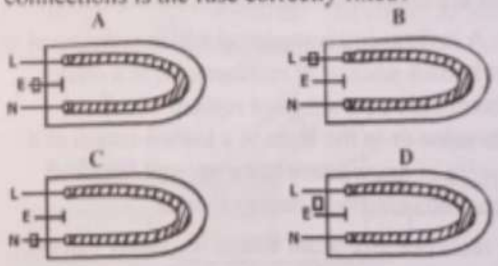
The conventional way of connecting the three-pin plug is that the earth wire is connected to the top pin and the live wire is connected to the pin to which the fuse is connected. The neutral wire is then connected to the remaining pin.
In line with the conventional way of connecting these wires, the wires P, Q and R respectively are:
Neutral, earth and live (B)

Additional Information

The conventional colours for the wires are:
Earth wire → yellow/green
Live wire → Red
Neutral → Black

2017/39

The diagrams below illustrate electrical connections to the element of an electric pressing iron. In which of the connections is the fuse correctly fixed?



Solution

L = live, E = Earth, N = Neutral
The fuse is always fixed to the live. (B)

2018/34 Neco Exercise 7.1

The property considered when selecting a wire to be used as a fuse is its

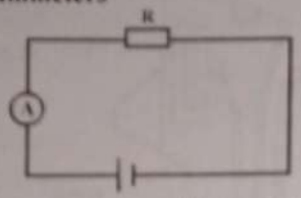
A conductivity B cross sectional area
C length D melting point E resistivity

The simple continuity tester

The simple continuity tester is a device used to detect faults in a circuit. When a circuit is not continuous, that is, circuit broken, then there is a fault in the circuit. A continuity tester is used to test whether a circuit is continuous or broken at a certain point.
The tester consists of a bulb which lights up when there is continuous flow and fails to light up when the circuit is broken.

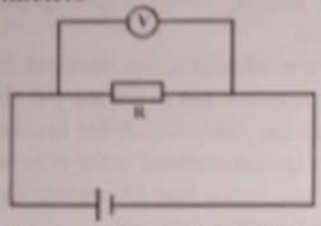
Connection of Ammeters and Voltmeters in Circuits

i. **Ammeters**



The ammeter must always be connected in series in a circuit. This is because it measures the current that flows through it directly. In order not to alter the current it measures, the ammeter is designed to have a low resistance.

ii. **Voltmeters**



A voltmeter measures the potential difference (p.d) between (across) two points along a conductor. That is why it must always be connected in parallel with or across these two points.

Voltmeters are designed to have a large electrical resistance so that it can draw only a negligible amount of current.

Other major components of the circuit

i. Cell/battery: A cell is a device for converting chemical energy into electrical energy. It is the source of energy which drives the current round the circuit. When two or more cells are combined together it is called battery.

ii. Resistor: A resistor is a component which is designed to provide a known amount of resistance, R in a circuit. The resistor could be a standard resistor of a fixed resistance value or in the form of a known length of a resistant wire of known resistance per unit length. A resistor converts electrical energy to heat.

iii. Variable resistors: Are those whose resistance can be varied. Examples are the Rheostat and Resistance box.

iv. Key/Switch: A switch or key is a component of a circuit by which the circuit is closed or open. When the circuit is closed, current flows and when the circuit is open, current stops to flow.

2018/37 Exercise 7.2

A resistor with fixed resistance value is called a

A resistance box   B standard resistor

C shunt   D multiplier

Potential difference P.D

The potential difference between any two points in an electric field is the work done in moving a unit positive charge from one point to another. The potential difference between any two points in an electric circuit is the work done in moving a unit positive charge from one point in the circuit to the other.

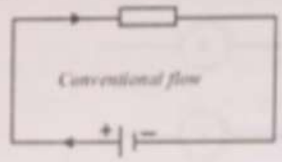
Before current can flow from one point to another in a circuit, the two points must be at different potential.

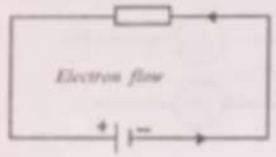
Generally, current would flow from the point of high potential to the point of low potential. The flow of current in a circuit can be likened to the flow of water along a pipe. For water to flow along a pipe there must be a pressure difference between one end of the pipe and the other. Generally water would flow from the point of high pressure to the point of low pressure.

Because of this similarity, potential difference between any two points in a circuit could be termed as the electrical pressure difference between those points. Potential difference is measured in volts (V).

Conventional current and Electron flow

The positive terminal of a cell is taken to be at a higher potential than the negative terminal. Thus the conventional flow of electric current (flow of electrons) is usually represented as flowing from the positive end of the cell. However, it should be noted that electrons are actually flowing from the negative to the positive end of the cell.





Electromotive force e.m.f

Electromotive force is the total work done in driving one coulomb of electricity round a circuit. OR The total energy per coulomb obtained from a cell or battery.

The cell/battery serves as the source of potential difference that makes it possible for the current to flow.

Given that potential difference p.d = V, work done = W and

Quantity of charge = Q and p.d = $\frac{workdone}{charge}$,

Then $V = \frac{W}{Q}$

$W = QV$

Also emf $E = \frac{work}{charge}$

$E = \frac{W}{Q}$

W is in Joules (J) and Q in Coulomb (C).

The e.m.f of a cell is also defined as the p.d between the terminals of the cell when it is not delivering any current to an external load or the p.d between the terminals of a cell when it is in an open circuit.

The unit of e.m.f is the volt(V). From the above relationship

$V = \frac{W}{Q}$,

The volt is the p.d between two points on a conductor when one joule of work is done in moving one coulomb of charge from one point to the other.

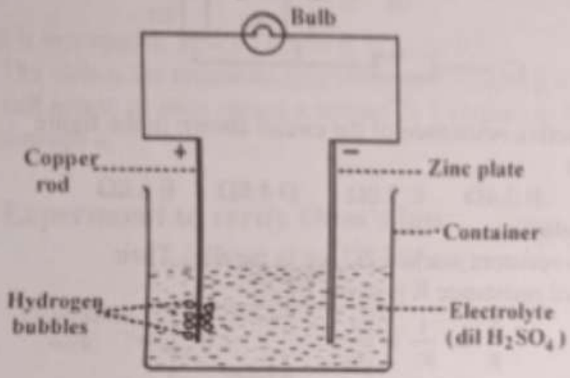
Production of Electric current

Electric current (electricity) can be generated from
(i) chemical energy (ii) heat energy (iii) mechanical energy (iv) solar energy.

i. From chemical energy:

Electricity can be produced from chemical energy through the use of electric cells. A cell consists of two dissimilar metals (electrodes) separated by an acid or salt solution (electrolyte). The positive electrode is called anode while the negative electrode is called the cathode.

A simple cell consists of a copper rod (anode) and a zinc plate (cathode) Immersed in a container filled with dilute tetraoxosulphate (VI) acid. When the terminals of the copper rod and zinc plate are connected to a bulb, using a conductor such a metallic wire, the bulb lights up, showing that current is flowing through it.



