PHYSICS

ELECTRICITY

Concepts Covered

- Electric Charge and its Properties
- Electric Current and Electric Potential
- Ohm's Law
- Resistance & Specific Resistivity
- Circuit Diagrams
- Series and Parallel Combination
- Heating Effect of Electric Current
- Electric Power
- Commercial Units of Electricity

Current Electricity
The branch of physics that deals with the study of charges in motion is called current electricity.

Electric Charge and its Properties
Electric charge is property of matter which arises due to either excess or deficiency of electrons.

- Electric charge is of two types which is positive and negative charge. Proton is said to be positively charged while electron is said to be negatively charged.
- Like charges repel while unlike charges attract each other. Thus, a proton repels a proton but attracts an electron.
- Charge can neither be created nor destroyed. The charge from one body can be transferred to another body but the total charge of a system remains constant. This is called the law of "Conservation of Charge".
- Protons and electrons are elementary charged particles. Though the charge on them is opposite in nature, the magnitude of charge possessed by them is same i.e., $\mathbf{1.6 \times 10^{-19}\ C}$. Charge on a body is always an integral multiple of this value. This is called "Quantization of Charge" i.e., Q = ne.
- When a body gains electron, it becomes negatively charged. When it loses electrons, it becomes positively charged. The positive charge being bound firmly in the nucleus, that's why they do not participate in charging.

Electric Current
The rate of flow of charges through a conductor is known as electric current. It is denoted by I. If "$\mathbf{q}$" is the net charge passing through any cross-sectional area of a conductor in a time "$\mathbf{t}$", then

Current $(\mathbf{I}) = \frac{\text{Charge }(\mathbf{q})}{\text{Time }(\mathbf{t})}$

Current is a scalar quantity.

S.I. unit of current is ampere (A).

Some large units of current are kiloampere $\left(\mathbf{1\ kA = 10^3\ A}\right)$, Megaampere $\left(\mathbf{1\ MA = 10^6\ A}\right)$ while some small units are $\mathbf{1\ mA}$($\mathbf{1}$ milliampere $= \mathbf{10^{-3}\ A}$) and microampere $\left(\mathbf{1\ \mu A = 10^{-6}\ A}\right)$.

One ampere
The current passing through a conductor is said to be one ampere when the net flow of charge per second through its cross-sectional is one coulomb.

Since, current $(\mathrm{I}) = \frac{\mathrm{Q}}{\mathrm{t}}$ or $\mathrm{I} = \frac{\mathrm{ne}}{\mathrm{t}}$
where, e = magnitude of charge of an electron
n = number of electrons
t = time.

Electricity travels at the speed of light, about 300,000 kilometers per second.

DID you KNOW

Example:

Q.1 Calculate the number of electrons transferred, if 10 C of charge transferred from one body to another?
Solution: We know, Q = ne
$10 = n \times 1.6 \times 10^{-19}$
So, $n = 6.25 \times 10^{19}$.

Q.2 Calculate current in the wire if charge of 20 C flows through it for 5 s.
Solution: $I = \frac{Q}{t}$
$I = \frac{20}{5} = 4$ A.

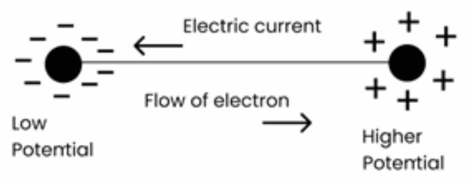
Check your Concept

(1) If 9.6×10^{19} electrons are transferred from body A to body B then calculate the amount of charge gets transferred.
(2) If 10 A current is flowing through a wire for 10 minutes then calculate the amount of charge flowing through it.
(3) If 5×10^{20} electrons are flowing through wire for 25 s. Calculate the current flowing through it.

Answer Key

(1) 6 C. **(2)** 6000 C. **(3)** 3.2 A.

Electric potential



It is our common observation that water flows from a place at a higher level to a place at a lower level or level irrespective of the amount of water at the two levels. Heat flows from a body at a higher temperature to a body at a lower temperature irrespective of the amount of heat contained by the two bodies. Similarly, electric charges move from one point to another if there exists a difference in the electric potential irrespective of the concentration of charges at the two points. Thus, electric potential determines the direction of flow of electric current. Charge flows from a body at higher potential to a body at lower potential. By convention, a positively charged body is always at a higher potential as compared to a negatively charged body. If positive charges like protons or positive ions are free to move they would move from higher potential point to lower potential point. Usually the movement of charges implies movement of electrons. It is clear that electrons will move from lower potential to higher potential. This constitutes electronic current. Since the convention is that flow is always from higher to lower level, the conventional current is taken opposite to the electronic current. It should be remembered that conventional current implies the movement of positive charges whereas electronic current is the movement of electrons.
As discussed earlier, concentration of charges determines the electric potential at a point. This can be increased by bringing charges at that point. In doing so some work has to be done on the charge. This work is stored as electric potential at that point. The electric potential can be measured in terms of work done and is defined as the work done in bringing unit positive charge from infinity to a point in an electric field is called electric potential (V). The electric potential is measured in Volts (V).

One Volt

The electric potential at a point is said to be 1 volt when 1 joule of work is done in bringing unit positive charge from infinity to a point in an electric field.
Note: At infinity electric potential is zero. i.e., $V_\infty = 0$.

Potential difference

To bring a unit positive charge from infinity to a point in an electric field, some work has to be done which is called electric potential. Within an electric field, if a unit positive charge has to be moved from one point to another against the direction of the field, some work has to be done which is called as potential difference between the two points.

Like electric potential, the potential difference is also measured in volts (V). Let Q coulombs of charge be moved from point A to the point B in an electric field and work done is W. Let V be the potential difference between two points. Therefore, the work done in moving a unit positive charge $= \frac{W}{Q}$.

By definition, this work done is also the potential difference.

$\therefore \Delta V = V_1 - V_2 = \frac{W}{Q}$

Where V_1 = Potential at point A.

V_2 = Potential at point B.

When 1 joule of work is done in moving a unit positive charge from one point to another point in an electric field, the potential difference between the two points is 1 volt.

$$V = \frac{1\text{ joule}}{1\text{ coulomb}}$$

$$= 1\text{ volt}\left(\because \frac{\text{joule}}{\text{coulomb}} = \text{volt}\right)$$

DID you KNOW

LED bulbs uses about one-sixth of the electricity of conventional bulbs, cost about one-fourth of the cost of traditional bulbs to power, and they last about 40 times longer.

Example:

Q.1 How much work will be done in bringing a charge of 5.0 milli-coulombs from infinity to a point P at which the potential is 24 V?

Solution: $\Delta V = \frac{W}{Q} \Rightarrow V - V_\infty = \frac{W}{Q}$

$\Rightarrow V - 0 = \frac{W}{Q}\ (\because V_\infty = 0) \Rightarrow 24 = \frac{W}{5 \times 10^{-3}} = 0.12$ J.

Q.2 If 50 J of work is needed to move a charge of 20 C from infinity to point A. Calculate the potential of point A.

Solution: $\Delta V = \frac{W}{Q}$

$\Rightarrow V_A - V_\infty = \frac{W}{Q}$

$\Rightarrow V_A - 0 = \frac{W}{Q}\ (\because V_\infty = 0)$

$\Rightarrow V_A = \frac{50}{20} \Rightarrow V_A = 2.5$ V.

Electricity travels at the speed of light more than 186,000 miles per second!