Defects of the simple cell

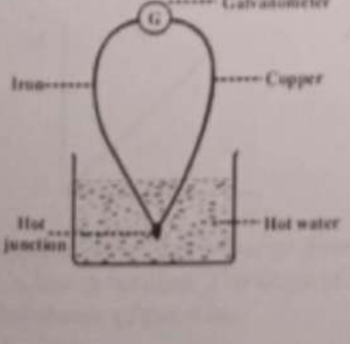
The simple cell has two defects namely polarization and local action. These make the cell to supply current only for a short time.

Polarization: is due to the formation of hydrogen bubbles around the copper plate. This creates a back emf between the zinc and the hydrogen bubbles which opposes the emf of the cell. Polarization can be reduced or prevented by the addition of a depolarizer such as manganese dioxide and potassium dichromate.

Local action: is due to impurities on the zinc plate. This situation leads to the dissolution of the zinc plate. Local action can be prevented by rubbing of mercury over the surface of the zinc plate – a process called amalgamation.

ii. From Heat Energy:

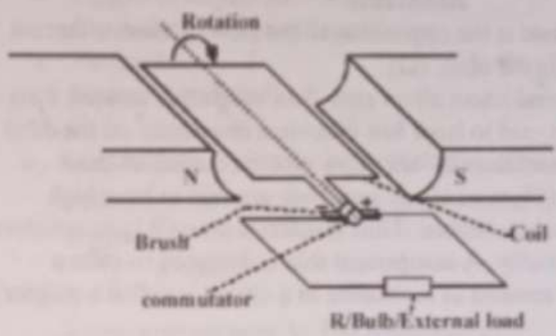
Electricity can be produced from heat energy using a device called a thermo – couple. A thermo-couple consists of two different metallic wires (such as copper and iron) joined at one end and the free ends connected to a galvanometer.



When the junction of the metals is put in hot water, the galvanometer shows deflection, which is an indication that current flows.

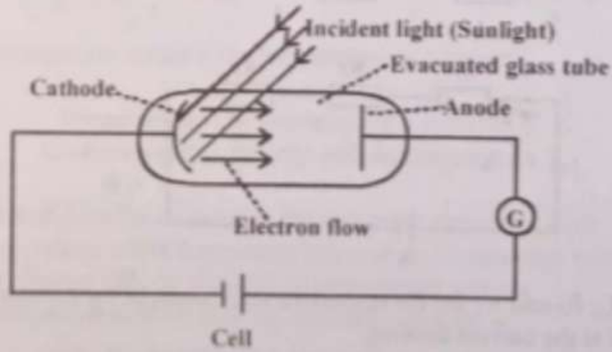
iii. From mechanical energy:

Electricity can be produced from mechanical energy using a device called the electric generator or a dynamo. When coils of insulated wire cut across the magnetic lines of force as they move across the magnetic field between two powerful magnets, current is induced in the coil. This current is tapped using split – ring commutators and carbon brushes. The generator is turned using a dam/turbine, wind mill e.t.c



iv. From solar energy:

Electricity can be produced from solar energy using a device called photoelectric cell or a photocell. A photocell consists of a photosensitive surface (e.g the surface of potassium) as a cathode and a wire ring as the anode in an evacuated glass tube. When visible light falls on this surface, electrons are emitted by photo-electric effect and the flow of these electrons constitute current flow which can be detected by a galvanometer. The electrons are usually accelerated from the cathode to the anode.



2018/1a Neco

Explain how electricity is produced from a dam.

Solution

- The dam stores a large volume of water behind it in the reservoir.
- Gravity causes the water to fall through the penstock on the turbine blades/propeller at the bottom of the penstock.
- The falling/moving water turns the turbine blades/propeller which turns a shaft that turns the coil of the generator.
- As the coils (armature) of the generator turns, electricity is produced.

Conductors and insulators

Conductors: are those materials through which electricity can flow easily. Examples are almost all metals (such as silver aluminium, copper, zinc, iron, brass etc), impure water, inorganic acid solutions, damp air, etc.
Insulators: are those materials which do not allow electric current to flow through them easily. Examples are ebonite, glass, dry wood, dry air, silk plastic, organic acid solutions etc.

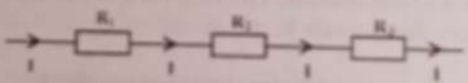
Resistance

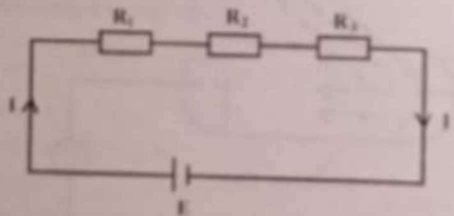
Resistance is the opposition to the flow of electric current its unit is the ohm. (Ω).
Since conductors allow easy flow of electric current, then they are said to have low electrical resistance. on the other hand, insulators do not allow electric current to flow through them easily as such they are said to have high electrical resistance. Thus insulators are said to be resistors of electricity. A component that is designed to offer a certain amount of resistance in a circuit is called a resistor.

Arrangement/connection of Resistors in an electric circuit

i. Series connection

When two or more resistors are connected in a circuit such that they are connected end to end and the same current passes through each of them, then they are said to be connected in series. Generally in series connection, the current flowing from the cell does not branch but follows a single path round the circuit.



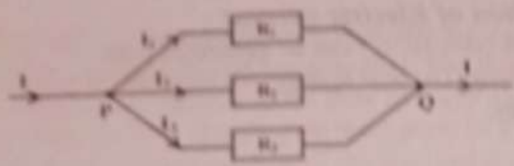


R_1, R_2 and R_3 are the respective resistances of the resistors. I is the current flowing.
The combined (equivalent or total) resistance R of the combination is given by

$$R = R_1 + R_2 + R_3$$

ii. Parallel connection

When two or more resistors are connected side by side in a circuit such that their corresponding ends are joined together at two common junctions, then they are said to be connected in parallel. The current flowing from the cell, on getting to the first common junction, branches into the different resistors and converges at the second common junction. The amount of current entering each resistor is inversely proportional to the value of its resistance.

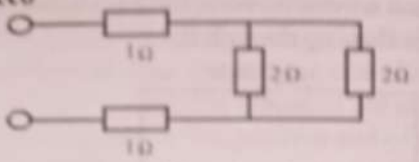


P and Q are the common junctions.
R_1, R_2 and R_3 are the respective resistances of the resistors.
The combined (equivalent or total) resistance R of the combination is given by

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

Note $I = I_1 + I_2 + I_3$

2006/46 Neco



The effective resistance of the circuit shown in the figure above is

A 1.6Ω B 2.4Ω C 3.0Ω D 4.0Ω E 6.0Ω

Solution

The two resistors marked 2Ω are in parallel. Their combined resistance R is given by

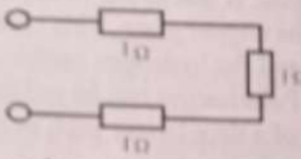
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_3}$$

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{2} = \frac{1+1}{2} = \frac{2}{2}$$

$$\frac{1}{R} = \frac{1}{1}$$

$$\therefore R = 1\Omega$$

The circuit now reduces to



These three resistors are now in series

$$\therefore R_T = R + R_3 + R_4$$
$$= 1 + 1 + 1$$
$$= 3.0\Omega \quad C$$

Ohm's law

Ohm's law state that the current passing through a metallic conductor, such as a wire, is directly proportional to the potential difference across its ends provided temperature and other physical properties of the conductor remains constant.

Given that current = I

and p.d = V

Then ohm's law state as follows:

$I \propto V$

$\therefore \frac{V}{I}$ = constant

This constant of proportionality is the resistance R offered by the conductor.

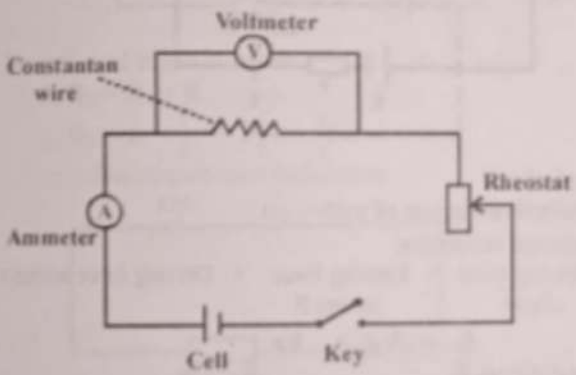
$\therefore \frac{V}{I} = R$

or $V = IR$ or $I = \frac{V}{R}$

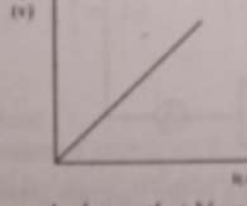
I is in amperes, V in volts and R in ohms (Ω).

The ohm is the resistance of a conductor when a p.d of 1 volt across its ends causes a current of 1 ampere to flow through it.

Experiment to verify Ohm's law



i. The circuit is connected as shown.
ii. The key is close and current flows in the circuit.
iii. The ammeter reading (I) and the voltmeter reading (V) are taken and recorded.
iv. The rheostat is adjusted to a new setting and the new values of I and V are read and recorded.
v. Using the same process, four other values of I and V are obtained.
vi. The readings are tabulated.
vii. A graph of V against I is plotted and a straight line graph passing through the origin is obtained as shown:



viii. The graph shows that V varies directly with I, thus ohm's law is verified. The slope of the graph gives the resistance of the wire.

Ohmic and non-Ohmic Conductors

Ohmic conductors: are those conductors that obey ohm's law. Examples are metallic conductors such as silver, copper, aluminium, iron, etc.

Non ohmic conductors: are those conductors that do not obey ohm's law. Examples are diodes, transistors, rectifiers gases etc.

Factors affecting the Electrical Resistance of a conductor

There are four factors that affect the resistance of a conductor namely:

1. Length of conductor
2. Cross sectional area of conductor
3. Temperature
4. Nature of material

1 **Length l**: the resistance of a conductor of uniform cross sectional area is directly proportional to its length.

$R \propto l$

2. **Cross sectional area A:** The resistance of a conductor (wire) is inversely proportional to its cross sectional area A.

$R \propto \frac{1}{A}$

Combining the above relationships we have that

$R \propto \frac{l}{A}$

$\therefore R = \text{Constant}\left(\frac{l}{A}\right)$

This constant of proportionality is called the resistivity ρ of the material of conductor.

$\therefore R = \frac{\rho l}{A}$

This equation is true if the temperature is constant.

3. **Temperature:** The resistance of a metallic conductor varies directly with its temperature T.

$R \propto T$

For non-metallic conductors the resistance decreases with temperature, while some materials such as Constantine wire are affected little by changes in temperature and are therefore suitable for making standard resistors.

4. **Nature of material:** Resistivity varies from material to material and so the resistance of a conductor depends on the material of which it is made.

2015/40

A wire of cross-sectional area $0.60mm^2$ has a resistivity of $7.2 \times 10^{-7}\Omega m$ calculate the length of the wire that will have a resistance of 3Ω.

A 0.25m B 2.50m C 3.60m D 36.00m

Solution

We must convert the units of the cross sectional area to m^2 to be in line with the units of resistivity and the length of the wire as given in the options.

1000mm = 1m, i.e 1mm = $(\frac{1}{1000}m)$

Cross-sectional area $A = 0.60mm^2 = 0.6\left[\frac{1}{1000}m\right]^2$

$$= 0.6\left[\frac{1}{1,000,000}m^2\right]$$

$$= \frac{0.6}{1,000,000}m^2$$

$$= 0.000,0006m^2$$

$$= 6.0 \times 10^{-7}m^2$$

$\rho = 7.2 \times 10^{-7}\ \Omega m$ = resistivity

$R = 3\Omega$ = resistance of wire

Now $R = \frac{\rho l}{A}$

$RA = \rho l$

$l = \frac{RA}{\rho}$

$l = \frac{3 \times 6.0 \times 10^{-7}}{7.2 \times 10^{-7}} = \frac{18}{7.2} = 2.5m$ (B)

2014/44

A wire of length 100cm has a resistance of 10Ω. If the cross-sectional area is $0.005cm^2$, determine its resistivity.

A 0.0005Ωcm B 0.0015Ωcm C 0.0016Ωcm D0.0700Ωcm

Solution

We have to watch out for the units whether they are consistent before we start calculating. If they are not consistent, we make the necessary conversions before calculating.

In this case all the units are consistent, that is, they are all in cm, we do not need any conversion.

l = length of wire = 100cm

R = resistance of wire = 10Ω

A = cross-sectional area of wire = $0.005cm^2$

ρ = resistivity of the material of wire and the given units in the options is Ωcm

Now $R = \frac{\rho l}{A}$

$RA = \rho l$

$\rho = \frac{RA}{l}$

$= \frac{10 \times 0.005}{100} = 0.0005\Omega cm$ (A)

2008/42 Neco

A 0.6Ω resistor is made from a wire of length 4m and resitivity $2.0 \times 10^{-6}\ \Omega$ m. The cross sectional area of the wire is

A $7.50 \times 10^{-4}m^2$ B $4.80 \times 10^{-6}m^2$ C $3.00 \times 10^{-5}m^2$

D $1.33 \times 10^{-5}m^2$ E $1.20 \times 10^{-6}m^2$

Solution

R = Resistance of wire = 0.6Ω

l = length of wire = 4m

ρ = resistivity of wire = $2.0 \times 10^{-6}\Omega m$

A = cross sectional area of wire = ?

$R = \frac{\rho l}{A}$

Make A the subject of formula

$RA = \rho l$

$A = \frac{\rho l}{R} = \frac{2.0 \times 10^{-6} \times 4}{0.6}$

$= \frac{8.0 \times 10^{-6}}{0.6} = 13.33 \times 10^{-6}m^2$

$= 1.33 \times 10 \times 10^{-6}m^2$

$= 1.33 \times 10^{-5}m^2$ D

2011/44 Neco Exercise 7.3

The resistance of a wire, 30cm long, is 1.5Ω. If it has a cross sectional area of $0.25m^2$, calculate the resistivity of the material.