DID you KNOW

Q.3 Name a device that helps to maintain a potential difference across a conductor.

Answer: A cell, battery, power supply, etc. helps to maintain a potential difference across a conductor.

(1) How much energy is given to each coulomb of charge passing through a 6V battery?

(2) If 60 J of work is needed to move a charge of 30 mC from infinity to point A. Calculate the potential of point A.

Answer Key

(1) 6 J. **(2)** 2000 V.

Check your Concept

Ohm's Law

We have studied that when a potential difference is applied between the ends of a conductor, current begins to flow through it. George Simon Ohm, a German physicist performed a series of experiments to determine the relationship between the potential difference and electric current. On the basis of these experiments he formulated a law which is called Ohm's law and it can be stated as, the current flowing through a conductor is directly proportional to the potential difference applied across the terminals of conductor, provided the physical state of the conductor remains the same. The factors which constitute physical state of conductor are its length, area of cross section, temperature and material.

According to Ohm's law $\mathbf{V \propto I}$

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

The constant in the above relation is called resistance (R) of the conductor.

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

If the potential difference is measured in volts and current in amperes, the resistance of conductor is measured in ohms.

$$\frac{\text{volt}}{\text{ampere}} = \text{ohm.}$$

One Ohm

The resistance of a conductor is said to be 1ohm if the potential difference of 1 volt causes a current of 1 ampere to pass through the conductor.

$$\frac{1\text{ volt}}{1\text{ ampere}} = 1\text{ ohm}.$$

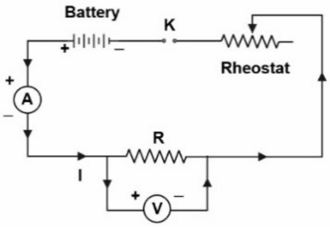
Activity:

To prove Ohm's Law

Material Required:

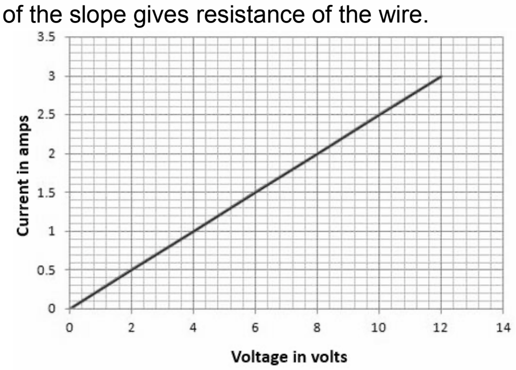
A resistor of about 5 Ω, an ammeter (0 - 3 A), a voltmeter (0 - 10 V), four dry cells of 1.5 V each with a cell holder (or a battery eliminator), a plug key, connecting wires, and a piece of sand paper.

Steps to Perform Activity:



- Draw the circuit diagram as shown above.
- Arrange the apparatus as per the circuit diagram.
- Clean the ends of the connecting wires with sand paper and make them shiny.
- Make the connections as per circuit diagram. All connections must be neat and tight. Take care to connect the ammeter and voltmeter with their correct polarity. (+ve to +ve and -ve to -ve).
- Adjust the rheostat to pass a low current.
- Insert the key K and slide the rheostat contact to see whether the ammeter and voltmeter are showing deflections properly.
- Adjust the rheostat to get a small deflection in ammeter and voltmeter.
- Record the readings of the ammeter and voltmeter.
- Take atleast six sets of readings by adjusting the rheostat gradually.
- Plot a graph with V along x-axis and I along y-axis.
- The graph will be a straight line which verifies Ohm's law.
- Determine the slope of the V-I graph. The reciprocal of the slope gives resistance of the wire.

Voltage across V	Current through A
0	0
2	0.5
4	1
6	1.5
8	2
10	2.5
12	3



Electrical Resistance

Conductors conduct electricity owing due to presence of a large number of free electrons. When a potential difference is applied across a conductor these electrons begin to drift from the end at low potential to the end at high potential. While drifting they collide with other electrons as well as with fixed positive ions. The fixed ions are formed from the atoms which give free electrons. Thus, even as conductor conducts electricity, at the same time it offers some obstructions to the flow of charges.

The obstruction offered by a conductor to the flow of electric current is called its resistance.

As the collisions suffered by drifting electrons increase, the resistance offered by the conductor also increases. Thus, the resistance depends basically on the arrangement of atoms and the configuration of electrons around the atoms of the conductor.

Units of Resistance

The SI unit of resistance is ohm. It is denoted by Greek symbol **Ω** (Omega).

Higher units of resistance are:

- $\textbf{kilo}-\textbf{ohm}\ (\textbf{k}\Omega) = \mathbf{10^3}\ \boldsymbol{\Omega}$
- $\textbf{Mega}-\textbf{ohm}\ (\textbf{M}\Omega) = \mathbf{10^6}\ \boldsymbol{\Omega}$
- $\textbf{Giga}-\textbf{ohm}\ (\textbf{G}\Omega) = \mathbf{10^9}\ \boldsymbol{\Omega}$

Lower units of resistance are:

- $\text{mili–ohm}\ (\text{m}\Omega) = \mathbf{10^{-3}}\ \Omega$
- $\text{micro–ohm}\ (\mu\Omega) = \mathbf{10^{-6}}\ \Omega$

Factors Affecting Resistance

- Resistance of a conductor depends upon nature of conductor.
- **Law of length:**
  Resistance of a conductor is directly proportional to its length.

Let ℓ and R be the length and resistance of conductor, then consider two conductors of same material such that ℓ_1 and ℓ_2 are their lengths and, R_1 and R_2 are their resistances respectively. Then

$R_1 \propto \ell_1$

$R_2 \propto \ell_2$

$\therefore \frac{R_1}{R_2} = \frac{\ell_1}{\ell_2}$

Electricity was first discovered in 600 BC. DID you KNOW

- **Law of area of cross-section:**
  Resistance of a conductor is inversely proportional to its area of cross section.
  Let a be the area of cross section of a conductor whose resistance is R.
  $R \propto \frac{1}{A}$
  Considering two conductors of area of cross sections A_1 and A_2 and resistances R_1 and R_2.
  Then,
  $R_1 \propto \frac{1}{A_1}$
  $R_2 \propto \frac{1}{A_2}$
  $\therefore \frac{R_1}{R_2} = \frac{A_2}{A_1}$
  $= \frac{\pi r_2^2}{\pi r_1^2}$ $(\because A = \pi r^2)$
  $\frac{R_1}{R_2} = \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2$
  Where r_1 and r_2 are the radii of the two conductors.
  Combining the 2nd and 3rd laws, we get
  $R \propto \frac{\ell}{A}$
  $R = \rho\frac{\ell}{A}$
  Where $\boldsymbol{\rho}$ is the constant of proportionality and known as Specific resistance or Resistivity.

A spark of static electricity can measure up to 3,000 volts. That is why you should use caution when pumping gas or working around flammable items when you could be charged with static electricity. DID you KNOW

- **Temperature:**
  The resistance of a conductor increases with temperature.
  When the temperature of a conductor is increased, the average kinetic energy of the molecules of the conductor increases, so the number of collisions of the free electrons passing through the conductor also increases leading to an increase in resistance.

Specific Resistance or Resistivity

We have seen that

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

The constant of proportionality ρ is called the specific resistance or resistivity of a given conducting material like copper, aluminum etc. It is a characteristic property of conducting material and independent of the size and shape of the conductor.

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

Consider a conductor having unit area of cross section and unit length.

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

$\therefore \rho = R.$

Thus, specific resistance or resistivity can be defined as the resistance of a conducting material having unit area of cross section and unit length.

Unit of resistivity

$$\text{Unit of } \rho = \frac{\text{unit of } R \times \text{ unit of } A}{\text{unit of } \ell} = \frac{\text{ohm} \times (\text{metre})^2}{\text{metre}}$$

unit of $\rho =$ ohm-metre $= \Omega m$

Electrical Resistivity of some substances at $20^\circ C$.

	Material	Resistivity (Ωm)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}

	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
Insulators	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Example:

Q.1 On what factors does the resistance of a conductor depend?

Solution: The resistance of a conductor depends upon the following factors:

- Length of the conductor
- Cross-sectional area of the conductor
- Material of the conductor
- Temperature of the conductor.

Q.2 Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?

Solution: Resistance (R) is inversely proportional to the area of cross-section (A) of the wire.
So, thicker the wire, lower is the resistance of the wire and vice-versa.
Therefore, current can flow more easily through a thick wire than a thin wire.

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

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

Q.3 Calculate the Resistance of wire if potential difference between wire is 20 V and current flowing through it is 2A.

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

$R = \frac{20}{2} = 10\ \Omega$

Q.4 Calculate the resistance of a copper wire of length $2\ \mathrm{m}$ and area of cross section $10^{-6}\ \mathrm{m}^2$. Resistivity of copper is $1.7 \times 10^{-8}\ \Omega\mathrm{m}$.

Solution:

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

$$R = 1.7 \times 10^{-8} \times \frac{2}{10^{-6}}$$

$R = 3.4 \times 10^{-2}\ \Omega$.

Q.5 The value of current, I, flowing in a given resistor for the corresponding value of potential difference, V, across the resistor are given below:

I (ampere)	:	0.5	1.0	2.0	3.0	4.0
V (volt)	:	1.6	3.4	6.7	10.2	13.2

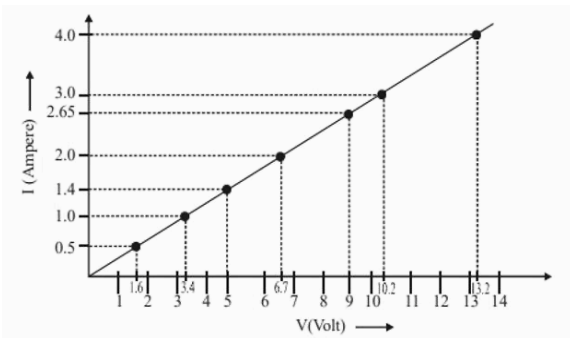
Plot a graph between V and I and calculate the resistance of resistor.

Answer:

For $V = 4\ V$ (i.e., $9\ V - 5\ V$), $I = 1.25\ A$ (i.e., $2.65\ A - 1.40\ A$). Therefore,

$$R = \frac{V}{I} = \frac{4\ V}{1.25\ A} = 3.2\Omega$$

The value of R obtained from the graph depends upon the accuracy with which the graph is plotted.



Q.6 A given copper wire of 10Ω resistance is stretched to double its original length,its new resistance is

Solution: Given: $R_1 = 10\Omega$ and $l_2 = 2l_1$

As we know that the resistance of the wire is,

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

When the wire is stretched then, then its area will decrease automatically. But the volume of the wire will be the same.

∴ The volume of original wire = volume of new wire

$$\Rightarrow A_1 l_1 = A_2 l_2$$
$$\Rightarrow A_1 l = A_2\, 2l_1$$
$$\Rightarrow A_2 = A_1/2$$

The resistance of the wire in 1^{st} case

$$\Rightarrow R_1 = R = \frac{\rho l_1}{A_1} \cdots (1)$$

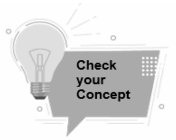
The resistance of the wire in 2^{nd} case

$$\Rightarrow R_2 = \frac{\rho l_2}{A_2} = \frac{\rho 2l_1}{\frac{A_1}{2}} = \frac{4\rho l_1}{A_1}$$

Divide equation 1 and 2, we get

$$\frac{R_1}{R_2} = \frac{\rho \frac{l_1}{A_1}}{\rho \frac{4l_1}{A_1}} = \frac{1}{4}$$

$$R_2 = 4R_1 = 4 \times 10 = 40\Omega$$



(1) A copper wire of length $1\ \text{m}$ and area of cross-section $2.7 \times 10^{-6}\ \text{m}^2$ has a resistance of 2×10^{-2} ohms. Calculate the resistivity of copper.

(2) Calculate the current flowing through a wire of resistance $5\ \text{m}\Omega$ maintained at a potential difference of 2V.

(3) A copper wire has a diameter of $0.5\ \text{mm}$ and resistivity of $1.6 \times 10^{-8}\ \Omega\text{m}$. What will be the length of this wire to make its resistance $10\ \Omega$? How much does the resistance change if the diameter is doubled?

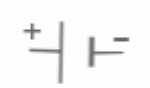
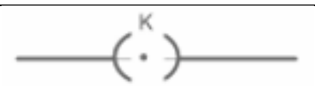
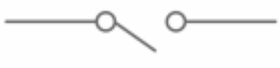
Answer Key

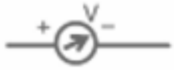
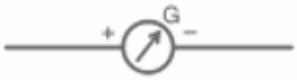
(1) $5.4 \times 10^{-8}\ \Omega\text{m}$ **(2)** 400 A. **(3)** 122.65 m, 2.5 Ω

Electric Circuits and Circuit Diagrams

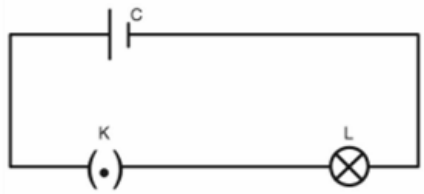
In order to make use of electric energy, the current has to be passed through various devices and electric components. For this, they need to be connected properly with respect to each other and electric source. This systematic arrangement of electric components and devices with the electric source is called electric circuit. It is also important that the circuit arrangement should be represented schematically. The schematic representation of electric circuit is called circuit diagram. In order to draw a circuit diagram, various electric components and devices are represented by suitable symbols.

The table below gives conventional symbols for some common components.

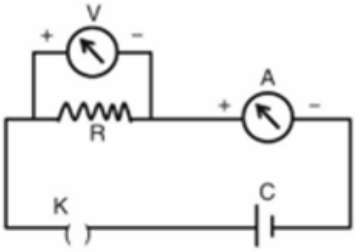
A cell	
A battery	
Alternating current source	
Plug key	
Switch	
Tapping Key	

Conducting Wire	
An ammeter	 or 
A Voltmeter	 or 
A resistance (fixed value)	
A variable resistance or rheostat	 or 
Galvanometer	 or 
Load	
Heater	
Bulb	

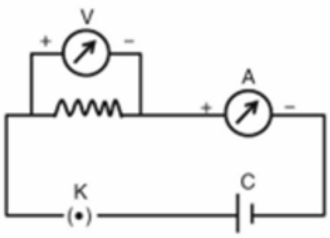
A simple electric circuit can be represented by the following diagram. Here ' C ' represents the cell that supplies electrical energy, ' K ' represents the plug key that is used to connect or disconnect the cell from rest of the circuit and 'L' represents the load, i.e., any device that utilizes electrical energy. When the plug key is shown with a dot in between, i.e., (·), it represents the circuit with connection made with the cell and current flows through the circuit. In this condition, we say, the circuit is closed. When the plug key is shown without a dot in between, i.e., ( ), it represents the circuit is disconnected from the cell and no current flows in the circuit. In this condition, we say, the circuit is open. If an ammeter, i.e., a device that measures electric current through the circuit is to be connected, it is always connected in series in the circuit. Similarly, if a voltmeter, i.e., a device that measures potential difference across the ends of a conductor or a resistor is to be connected in a circuit, it is always connected in a position that is parallel to the conductor or the resistor as the case may be. The following figures show an ammeter and a voltmeter connected in the circuit in open and closed conditions respectively.