A1.02Ωm B1.25Ωm C2.11Ωm D2.07Ωm E3.01Ωm

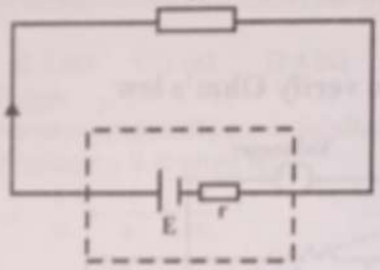
2009/40 Exercise 7.4

A wire of resistivity $4.40 \times 10^{-5}\Omega cm$ has a cross sectional area of $7.50 \times 10^{-4}cm^2$. Calculate the length of this wire that will be required to make a 4.0Ω resistor.

A 82.50cm B 68.18cm C 15.90cm D 11.94cm

Internal Resistance of a Cell

When a voltmeter is connected directly across the terminals of a cell, that is no external load, the voltmeter records the emf E of the cell. When the cell is connected to an external load and a voltmeter is connected across it, there will be a drop in the voltmeter reading. This is due to the internal resistance of the cell.



E = emf of cell

r = internal resistance of cell

R = external resistance

Total driving force of cell = Driving force across R + Driving force across r

$$E = V_R + Vr$$

V_R = p.d across R

V_r = p.d across r

$$\therefore E = IR + Ir$$

$$E = I(R + r)$$

$$I = \frac{E}{R + r}$$

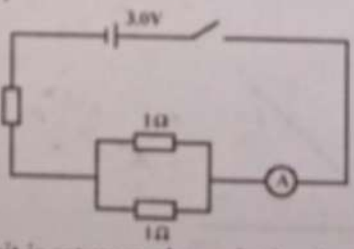
If the internal resistance of the cell is neglected, then

$$I = \frac{E}{R}$$

$$E = IR = V$$

or $E = V = IR$

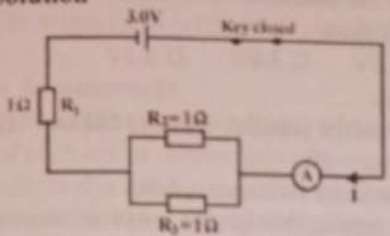
2017/37



A circuit is set up as shown in the diagram above. When the key is closed, the reading on the ammeter will be

A 6A B 4A C 2A D 1A

Solution



The first step is to find the combined resistance of the resistors R_1 R_2 and R_3.

Now R_2 and R_3 are in parallel

$$\frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_3}$$

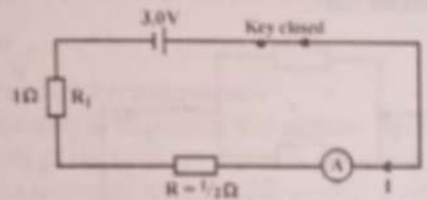
$$\frac{1}{R} = \frac{1}{1} + \frac{1}{1} = \frac{1+1}{1} = \frac{2}{1}$$

$$\frac{1}{R} = \frac{2}{1}$$

$$2R = 1$$

$$R = \frac{1}{2}\Omega$$

The circuit now reduces to

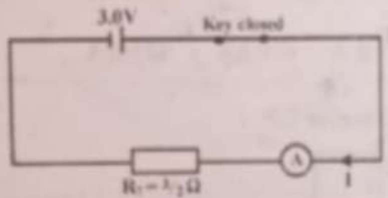


Now R_1 and R are in series

$$R_T = R_1 + R$$

$$R_T = 1 + \frac{1}{2} = 1\frac{1}{2} = \frac{3}{2}\Omega$$

The circuit now reduces to



When the key is closed, current begins to flow. The ammeter reading is the current I that flows through it. *We are not given the internal resistance of the cell, therefore we neglect it.* This means that

$E = V = IR$

E = emf of the cell = 3.0V

V = p.d across the resistor R_T = 3.0V

I = current

$R = R_T$ = combined resistance/external load. $R_T = \frac{3}{2}\Omega$

Now $V = IR_T$

$$I = \frac{V}{R_T} = \frac{3.0}{\frac{3}{2}}$$

$$I = 3.0 \div \frac{3}{2}$$

$$I = 3.0 \times \frac{2}{3} = 2A \qquad (C)$$

2009/43 Neco

When a resistor of resistance R is connected across a cell, the terminal p.d of the cell is reduced to three quarters of its emf. The cells internal resistance in terms of R is

A $\frac{R}{4}$ B $\frac{R}{3}$ C $\frac{R}{2}$ D $\frac{2R}{3}$ E R

Solution

$E = IR + Ir$

E = emf of the cell

The terminal p.d $V = IR$

The term Ir represents the lost voltage or the difference between the emf and V. If the terminal p.d is reduced to ¾ of its emf then

$$V = IR = \frac{3}{4}E$$

$$E = \frac{4}{3}IR$$

Now $E - IR = Ir$

$$r = \frac{E - IR}{I}$$

Put $E = \frac{4}{3}IR$ in the above equation.

$$\Rightarrow r = \frac{\frac{4}{3}IR - IR}{I} = \frac{\frac{4IR - 3IR}{3}}{I}$$

$$= \frac{\frac{IR}{3}}{I} = \frac{IR}{3I} = \frac{R}{3}$$

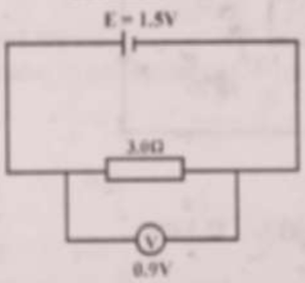
$$\therefore r = \frac{R}{3}$$

2009/39

A cell of e.m.f. 1.5V is connected in series with a resistor of resistance 3.0Ω. A voltmeter connected across the cell registers 0.9V. Calculate the internal resistance of the cell.

A 2.0Ω B 3.0Ω C 5.0Ω D 6.0Ω

Solution



$E = 1.5V$, $R = 3.0\Omega$, $V = 0.9V$, $r = ?$

$$I = \frac{E}{R + r}$$

First we find I from

$$V = IR$$

$$\therefore I = \frac{V}{R} = \frac{0.9}{3.0} = 0.3A$$

Then we proceed as

$$I = \frac{E}{R + r}$$

$$0.3 = \frac{1.5}{3.0 + r}$$

$$0.3(3.0 + r) = 1.5$$

$$0.9 + 0.3r = 1.5$$

$$0.3r = 1.5 - 0.9$$

$$0.3r = 0.6$$

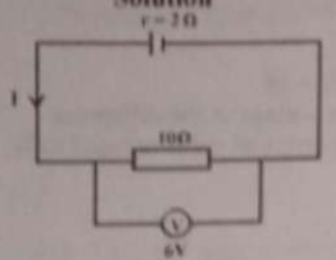
$$r = \frac{0.6}{0.3} = 2.0\Omega \text{ A.}$$

2004/37 (Nov)

A battery of internal resistance 2Ω is connected in series with a resistor of 10Ω. If the p.d across the resistor is 6V, calculate the emf of the battery

A 2.0V B 4.8V C 6.0V D 7.2V

Solution



$V = 6V$, $R = 10\Omega$, $r = 2\Omega$, $E = ?$

There is no big deal about the battery and the 10Ω resistor that are connected in series. The circuit is as simple as shown.