A Simple Circuit



An Open Circuit

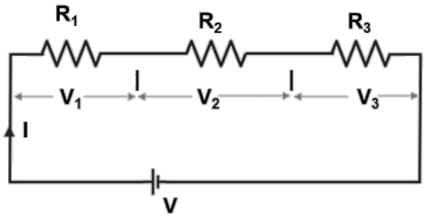


A Closed Circuit

Resistances in Series

Resistances are said to be connected in series, when there exists only one path for the flow of current and the current through each resistor is equal.

Resistances R_1, R_2 and R_3 are connected in series as shown above. Applying a voltage "V" across the series combination. Let V_1, V_2 and V_3 be the voltage drop across R_1, R_2 and R_3 respectively as shown in the figure. Let the current I flow through all the three resistances.



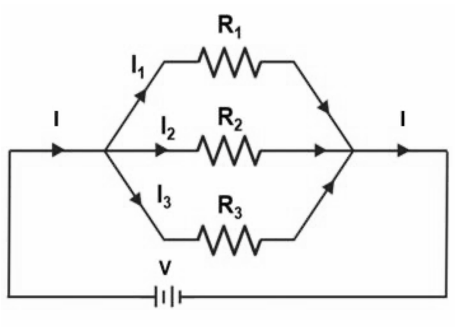
Therefore, the voltage V_1 across $R_1: V_1 = IR_1$
the voltage V_2 across $R_2: V_2 = IR_2$
the voltage V_3 across $R_3: V_3 = IR_3$
The applied voltage $V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$
If R_{eff} is the effective resistance, then $V = IR_{eff}$
$IR_{eff} = IR_1 + IR_2 + IR_3$
$IR_{eff} = I(R_1 + R_2 + R_3)$
$\therefore R_{eff} = R_1 + R_2 + R_3$.

Characteristics of Series Circuit

(i) Same current is flowing through all the resistances.
(ii) The effective resistance is the sum of the individual resistances.
Effective resistance $\mathbf{R_{eff} = R_1 + R_2 + R_3}$
(iii) The applied voltage $\mathbf{V = V_1 + V_2 + V_3}$
(iv) The maximum power is consumed by the resistor having the highest resistance, or the voltage drop is maximum across the highest resistance.

Resistances in Parallel

Resistances are said to be connected in parallel, when same potential difference exists across all of them, i.e., the potential drop across each resistor is same. Let three resistors $\mathbf{R_1, R_2}$ and $\mathbf{R_3}$ be connected across the voltage source $\mathbf{V}$ in parallel. The current $\mathbf{I}$ drawn from the battery is divided into three parts $\mathbf{I_1, I_2}$ and $\mathbf{I_3}$ flowing through the resistors $\mathbf{R_1, R_2}$ and $\mathbf{R_3}$ respectively are as shown above.



Total current $\mathbf{I = I_1 + I_2 + I_3}$
Let $\mathbf{R_{eff}}$ be the effective resistance.
Applying Ohm's law $I = \frac{V}{R_{eff}}$;
$\mathbf{I_1} = \frac{V}{R_1}$; and $\mathbf{I_2} = \frac{V}{R_2}, \mathbf{I_3} = \frac{V}{R_3}$

$$\mathbf{As, I = I_1 + I_2 + I_3; \frac{V}{R_{eff}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}}$$

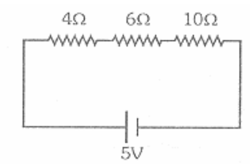
$$\therefore \mathbf{\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right); \Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Characteristics of a Parallel circuit

(i) The potential drop across each resistance is the same.
(ii) The reciprocal of the effective resistance is equal to the sum of the reciprocals of the individual resistances.
(iii) Current in the circuit $\mathbf{I = I_1 + I_2 + I_3} + \cdots$
(iv) The effective resistance is less than the least resistance in the circuit.
(v) Maximum power is consumed by the least resistance, or the maximum current flows through the least resistance.

Example:

Q.1 Calculate net resistance in the circuit shown in figure.



Solution: As all resistances are in series
So, $R_s = 4\Omega + 6\Omega + 10\Omega = 20\Omega$.

Q.2 A battery of 9 V is connected in series with resistors of 0.4Ω, 0.7Ω, 0.9Ω and 10Ω. How much current would flow through the 10Ω resistor?

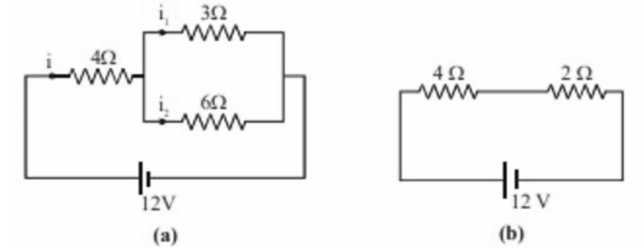
Solution: Since all the resistors are in series, equivalent resistance.
$R_s = 0.4\Omega + 0.7\Omega + 0.9\Omega + 10\Omega = 12\Omega$
Current through the circuit, $I = \frac{V}{R_s} = \frac{9V}{12\Omega} = 0.75\ A$
In series, same current (I) flows through all the resistors.
Thus, current flowing through 10 Ω resistor = 0.75 A.

Q.3 Calculate the net resistance if 6 Ω and 12 Ω are connected in parallel.

Solution: $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6} + \frac{1}{12}$

$R_p = 4\ \Omega.$

Q.4 Consider the circuit shown in figure. Calculate the current through the 3Ω resistor.



Solution: The 3Ω resistor and the 6Ω resistor are joined in parallel. Their equivalent resistance is

$$R = \frac{(3\Omega)\times(6\Omega)}{(3\Omega)+(6\Omega)} = 2\Omega.$$

Thus, the two resistors may be replaced by a single resistor of resistance 2Ω. The circuit can be redrawn as shown in figure. The two resistors in the figure are joined in series. The equivalent resistance is $4\Omega + 2\Omega = 6\Omega$.

The current through the battery is $i = \frac{12\ V}{6\Omega} = 2\ A.$

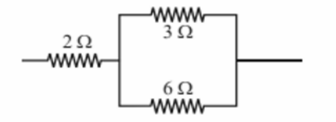
Now look at Figure (a). The current through the battery and the 4Ω resistor is $2\ A$. This current is divided in the two resistors (3Ω and 6Ω) which are joined in parallel.

Using $i_1 = \frac{R_2 i}{R_1+R_2}$, the current through the 3Ω resistors is

$$i_1 = \frac{(6\Omega)\times(2\ A)}{(3\Omega)+(6\Omega)} = \frac{12\Omega A}{9\Omega} = 1.33\ A$$

How can three resistors of resistance $2\Omega, 3\Omega$ and 6Ω be connected to give a total resistance of (a) 4Ω, (b) 1Ω ?