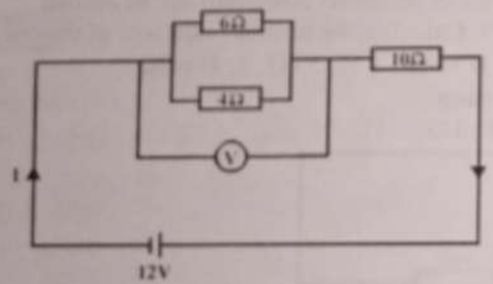
Connecting formula $I = \frac{E}{R + r}$

I was not given but we find *I* from $I = \frac{V}{R} = \frac{6}{10} = 0.6A$

$$I = \frac{E}{R + r}$$
$$E = I(R + r)$$
$$E = 0.6\,(10 + 2)$$
$$= 0.6(12) = 7.2V \quad D$$

2010/36 – 37

Use the diagram below to answer questions 36 and 37.



36. Calculate the current I

A 0.60A B 0.97A C 1.03A D 5.00A

Solution

The 6Ω and 4Ω resistors are in parallel and their equivalent resistance R is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{6} + \frac{1}{4}$$
$$= \frac{2 + 3}{12}$$
$$\frac{1}{R} = \frac{5}{12}$$
$$\therefore\ R = \frac{12}{5} = 2.4\,\Omega$$

This is in series with the 10Ω resistor.

Series combination of R and R_3 gives

$$R_T = R + R_3$$
$$R_T = 2.4 + 10 = 12.4\Omega$$

R_T is the combined resistance of all the resistors.

Now the internal resistance is neglected.

$E = 12V$, $R_T = 12.4\Omega$

$$I = \frac{E}{R}$$
$$= \frac{12}{12.4} = 0.97A \quad (\text{B})$$

37. Determine the potential difference, V across the parallel resistors.

A 2.0V B 2.3V C 3.0V D 0.7V

Solution

The P.D, V across the parallel resistors 6Ω and 4Ω, is given by

$$V = IR$$

R is their combined resistance = 2.4Ω

I = The current passing through this combined resistors = 0.97A

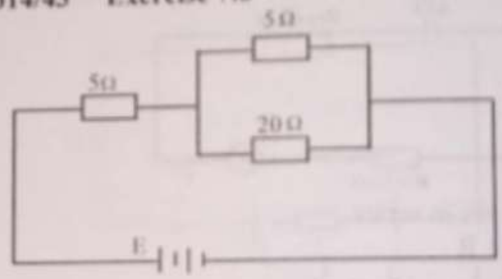
$$V = 0.97 \times 2.4$$
$$= 2.3V \quad (\text{B})$$

2009/41 Exercise 7.5

A battery of emf 12.0v and internal resistance 0.5Ω is connected to 1.5Ω and 4.0Ω series resistors. Calculate the terminal voltage of the battery.

A 13.0V B 11.0V C 3.0V D 1.0V

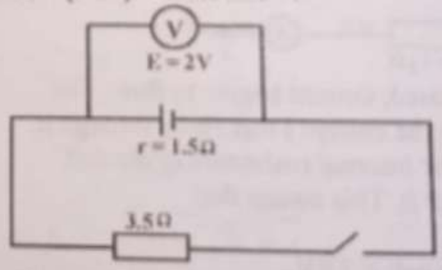
2014/43 Exercise 7.6



In the circuit diagram above, E is a battery of negligible internal resistance. If its emf is 9.0V, calculate the current in the circuit.

A 1.8 A B 1.0 A C 0.8A D 0.3A

2006/39 (Nov) Exercise 7.7



The diagram above shows a cell of emf 2V and internal resistance 1.5Ω connected in series with a 3.5Ω resistor. Determine the voltmeter reading when the key is closed.

A 2.6V B 2.0V C 1.4V D 0.4V

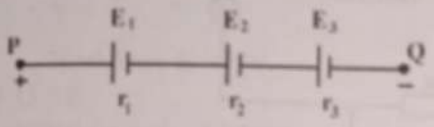
Arrangement of cells in circuits

Cells can be arranged in *series* or in *parallel*.

i. Series Arrangement

Cells are said to be arranged in series when the positive terminal of each cell is connected to the negative terminal of the next cell. In this arrangement, the cells support each other and a greater value of emf is obtained. This gives rise to a greater current flowing in the circuit.

Given that three cells of emf E_1, E_2 and E_3 and internal resistance r_1, r_2 and r_3 are arranged in series as shown;



The total emf E of the arrangement is given by

$$E = E_1 + E_2 + E_3$$

The total internal resistance r of the arrangement is given by

$$r = r_1 + r_2 + r_3$$

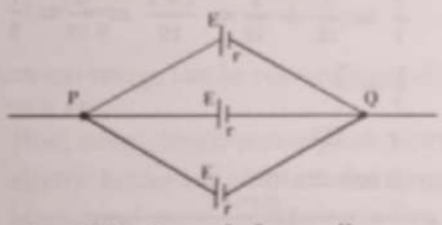
Note that the same current passes through each cell.

ii. Parallel Arrangement

Cells are said to be arranged in parallel when all the positive terminals of the cells are joined to one point, P and all the negative terminals are joined to another point Q.

Note that only identical cells can be arranged in parallel.

Given that three cells each of emf E and internal resistance r, are arranged in parallel as shown:



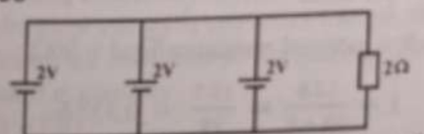
The total emf E is the emf of one cell.

The total internal resistance r_T is given by;

$$\frac{1}{r_T} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r}$$

This is so because, since the cells arranged in parallel their internal resistance are also arranged in parallel and the method of calculating the total resistance of resistors in parallel is applied.

2013/36



An electric circuit is connected as illustrated above. Determine the equivalent emf and current flowing through the circuit respectively, neglecting the internal resistance of the cells.

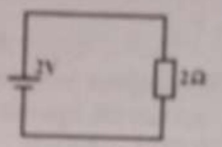
A 2V, 1.0A B 2V, 4.0A C 6V, 0.3A D 6V, 3.0A

Solution

The cells are arranged in parallel therefore the equivalent (combined) emf is the emf of one cell,

$$E = 2V$$

The circuit now reduces to



Since we are neglecting the internal resistance of the cell,

$$I = \frac{E}{R}$$

I = current flowing through the circuit.

R = resistance of resistor = 2Ω

$$\therefore I = \frac{2}{2} = 1A$$

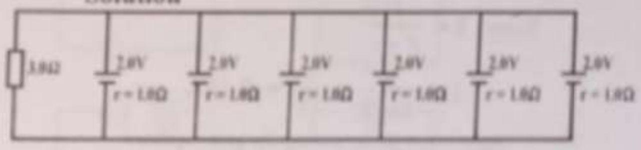
∴ equivalent emf = 2V, current = 1.0A option A

2012/37

Six dry cells each of emf 2.0V and internal resistance of 1.0Ω are connected in parallel across a load of 3.0Ω. Calculate the effective current in the circuit.

A 0.63A B 0.50A C 0.31A D 0.22A

Solution



The combined emf E = emf of one cell

$$E = 2.0V$$

The combine internal resistance r is given as

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4} + \frac{1}{r_5} + \frac{1}{r_6}$$

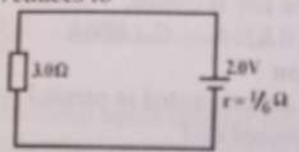
Since the cell are in parallel then their internal resistances are also in parallel and are treated as resistors in parallel.

$$\frac{1}{r} = \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1}$$

$$\frac{1}{r} = \frac{6}{1}$$

$$\therefore r = \frac{1}{6}\Omega$$

The circuit now reduces to



I = effective current

R = load (external resistance) = 3.0Ω

$$\text{Now } I = \frac{E}{R + r}$$

$$I = \frac{2}{3 + \frac{1}{6}} = \frac{2}{\frac{3}{1} + \frac{1}{6}} = \frac{2}{\frac{18+1}{6}} = \frac{2}{\frac{19}{6}} = 2 \times \frac{6}{19}$$

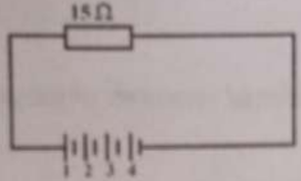
$$= 0.63A \text{ (A)}$$

2010/43 Neco

Four identical cells each of emf 1.5V and internal resistance 0.5Ω are connected in series across an external load of resistance 15Ω. Calculate the current that passes through the load.

A 0.21A B 0.60A C 1.71A D 3.00A E 6.00A

Solution



$E_1 = E_2 = E_3 = E_4 = 1.5V$

$r_1 = r_2 = r_3 = r_4 = 0.5\Omega$

Since the cells are connected in series

Total emf $E = E_1 + E_2 + E_3 + E_4$

$= 1.5 + 1.5 + 1.5 + 1.5$

$= 6.0V$

Combine/Total internal resistance

$r = r_1 + r_2 + r_3 + r_4$

$r = 0.5 + 0.5 + 0.5 + 0.5$

$r = 2.0\Omega$

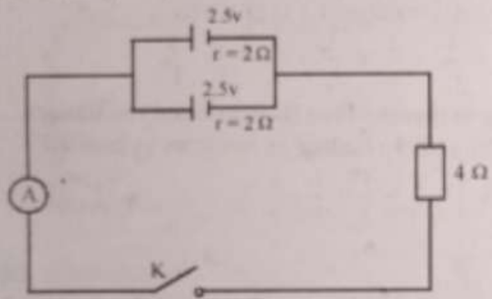
R = external resistance/load = 15Ω

Now $I = \frac{E}{R+r}$

$I = \frac{6}{15+2} = \frac{6}{17} = 0.35A$

Answer not found among the given options

2005/39 (Nov)



The diagram above shows two identical cells each of e.m.f 2.5V and internal resistance of 2Ω. Determine the ammeter reading when the key is closed.

A 0.500A B 0.625A C 1.000A D 1.250A

Solution

Since the e.m.f are connected in parallel as seen in the circuit, the combined emf

E = emf of one cell = 2.5V

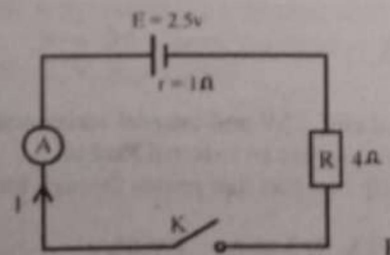
For their internal resistance which are also in parallel, the combined internal resistance r is given by:

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$= \frac{1}{2} + \frac{1}{2} = \frac{1+1}{2} = \frac{2}{2} = \frac{1}{1}$$

$\therefore r = 1\Omega$

The circuit now reduces to



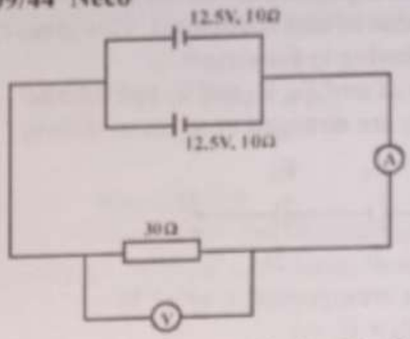
E = 2.5V, r = 1Ω, R = 4Ω, I = ?

When the key, K, is closed, the ammeter reading is the current I

$$I = \frac{E}{R+r} = \frac{2.5}{4+1}$$

$$I = \frac{2.5}{5} = 0.500A \quad (A)$$

2009/44 Neco



Determine the p.d across the load in the diagram above, if the ammeter is of negligible internal resistance.

A 6.3V B 10.7V C 12.5V D 20.0V E 25.0V

Solution

The cells are in parallel and hence their combined emf E is the emf of one cell = 12.5V.

However since the cells are in parallel, the internal resistances of the cells are also in parallel and the combined internal resistance r of the cells is obtained as follows:

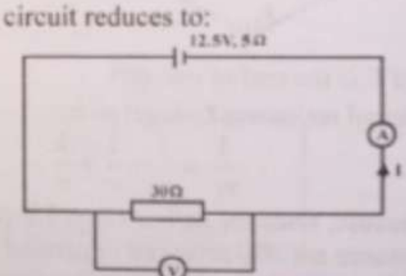
$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$\frac{1}{r} = \frac{1}{10} + \frac{1}{10} = \frac{1+1}{10} = \frac{2}{10} = \frac{1}{5}$$

i.e $\frac{1}{r} = \frac{1}{5}$

$\Rightarrow r = 5\Omega$

The circuit reduces to:



The statement that the ammeter is of negligible internal resistance simply means that the ammeter allows all the current I, to flow through it.

$$I = \frac{E}{R+r}$$

Where R = external resistance/load = 30Ω

$$I = \frac{12.5}{30+5} = \frac{12.5}{35} = 0.357A$$

P.d across the load = $V = IR$

$V = 0.357 \times 30$

$= 10.7V$ (B)

2007/40 Neco Exercise 7.8

Three identical cells each of e.m.f. 1.5v and internal resistance 1.0Ω are connected in parallel across an external load of resistance 2.67Ω. Calculate the current in the load.

A 0.26A B 0.41A C 0.50A D 0.79A E 1.50A

Electrical work done/energy

We defined potential difference between any two points in an electric circuit as the workdone in moving a unit positive charge from one point in the circuit to the other. Thus work is done when electricity flows from one point to another of different potential. This workdone equals the electrical energy of the circuit.

Now $\quad p.d = \frac{workdone}{charge}$

p.d = V, Workdone = W, Quantity of charge = Q

$\therefore V = \frac{W}{Q}$

Workdone W = QV

But Q = It

I = electric current, t = time

$\therefore W = Itv = I\,vt$

$\therefore E = Ivt$ ------------------------- (1)

Where E = electrical energy.