(a) We get 4Ω resistance if 3Ω and 6Ω resistors are connected in parallel and this parallel combination is connected in series with 2Ω as shown in figure.



Equivalent resistance of 3Ω and 6Ω is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} = \frac{1}{2}$$

Or $R = 2\Omega$

Now 2Ω and 2Ω are in series,

So net resistance $= 2\Omega + 2\Omega = 4\Omega$

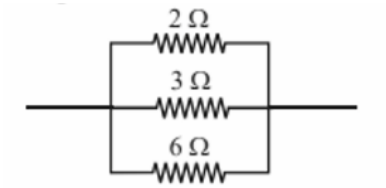
(b) We get 1Ω resistance if all three resistors are connected in parallel.

Therefore

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

$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{3+2+1}{6} = \frac{6}{6} = 1$$

or $R = 1\Omega$



(1) If 3 Ω, 6 Ω and 9 Ω are connected in series then find the net resistance.
(2) If 2 Ω, 3 Ω and 6 Ω are connected in parallel then find the net resistance.
(3) Show how you would connect three resistors, each of resistance 6Ω, so that the combination has a resistance of (i) 9Ω (ii) 2Ω.

Answer Key

(1) 18 Ω. **(2)** 1 Ω.

Heating Effect of Electric Current

When a potential difference is applied between the ends of a conductor, current begins to flow through it. The current flows in conductor contains large number of free electrons which begin to drift from the end at lower potential to the end at higher potential. In the process they constantly keep on colliding with the atoms of conductor. The atoms gain energy and begin to vibrate more vigorously about their mean position. The average kinetic energy of atoms of conductor increases. This results in a rise in the temperature of the conductor and we say that the conductor has been heated. Thus, flow of current has a heating effect on the conductor. The heat produced (H) depends on the following factors.

- Resistance of conductor: More the resistance of conductor more is the number of collisions between free electrons and atoms. Hence if a conductor offers more resistance to the flow of current, the heat produced in it will be more.
  $H \propto R$
- Current flowing through the conductor: Heat produced increases with the increase in the strength of the current flowing through conductor.
  $H \propto I^2$
- Time of flow of current: As the time of flow of current increases, the heat produced also increases.
  $H \propto t$
  Thus a conductor having larger resistance will generate more heat when a stronger current passes through it for a longer time.
- If I is the current flowing in a conductor of resistance $\mathbf{R}$ for time $\mathbf{t}$, the heat produced (H) is given by
  $\mathbf{H} = \mathbf{I^2Rt}$ this is known as Joule's law of heating.

Applications of Heating Effect of Electric Current

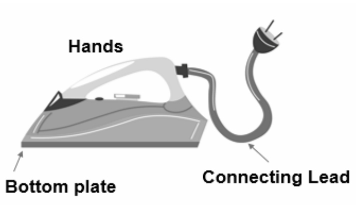
Electric Heater

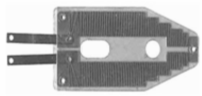
It uses nichrome wire as a heating coil. The spiral coil of nichrome wire is placed in a groove in a porcelain frame in a zig-zag manner. When current is passed through it, the wire gets red hot due to high resistance. The heat generated is used for cooking or heating purposes. Porcelain being an insulator of heat, does not become hot.

An Electric stove

Electric Iron

The coil of high resistance nichorme wire is enclosed in mica sheets which are placed in a heavy metal block. The coil is connected to power supply and transfer its heat to the metal block which is used to iron clothes. The heating coil is embedded between mica sheets as mica is a good conductor of heat but bad conductor of electricity.





Heating Coil

Electric power

The rate at which electric work is done is called electric power.
or
The amount of electric work done in one second is called electric power.
Let a cell do work W in time t, the power delivered by it is

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

Units of electric power

If work done is measured in joule and time in second, power is measured in watt (W).

$$\text{Watt} = \frac{\text{Joule}}{\text{second}}$$

The power developed is 1 watt if 1 joule of work is done in 1 second.

$$1 \text{ watt} = \frac{1 \text{ joule}}{1 \text{ second}}$$

Higher units of power
1 kilowatt $(kW) = 1000 \text{ W} = 10^3 \text{ W}$
1 Megawatt $(MW) = 10^6 \text{ W}$
1 Horsepower $(hp) = 746 \text{ W}$
$1KW = 1.34 \text{ hp}$

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

But W = VIt $= \frac{V^2}{R}t = I^2Rt$

$$\therefore P = \frac{W}{t} = VI = I^2R = \frac{V^2}{R}$$

DID you KNOW

Even when switched off, an appliance that is plugged in uses energy. The average laptop idles at 20 watts while a desktop computer idles at 80 watts. It is wise to unplug appliances while not in use.

Commercial Units of Electrical Energy

Electric power $= \frac{\text{Electric work}}{\text{Time}} = \frac{\text{Electric Energy}}{\text{Time}}$
$\therefore$ Electric Energy = Electric power × Time
Unit of electric energy = Unit of electric power × Unit of time = Watt × Second
The unit watt second gives the energy consumed by an electrical appliance, in t seconds whose power is P watt. However for practical purposes, higher units of energy are used. The higher units of electrical energy are watt-hour (W h) or kilowatt-hour (kW h).
If an electric appliance of power P watt is used for 1 hour, the energy consumed by it is 1 watt hour.
1 watt hour = 1 watt × 1 hour
$= 1 \text{ W} \times (60 \times 60)\text{s} = 3600 \text{ W s}$
1 Watt hour $= 3600 \text{ J } (\text{Ws} = \text{J})$
One kilowatt hour is the energy consumed in hour by an electric appliance whose power is 1 kilowatt.

1 kilowatt – hour = 1 kilowatt × 1 hour = $1\ \mathrm{kW} \times (60 \times 60)\mathrm{s} = 1000\ \mathrm{W} \times 3600\ \mathrm{s}$
1 kilowatt hour $= 3.6 \times 10^6\ \mathrm{J}$
$1\ \mathrm{kWh} = 3.6\ \mathrm{MJ}$
The electric meter installed at our homes measures the energy consumed in kilowatt hour.

Example:

Q.1 Calculate the heat produced in a device of resistance 10 Ω, if 10 A current flows through it for 5 hours.
Solution: $H = I^2Rt$
$H = (10)^2 \times 10 \times 5 \times 3600 = 1.8 \times 10^7\ \mathrm{J}.$
Q.2 Calculate the power if voltage is 20 V and current is 5 A.
Solution: P = VI
P = 20 × 5
P = 100 W.
Q.3 Calculate the net resistance if 6 Ω and 12 Ω are connected in parallel.
Solution: $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6} + \frac{1}{12}$
$R_p = 4\ \Omega.$

Q.4 Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then in parallel in electric circuit. The ratio of the heat produced in series and parallel combinations would be :
Solution: Since both the wires are made of the same material and have equal lengths and equal diameters, these have the same resistance. Let it be R.
When connected in series, their equivalent resistance is given by
$R_s = R + R = 2R$
When connected in parallel, their equivalent resistance is given by
$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \text{ or } R_p = \frac{R}{2}$$
Further, electrical power is given by $P = \frac{V^2}{R}$
Power (or heat produced) in series, $P^2 = \frac{V^2}{R_s}$
Power (or heat produced) in parallel, $P_p = \frac{V^2}{R_p}$
Thus, $\frac{P_i}{P_p} = \frac{V^2/R_s}{V^2/R_p} = \frac{R_p}{R_s} = \frac{R/2}{2R} = \frac{1}{4}$ or $P_s : P_p :: 1:4$
thus, (C) is the correct answer