From ohm's law: V = IR

Put this in (1)

$W = E = I(IR)t$

$E = I^2Rt$ ----------------------- (2)

Also from ohm's law

$I = \frac{V}{R}$

Put this in (1)

$\therefore\ W = E = \frac{V}{R}(vt)$

$E = \frac{V^2t}{R}$ ----------------------- (3)

This electrical energy can be converted into other forms of energy such as:

- Heat, using electric pressing iron, electric cookers, electric kettles and electric heaters.
- Mechanical energy, using electric fans, electric motors and washing machines.
- Light, using electric filament lamp or bulb, where the current flowing through the filament wire, heats it up to a high temperature such that the filament glows bright thereby giving light to its surrounding.
- Sound, using telephone earpiece and loud speakers.

Heating Effect of current

When electrical energy is converted to heat, the heat generated by the conductor or the heating element of the device used is given by

$H = I^2Rt$

H = heat generated

I = current flowing through the conductor/heating element

R = resistance of the conductor/heating element.

t = time for which the flow of current lasted.

Thus electrical energy being converted to heat is in the form I^2Rt and the heat generated is proportional to the square of the current.

2012/39

A 12Ω resistor dissipates 8KJ of heat in 20s. Calculate the current through the resistor.

A 5.8A B 6.9A C 30.0A D 33.3A

Solution

R = 12Ω = resistance

E = H = 8KJ = 8000J = heat dissipated

t = 20s = time take to dissipate heat.

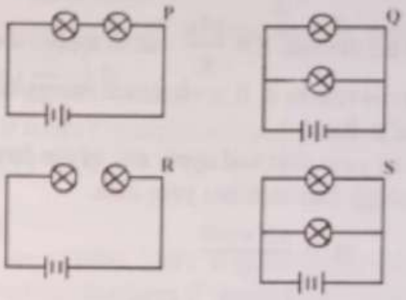
$H = I^2Rt$

$I^2 = \frac{H}{Rt}$

$I = \sqrt{\frac{H}{Rt}} = \sqrt{\frac{8000}{12\times20}} = = \sqrt{33.33} = 5.77A$

$\approx 5.8A$ (A)

2012/38

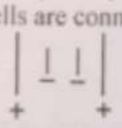


Two similar cells are used to light two similar lamps as illustrated in the diagrams above. In which of the circuit diagrams are the lamps brightest?

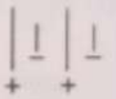
A. P B. Q C. R D. S

Solution

In the first instance, the lamps in R and S will not light because the polarity of the cells is wrong in both cases. That is, the cells are connected wrongly.



Is wrong connection



Is correct connection

Now for P and Q, the lamp lights because its filament (resistor) converts electrical energy into heat. This heat causes the filament to glow and the more the current the more the heat and hence the more the filament glows. ($H = I^2Rt$).Thus the brightness of the lamp is a function of the current.

In P the current delivered by the cells (same current) flows through each of the lamps since the lamps are connected in series.

While in Q, the current delivered by the cells is shared equally between the lamps, since the lamps are connected in parallel. Thus a lamp in Q receives half of the current received by a lamp in P.

Therefore it is in circuit diagram P that the lamps are brightest. Option A

2013/37

A potential difference of 12V is applied across the ends of a 6Ω resistor for 10minutes. Determine the quantity of heat generated.

A 720J B 1200J C 14400J D 43200J

Solution

Electrical energy converted to heat is given as

$$H = I^2Rt$$

H = heat generated

I = current

R = resistance = 6Ω

t = time in seconds = 10×60 = 600s (60 seconds = 1 minute)

V = p.d applied = 12V

But $I = \frac{V}{R}$

$$\therefore H = \left(\frac{V}{R}\right)^2 Rt$$

$$H = \frac{V^2}{R^2} Rt$$

$$= \frac{V^2t}{R} = \text{Electrical energy E}$$

You can see that the formula $E = \frac{V^2t}{R}$ can be applied directly.

There is no special rule to it. It is electrical energy that is being converted to heat.

Therefore list out your data and apply any of the formulae for electrical energy that matches your data.

$$H = \frac{12^2 \times 600}{6}$$

$$= 14400J \quad (C)$$

Electrical power

Power is defined as the time rate of doing work or energy expended per unit time.

$\text{Power} = \frac{workdone}{time}$ or

$\text{Power} = \frac{energy\ expended}{time\ taken}$

$\therefore$ Electrical power $= \frac{electrical\ energy}{time}$

Electrical power = P

Electrical energy = E

Time = t

$$P = \frac{E}{t}$$

From (1), $P = \frac{Ivt}{t}$

$\therefore P = IV$ ---------------------- (4)

From (2), $P = \frac{I^2Rt}{t}$

$\therefore P = I^2R$ ------------------ (5)

This is electrical power loss in form of heat.

From (3), $P = \frac{V^2t}{Rt}$

$\therefore P = \frac{V^2}{R}$ ---------------------- (6)

2015/36

An electric generator rated 12kw, 2kv distributes power through a cable of resistance 20Ω. Calculate the power loss in the cable.

A 120W B 360W C 720W D 2400W

Solution

P = power = 12kw = 12000w

V = Voltage = 2kv = 2000v

I = current = ?

R = resistance of cable = 20Ω

$$P = IV$$

$$I = \frac{P}{V} = \frac{12000}{2000} = 6A$$

A resistor converts electrical energy to heat. Thus the power loss in the resistance cable (resistor) is the rate at which the electrical energy is lost in form of heat.

Electrical power loss in form of heat is given as

$$P = I^2R$$

$$P = 6^2 \times 20 = 36 \times 20 = 720w \quad C$$

2009/7 Neco

A cell of electromotive force E and internal resistance r is connected in series with an ammeter and an external load of resistance R. Derive an expression for the power dissipated by the external load in terms of the given parameters.

Solution

The ammeter measures the current I flowing in the circuit.

Now $I = \frac{E}{R+r}$

The power dissipated by the external load is given by

$$P = I^2R$$

$$P = \left(\frac{E}{R+r}\right)^2 R$$

$$= \frac{E^2R}{(R+r)^2}$$

You can see that the expression is in terms of the given parameters only

2003/38

A lamp is rated 240V 60W, calculate the resistance of its filament

A 240Ω B 360Ω C 960Ω D1440Ω

Solution

V = 240V

P = Power = 60W

R = resistance = ?

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{240^2}{60} = 960\Omega \quad C$$

2009/38

A resistor of resistance R is connected to a battery of negligible internal resistance. If a similar resistor is connected in series with it, the

A effective resistance of the circuit is halved.

B total power dissipated is doubled

C total current in the circuit is halved

D terminal voltage is halved. •

Solution

With a similar resistor connected in series total resistance

$$R_T = R + R = 2R$$

Thus the effective resistance is doubled – **option A is wrong**.

With the initial connection:
When we talk of total power dissipated, we mean electrical power lost/used/converted to heat in the resistor and it is given as

$P = I^2R$. Also $V = IR$ and $I = \frac{V}{R}$

With the second resistor added:

$$I = \frac{V}{2R} = \frac{1}{2}\left(\frac{V}{R}\right) = \frac{1}{2}I$$

$$\therefore P = \left(\frac{I}{2}\right)^2 \times 2R = \frac{I^2}{4} \times 2R$$

$$P = \frac{(I^2R)}{2}.$$

Meaning the total power dissipated is halved.

With this, option B is wrong.

Alternatively, with the initial connection:

Power can be expressed as $= \frac{V^2}{R} = \frac{E^2}{R}$

Note that because the internal resistance is negligible $E = V$

With the second resistor added:

$$\text{Power} = \frac{E^2}{2R} = \frac{1}{2}\frac{E^2}{R}$$

meaning that **power** is **halved**. With this, **option B is wrong.**

With the initial connection:

Terminal voltage $V = IR$

With the second resistor added:

$$V = I \times 2R = 2IR$$

The implication is that the terminal p.d is doubled – **option D is wrong**.

With the initial connection:

Total current I in the circuit is given by $I = \frac{E}{R}$

(Internal resistance is negligible)

With the second resistor added;

$$I = \frac{E}{2R} = \frac{1}{2}\frac{E}{R}$$

The implication is that the total current is halved – **Option C is correct.**

2007/41
A bulb marked 240V, 40W is used for 30minutes. Calculate the heat generated.
A 320J B 400J C 10800J D 72000J

Solution

Power = 40W
Time = 30min = 30 × 60s = 1800s
Heat(energy) = ?

Connecting formula: $\text{Power} = \frac{\text{energy}}{\text{time}}$

$\therefore$ Energy (heat) = power × time
= 40 × 1800 = 72, 000J

You can see that we did not use the rated voltage of 240V.

2003/39 Exercise 7.9
The maximum power dissipated by a 100Ω resistor in a circuit is 4W, calculate the voltage across the resistor.
A 10V B 20V C 25V D 400V

Commercial Electricity

Electrical energy consumption is measured and sold in units of kilowatt – hour (KWh).
One kilowatt – hour is the electrical energy consumed by an appliance when a power of one kilowatt is used by the appliance for one hour.
Thus electrical energy consumed in KWh is given as

$$\text{Energy} = \left(\frac{P}{1000} \times T\right) \text{kwh}$$

P = electrical power in watts; T = time in hours.
Note that 1KW = 1000W
If the electrical distribution company charges Q kobo per kwh, then cost of electrical energy consumed is given as

$$\text{Cost} = \left(\frac{PT}{1000}\right)Q \text{ in kobo} \quad \textbf{\textit{or}}$$

$$\text{Cost} = \left(\frac{PT}{1000}\right)\frac{Q}{100} \text{ in Naira}$$

If the company charges N naira per kwh then

$$\text{Cost} = \left(\frac{PT}{1000}\right)N$$

Note that when P is expressed in KW, we do not need to divide it by 1000.

2017/41
A lamp rated 100W, 240V is lit for 5 hours. Calculate the cost of lighting the lamp if 1kwh of electrical energy cost ₦5.
A ₦2.50 B ₦3.20 C ₦6.50 D ₦9.60

Solution

$$\text{Cost} = \left(\frac{PT}{1000}\right)N$$

P = electrical power in watts = 100W
T = time in hours = 5 hours
N = cost per kwh in naira = ₦5.00
Note that it is because the power is expressed in watts hence we are dividing by 1000 to convert the units to kilowatt (kw)

$$\text{Cost} = \left(\frac{100 \times 5}{1000}\right)5$$

$$\text{Cost} = \left(\frac{1}{2}\right)5 = ₦2.50 \quad \text{A}$$

2008/43 Neco
A man has five 60W bulbs and a 240W water heater in his apartment. If the bulbs and the water heater are switched on for four hours daily and the cost of electricity is ₦1.20per kwh , calculate his bill for 30 days.
A ₦19.44 B ₦43.20 C ₦77.76 D ₦248.40 E ₦388.80

Solution

Cost of electrical energy consumed is given by

$$\text{Cost} = \left(\frac{PT}{1000}\right)N$$

P = electrical power in watts = (5×60) +240 = 540W
T = time in hours = 4hours
N = cost per KWh in naira = ₦1.20

Remember that we have to divide by 1000 to convert the unit of power from watt to kilowatt (KW).

$$\text{Cost} = \left(\frac{540 \times 4}{1000}\right) \times 1.20 \quad \text{for one day}$$

$$\therefore \text{Cost (bill) for 30 days} = \left(\frac{540 \times 4}{1000}\right) \times 1.20 \times 30$$

= ₦77.76 C

2012/14e (Nov)
In a certain house, three ceiling fans each of 80 W, an air – conditioner rated 1500W are operated for 6 hours each day, seven lamps each rated 40W are switched on for 10 hours each day. The home theatre 100W and television set 80W are operated each day for 5 hours after which they are kept in the standby mode. In the standby mode, the power consumption is 5% of the power rating. Calculate the:
(i) Total energy consumed in the house for 30 days in Kwh.
(ii) Cost of operating all the appliances for 30 days at ₦10.00 per kwh.

Solution

(i) Energy consumed:

- Ceiling fans → $3 \times 80 = 240W = 0.24KW$
  × 6 hrs = 1.44 kwh per day
- Air conditioner → $1500W = 1.5kw$
  × 6 hrs = 9.00kwh per day
- Lamps → $7 \times 40 = 280W = 0.28KW$
  × 10 hrs = 2.80kwh per day
- Home theatre normal mode → $100W = 0.10KW$
  × 5 hrs = 0.50 Kwh per day
- Home theatre standby mode → 5% of 100

$= \frac{5}{100} \times 100 = 5W = 0.005KW$

Number of hours for standby mode
$= 24 - 5 = 19$ hours

∴ Energy for standby mode
$= 0.005 \times 19 = 0.095$kwh per day

- Television normal mode → $80W = 0.08KW$
  × 5 hrs = 0.4kwh per day.

Television standby mode → 5% of 80 $= \frac{5}{100} \times 80 = 4W$
$= 0.004KW \times 19$ hours for standby
$= 0.076$kwh per day.

Total energy for one day:

Ceiling fans = 1.44
A/C = 9.00
Lamps = 2.80
Normal home theatre = 0.50
Home theatre standby = 0.095
TV normal = 0.40
TV standby = 0.076

Total energy for one day = 14.311kwh

∴ Total energy consumed for 30 days
$= 14.311 \times 30 = 429.33$kwh

(ii) Cost at ₦10.00 per kwh
$= 429.33 \times 10 =$ ₦ 4,293.30

2002/45 Neco
An electric heater takes 4A when operated on a 250V supply. What is the cost of the electricity consumed at 10k per kwh when the heater is used for 5 hours?
A 10k B 50K C ₦1.00 D ₦5.00 E ₦10.00

Solution

$P = VI = 250 \times 4 = 1000W = 1KW$
T = Time in hours = 5hours
Q = amount in kobo = 10K
∴ Cost = (PT)Q in kobo
Cost = $(1\times5)10$ in kobo
Cost = 50K B

2007/44 Exercise 7.10
Five 80–w and three 100–w lamps are run for 8 hours. If the cost of energy is ₦5.00 per unit, calculate the cost of running the lamps. (1 unit = 1kwh)
A ₦280.00 B ₦28.00 C ₦7.20 D ₦1.44

2016/36 Exercise 7.11
The electricity meters in houses measure energy consumed in
A kilowatt – hour B volt C ampere D coulomb