Q.5 An electric bulb is rated $220\ \mathrm{V}$ and $100\ \mathrm{W}$. When it is operated on $110\ \mathrm{V}$, the power consumed will be
Solution: Resistance of the electric bulbs,
$$R = \frac{V^2}{P}\ (P = V^2/R)$$
or $R = \frac{(220)^2}{100} = 484\Omega$
power consumed by the bulb when it is operated at $110\ \mathrm{V}$ is given by
$$P' = \frac{V'^2}{R} = \frac{(110)^2}{484} = \frac{110 \times 110}{484} = 25\ \mathrm{W}$$
$(V' = 110\ \mathrm{V})$

Check your Concept

(1) Calculate heat produced in the bulb if voltage across it is 20 V and current flowing through it is 5 A for 2 hours.
(2) 10 V voltage is maintained across the bulb of resistance 20 Ω. If the bulb glow for 30 minutes then calculate the heat produced.
(3) If 20 A current flows through wire of resistance 15 Ω then calculate the power consumed by resistor.
(4) How many 176Ω resistors (in parallel) are required to carry $5\ \mathrm{A}$ in $220\ \mathrm{V}$ line?

Answer Key

(1) 7.2×10^5 J. **(2)** 9 kJ. **(3)** 6 kW.
(4) 4

Solved Examples

(1) Which of the following terms does not represent electrical power in a circuit:

(A) I^2R (B) IR^2
(C) VI (D) V^2/R

Answer: (B) IR^2

Reason: Electrical power $P = VI = (IR)R = I^2R = V\left(\frac{V}{R}\right) = \frac{V^2}{R}$

Obviously, IR^2 does not represent electrical power in a circuit.

(2) How is voltmeter connected in the circuit to measure potential difference between two points?

Answer: A voltmeter is always connected in parallel across the points where the potential difference is to be determined.

(3) Keeping the potential difference constant, the resistance of a circuit is doubled. By how much does the current change?

Solution: V = IR

As V is constant so, $I \propto \frac{1}{R}$

Since, the resistance and the current are inversely proportional, the current will become half.

(4) If the current passing through a conductor is doubled, what will be the change in the heat produced?

Answer: Heat produced will increase by four times ($H \propto I^2$).

(5) Define Electric Current.

Answer: Electric current is the rate of flow of electric charges. It is denoted by I. It is given by:

Electric current $= \frac{\text{electric charge}}{\text{time}}$ or $I = \frac{Q}{t}$

(6) Name some devices which work on heating effect of electric current.

Answer: Electric bulb, Electric iron, Electric geyser and Electric fuse are some devices which work on the principle of heating effect of electric current.

(7) How is heating effect of electric current used in an electric bulb?

Answer: Electric bulb works on the principle of heating effect of electric current. When electric current passes through a very thin, high resistance tungsten filament of an electric bulb, the filament becomes white hot and emits light.

(8) A current of 4 A flows through a 12V car headlight bulb for 10 minutes. How much energy transfer occurs during this time?

Solution: Given: I = 4 A, V = 12 V, t = 10 min = 600 s

Energy transferred = VIt = 12 × 4 × 600 = 28800 J.

(9) When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.

Answer: Here, V = 12 V, I = 2.5 mA = 2.5×10^{-3} A

Resistance,

$$R = \frac{V}{I} = \frac{12\ \text{V}}{2.5 \times 10^{-3}} = 4800\Omega$$

(10) A heating element is marked 210 V, 630 W. What is the current drawn by the element when connected to 210 V D.C. mains? What is the resistance of the element?

Solution: Given, P = 630 W, V = 210 V

Current drawn, $I = \frac{P}{V} = \frac{630}{210} = 3\text{A}.$

(11) Distinguish between resistances in series and resistances in parallel.

Answer: Resistances in series:

- If a number of resistances are connected in such a way that the same current flows through each resistance, then the arrangement is called resistances in series.
- The current across each resistance is same.
- The equivalent resistance in series combination is greater than the individual resistances.
- This combination decreases the current in the circuit.

Resistances in parallel:

- If a number of resistances are connected between two common points in such a way that the potential differences across each of them is same, then the arrangement is called resistances in parallel.
- The voltage across each resistance is same.
- The equivalent resistance in parallel combination is smaller than each of the individual resistances.
- This combination increases the current in the circuit.

(12) A copper wire of resistivity 2.6 × 10^{-8} Ωm, has a cross sectional area of 30 × 10^{-8} cm^2. Calculate the length of this wire required to make a 10 Ω coil.

Solution: Given: R = 10Ω, ρ = 2.6 × 10^{-3} Ωm,

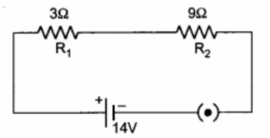
$R = \frac{\rho l}{A}$

∴ ρl = RA

$$l = \frac{RA}{\rho} = \frac{10 \times 30 \times 10^{-8}\ m^2}{2.6 \times 10^{-8} \Omega m} = \frac{30}{26} \times 100 = \frac{30}{26} \times 10^2 = 1.15 \times 10^2\ m$$

(13) Two coils of resistance R_1 = 3Ω and R_2 = 9Ω are connected in series across a battery of potential difference 14 V. Draw the circuit diagram. Find the electrical energy consumed in 1 min in each resistance.

Solution: Given: R_1 = 3Ω, R_2 = 9Ω



$R_s = R_1 + R_2$ = 9 + 3 = 12 Ω

Now, I = $\frac{V}{R}$ = $\frac{14}{12}$ = 1.167 Amp. [I in series remains constant.]

Electric energy consumed in R_1

$H_1 = I^2R_1t = (1.167)^2 \times 3 \times 60$ = 245.14 J

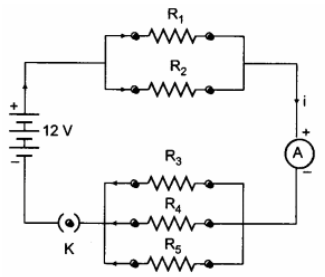
Electric energy consumed in R_2

$H_2 = I^2R_2t$ = 735.42 J

(14) If, in Figure R_1 = 10 ohms, R_2 = 40 ohms, R_3, = 30 ohms, R_4 = 20 ohms, R_5 = 60 ohms and a 12 V battery is connected to the arrangement, calculate:

(a) the total resistance and

(b) the total current flowing in the circuit.



Solution: (a) Let R' be the equivalent resistance of R_1 and R_2. Then,

$$\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10} + \frac{1}{40} = \frac{5}{40} = \frac{1}{8}$$

R' = 8Ω

Let R" be the equivalent resistance of R_3, R_4 and R_5. Then,

$$\frac{1}{R''} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60} = \frac{6}{60} = \frac{1}{10}$$

$R'' = 10\Omega$

Total Resistance, $R = R' + R'' = 8 + 10 = 18\Omega$

(b) Current,

$$I = \frac{V}{R} = \frac{12\ V}{18\Omega} = 0.67\ A.$$

(15) A household uses the following electric appliances:

(i) Refrigerator of rating 400 W for ten hours each day.

(ii) Two electric fans of rating 80 W each for twelve hours each day.

(iii) Six electric tubes of rating 18 W each for 6 hours each day.

Calculate the electricity bill of the household for the month of June if the cost per unit of electric energy is ₹ 3.00.

Solution: Energy consumed by refrigerator of rating 400 W for ten hours each day = P × t

= 400 W × 10 h = $\frac{400}{1000}$ kW × 10 h = 4.0 kWh.

Energy consumed by two electric fans of rating 80 W each for twelve hours each day

= 2 × P × t = 2 × 80W × 12h = $\frac{160}{1000}$ kW × 12 h = 1.92 kWh

Energy consumed by six electric tubes of rating 18 W each for 6 hours each day

= 6 × P × t = 6 × 18W × 6h = $\frac{108}{1000}$ W × 6 h = 0.648 kWh

Total energy consumed in the month of June (30 days) = (4.0 + 1.92 + 0.648) × 30 kWh

= 6.568 × 30 = 197.04 kWh

Electricity bill for the month of June = ₹ 197.04 × 3 = ₹ 591.12 = ₹ 591 (approx.)

(16) A piece of wire having resistance 'R' is cut into four equal parts.

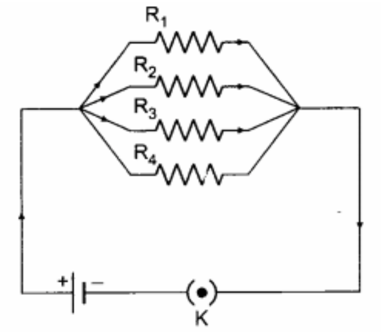
(a) How does the resistance of each part compare with the original resistance?

(b) If the four parts are placed in parallel, how will be the resistance of the combination compare with the resistance of the original wire?

Solution: (a) As R ∝ l, when the wire is cut into four equal pieces, the resistance of each part is R_4.

(b) When they are connected in parallel.

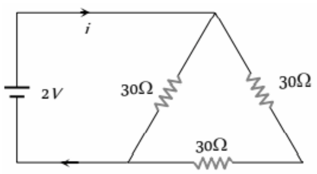
$$\frac{1}{R_p}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}$$
$$=\frac{4}{R}+\frac{4}{R}+\frac{4}{R}+\frac{4}{R}\qquad\left[\Rightarrow\frac{1}{R_p}=\frac{16}{R}\right]$$
$$\therefore\ R_p=\frac{R}{16}$$



(17) A uniform wire of resistance R is uniformly compressed along its length, until its radius becomes n times the original radius. Now resistance of the wire becomes

Solution: $\frac{R_1}{R_2}=\left(\frac{r_2}{r_1}\right)^4\Rightarrow\frac{R}{R_2}=\left(\frac{nr}{r}\right)^4\Rightarrow R_2=\frac{R}{n^4}$

(18) The current in the adjoining circuit will be



Solution:

$$R_{\text{equivalent}}=\frac{(30+30)30}{(30+30)+30}=\frac{60\times30}{90}=20\Omega$$
$$\therefore\ i=\frac{V}{R}=\frac{2}{20}=\frac{1}{10}\text{ ampere}$$

(19) Two resistances are joined in parallel whose resultant is $\frac{6}{8}$ ohm. If one of the resistance wires is broken then the effective resistance becomes 2Ω. Then find the resistance in ohm of the wire that got broken.

Solution: If resistances are R_1 and R_2 then,

$$\frac{R_1R_2}{R_1+R_2}=\frac{6}{8}\ldots..(i)$$

Suppose R_2 is broken then $R_1=2\Omega$

On solving equations (i) and (ii) we get $R_2=\frac{6}{5}\Omega$

(20) Two resistors are connected (a) in series (b) in parallel. The equivalent resistance in the two cases are 9 ohm and 2 ohm respectively. Then the resistances of the component resistors are

Solution: $R_1+R_2=9$ and $\frac{R_1R_2}{R_1+R_2}=2$

$\Rightarrow R_1R_2=18$

$R_1-R_2=\sqrt{(R_1+R_2)^2-4R_1R_2}=\sqrt{81-72}=3$

$R_1=6\Omega, R_2=3\Omega$

(21) A wire of stretched 50%, calculate percentage change in its resistance.

Solution: Resistance of the wire $R=\frac{\rho l}{A}$

We know that Volume V = Al

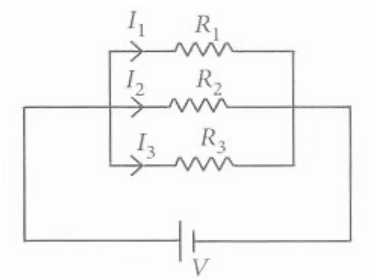
So, $R=\frac{\rho l^2}{V}$

New length of the wire $1'=1+0.51=1.51$

New resistance of the wire $R'=\frac{\rho(1.51)^2}{V}=2.25R$

Percentage change in resistance $\frac{R'-R}{R}\times100=\frac{2.25R-R}{R}\times100=125\%$.

(22) If two or more resistances are connected in such a way that the same potential difference gets applied to each of them, then they are said to be connected in parallel. The current flowing through the two resistances in parallel is, however, not the same. When we have two or more resistances joined in parallel to one another, then the same current gets additional paths to flow and the overall resistance decreases. The equivalent resistance is given by $\frac{1}{R_p}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$



(i) Three resistances, 2Ω, 6 Ω and 8 Ω are connected in parallel, then the equivalent resistance is
(A) less than 6 Ω but more than 2 Ω (B) less than 8 Ω but more than 6 Ω
(C) less than 2 Ω (D) more than 8 Ω

Answer: (C)

Solution: The equivalent resistance in the parallel combination is lesser than the least value, of the individual resistance.

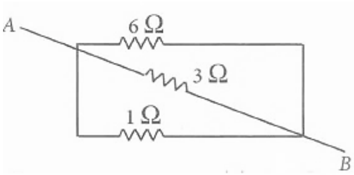
(ii) The two wires of each of resistance R, initially connected in series and then in parallel. In the graph it shows the resistance in series and in parallel. Which of the following is correct?
(A) $\frac{3}{8}\Omega$ (B) $\frac{4}{3}\Omega$
(C) $\frac{3}{4}\Omega$ (D) $\frac{5}{6}\Omega$

Answer: (B)

Solution: Resistance of each piece $= \frac{12}{3} = 4\Omega$

$$\frac{1}{R_p} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} = \frac{3}{4} \Rightarrow R_p = \frac{4}{3}\Omega$$

(iii) Three resistances are connected as shown. The equivalent resistance between A and B is
(A) $\frac{2}{3}\Omega$ (B) $\frac{3}{2}\Omega$
(C) $\frac{4}{3}\Omega$ (D) $\frac{3}{4}\Omega$



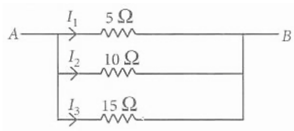
Answer: (A)

Solution: All the three resistors are in parallel.

$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} + \frac{1}{1} = \frac{1+2+6}{6} = \frac{9}{6}$$

$$R_p = \frac{6}{9} = \frac{2}{3}\Omega$$

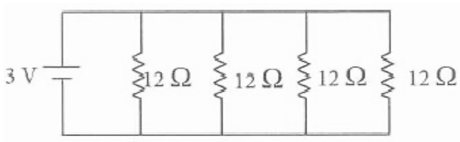
(iv) Which of the following relation is correct?
(A) $I_1 = 2I_2 = 3I_3$ (B) $I_1 = 4I_2 = 3I_3$
(C) $2I_1 = I_2 = 3I_3$ (D) $3I_1 = 2I_2 = I_3$



Answer: (A)

Solution: Voltage is same across each resistance.
So, $I_1 \times 5 = I_2 \times 10 = 15 \times I_3$
$I_1 = 2I_2 = 3I_3$

(v) Find the current in each resistance.
(A) 1 A (B) 2 A
(C) 3A (D) 0.25 A



Answer: (D)

Solution: All are in parallel.

$$\frac{1}{R_p} = \frac{1}{12} \times 4 = \frac{1}{3} \Rightarrow R_p = 3\Omega$$

$$I = \frac{3}{3} = 1 \text{ A}$$

So, current in each resistor $I' = \frac{3}{12} = \frac{1}{4}$ A

Exercise

OBJECTIVE TYPE QUESTIONS

(1) The resistance of some substance becomes zero at very low temperature, then those substances are called
(A) Good Conductors
(B) Super Conductors
(C) Bad Conductors
(D) Semi-Conductors

(2) A certain piece of silver of given mass is to made like a wire. Which of the following combination of length (L) and the area of cross-sectional (A) will lead to the smallest resistance.
(A) L and A
(B) $2\ \mathrm{L}$ and $\mathrm{A}/2$
(C) $\mathrm{L}/2$ and $2\ \mathrm{A}$
(D) Any of the above, as the volume of silver remains same.

(3) Power rating of an electric appliance indicates
(A) The rate of consumption of electrical energy
(B) Amount of heat evolved
(C) Brightness of the light
(D) Quality of the appliance

(4) A student did the experiment to find the equivalent resistance of two given resistor R_1 & R_2. First when they are connected in series and next when they are connected in parallel. The two values of the equivalent resistance obtained by him were R_s and R_p respectively. He would find that:
(A) $\mathrm{R}_\mathrm{s} < \mathrm{R}_\mathrm{p}$
(B) $\mathrm{R}_\mathrm{s} > \mathrm{R}_\mathrm{p}$
(C) $\mathrm{R}_\mathrm{s} = \mathrm{R}_\mathrm{p} = \left(\frac{\mathrm{R}_1+\mathrm{R}_2}{2}\right)$
(D) $\mathrm{R}_\mathrm{s} = \mathrm{R}_\mathrm{p}$ but not equal to $\left(\frac{\mathrm{R}_1+\mathrm{R}_2}{2}\right)$

(5) An iron box has a resistance coil of 30Ω and takes a current of $10\ \mathrm{A}$. Calculate the heat developed by it in kJ in 1 minute.
(A) $180\ \mathrm{kJ}$
(B) $90\ \mathrm{kJ}$
(C) $45\ \mathrm{kJ}$
(D) $135\ \mathrm{kJ}$

(6) Several 150Ω resistors are to be connected in such a way that a current of 2 A flows from a 50 V source. How many such resistors are required along with a mode to connect them?
(A) 6 series
(B) 8 series
(C) 6 parallel
(D) 8 parallel

(7) The resistance between two rectangular faces or a block of dimensions $4\ \mathrm{cm} \times 4\ \mathrm{cm} \times 10\ \mathrm{cm}$ of ($\rho = 48 \times 10^{-4}$ ohm m), will be
(A) $4.8\ \mu\Omega$
(B) $3.8\ \mu\Omega$
(C) $30\ \mu\Omega$
(D) $3\ \mu\Omega$

(8) A fuse wire repeatedly gets burnt when used with a good heater. It is advised to use a fuse wire of
(A) more length
(B) less radius
(C) less length
(D) more radius

(9) An electric bulb is rated $220\ \mathrm{V}, 100$ watt. The power consumed by it when operated on 110 volt will be
(A) 25 watt
(B) 50 watt
(C) 75 watt
(D) 40 watt

(10) Three equal resistors connected in series across a source of e.m.f. dissipate 10 watts of power. What will be the power dissipated in watts if the same resistors are connected in parallel across the same source of e.m.f.?
(A) $10\ \mathrm{W}$
(B) $30\ \mathrm{W}$
(C) $90\ \mathrm{W}$
(D) $\frac{10}{3}\ \mathrm{W}$

(11) When the length of wire in a circuit is doubled then the ammeter reading.
(A) decreases to one-half
(B) increases to one-half
(C) increases to 2 times
(D) decreases to 2 times

(12) An electric refrigerator rated $400\ \mathrm{W}$ operates 8 hours/day. What is the cost of the energy used to operate it for 30 days at ₹3.00 per unit?
(A) 286
(B) 285
(C) 288
(D) 289

(13) The rating of three bulbs P, Q and R are given below.
$P: 120\ V, 24\ W$
$Q: 120\ V, 60\ W$
$R: 240\ V, 60\ W$
Which of the following represents the ascending order of their resistance?
(A) P, Q, R
(B) Q, P, R
(C) R, P, Q
(D) Q, R, P

(14) The ratios of wire A and wire B respectively are $\frac{\text{Length } L_A}{\text{Length } L_B} = \frac{5}{18}$ and $\frac{\text{Diameter } D_A}{\text{Diameter } D_B} = \frac{2}{3}; \frac{\text{Resistivity } \rho_A}{\text{Resistivity } \rho_B} = \frac{4}{9}$.
What is the ratio of the resistance of wire A to the resistance of wire B ?
(A) $5:8$
(B) $5:27$
(C) $18:5$
(D) $27:5$

(15) Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combinations would be
(A) $1:2$
(B) $2:1$
(C) 1 : 4
(D) $4:1$

(16) If the specific resistance of a wire of length l and radius r is k then resistance is
(A) $\frac{k\pi r^2}{l}$
(B) $\frac{\pi r^2}{lk}$
(C) $\frac{kl}{\pi r^2}$
(D) $\frac{k}{lr^2}$

(17) Resistance $R, 2R, 4R, 8R \ldots \ldots \ldots \ldots$ are connected in parallel. Their resultant resistance will be
(A) R
(B) $R/2$
(C) 0
(D) ∞

(18) When current is passed through an electric bulb, its filament glows, but the wire leading current to the bulb does not glow because
(A) less current flows in the leading wire as compared to that in the filament.
(B) the leading wire has more resistance than the filament.
(C) the leading wire has less resistance than the filament.
(D) filament has coating of fluorescent material over it.

(19) Which one of the following heater element is used in electric press.
(A) copper wire
(B) nichrome wire
(C) lead wire
(D) iron wire

(20) A wire of resistance R is cut in three equal parts. If they are arranged in parallel and the equivalent resistance is R' then $\frac{R}{R'}$ will be equal to
(A) 3
(B) $\frac{1}{3}$
(C) 9
(D) $\frac{1}{9}$

Answer Key

OBJECTIVE TYPE QUESTIONS

(1)	(B)	**(6)**	(C)	**(11)**	(A)	**(16)**	(C)
(2)	(C)	**(7)**	(A)	**(12)**	(C)	**(17)**	(B)
(3)	(B)	**(8)**	(D)	**(13)**	(B)	**(18)**	(C)
(4)	(B)	**(9)**	(A)	**(14)**	(A)	**(19)**	(B)
(5)	(A)	**(10)**	(C)	**(15)**	(C)	**(20)**	(C)