

CHAPTER-12

ELECTRICITY

NUMERICALS

The upcoming numericals are based on:

PHYSICAL QUANTITY (SYMBOL)	FORMULA	S.I UNIT
Charge (Q)	$Q = ne$ Where n = number of electrons e = charge on one electron = $1.6 \times 10^{-19} \text{ C}$	Coulomb (C)
Current (I)	$I = Q/t$ Where Q = Electric charge (in C) t = time (in s)	Ampere (A)
Potential Difference (V)	$V = W/Q$ Where W = Work done (in J) t = time (in s)	Volt (V)

Always remember to keep all the quantities in the same unit system

CONVERSION TO REMEMBER

1 milliampere

$$1 \text{ mA} = 10^{-3} \text{ A}$$

$$= \frac{1}{10^3} = \frac{1}{1000} \text{ A}$$

1 microampere

$$1 \text{ } \mu\text{A} = 10^{-6} \text{ A}$$

$$= \frac{1}{10^6} = \frac{1}{1000000} \text{ A}$$

The SI unit of electric charge is coulomb (C), which is equivalent to the charge contained in nearly 6×10^{18} electrons. (We know that an electron possesses a negative charge of 1.6×10^{-19} C.) The electric current is expressed by a unit called ampere (A), named after the French scientist, Andre-Marie Ampere (1775–1836). One ampere is constituted by the flow of one coulomb of charge per second, that is, $1 \text{ A} = 1 \text{ C/1 s}$. Small quantities of current are expressed in milliampere

($1 \text{ mA} = 10^{-3} \text{ A}$) or in microampere ($1 \text{ } \mu\text{A} = 10^{-6} \text{ A}$).

An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit through which the current is to be measured. Figure 12.1 shows the schematic diagram of a typical electric circuit comprising a cell, an electric bulb, an ammeter and a plug key. Note that the electric current flows in the circuit from the positive terminal of the cell to the negative terminal of the cell through the bulb and ammeter.

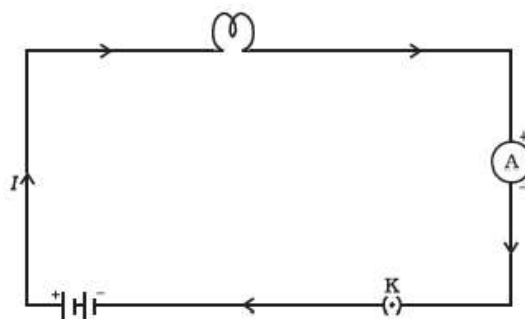


Figure 12.1

A schematic diagram of an electric circuit comprising – cell, electric bulb, ammeter and

Q. How much energy is given to each coulomb of charge passing through a 6 V battery?

(NCERT Page 202 Q3)

Concept Insight: The amount of work done to move to each coulomb of charge is equal to the energy given to it.

Charge, $Q = 1 \text{ C}$

Potential energy, $V = 6 \text{ V}$

Work done or Energy, $W = ?$

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

$$\begin{aligned}\Rightarrow W &= V \times Q \\ &= 6 \text{ V} \times 1 \text{ C} \\ &= 6 \text{ J}\end{aligned}$$

Q. Calculate the amount of work done to carry 4C from a point at 100 V to a point at 120 volts?

Concept Insight: The work done by a charged particle of charge q which moves from any point A to B which are at potential V_A and V_B is calculated as $W = q \times (V_B - V_A)$

Potential energy, $V = 120 \text{ V} - 100 \text{ V} = 20 \text{ V}$

Charge, $Q = 4 \text{ C}$

Work done, $W = ?$

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

$$\begin{aligned}\Rightarrow W &= V \times Q \\ &= 20\text{V} \times 4 \text{ C} \\ &= 80 \text{ J}\end{aligned}$$

Q. A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.
(NCERT Page 200 Ex 12.1)

Current, $I = 0.5 \text{ A}$

Time, $t = 10 \text{ min}$

$$= 10 \times 60 \text{ s} = 600 \text{ s}$$

Charge, $Q = ?$

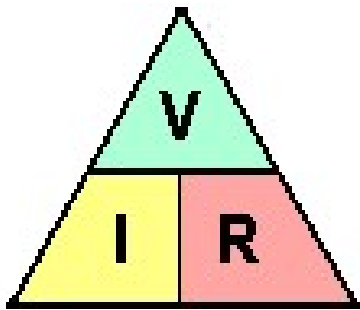
We know, $I = \frac{Q}{t}$

$$\Rightarrow Q = It$$

$$= 0.5 \text{ A} \times 600 \text{ s}$$

$$= 300 \text{ C}$$

The upcoming numericals are based on Ohm's Law



Ohm's law triangle

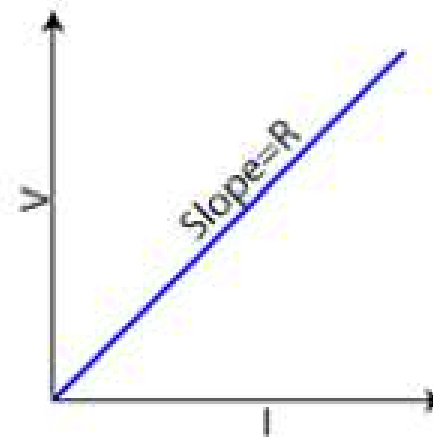
$$V = I \times R$$

$$I = V / R$$

$$R = V / I$$

S.I unit of resistance, $R = \text{Ohm } (\Omega)$

V-I GRAPH FOR OHM'S LAW



The slope of line V-I graph = Resistance (R)

$$R = \frac{V_2 - V_1}{I_2 - I_1}$$

Q. 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. (NCERT Back Exercise, Q8)

Concept Insight: - Convert all the quantities in the same unit system and then proceed with the calculations

Potential difference, $V = 12 \text{ V}$

Current, $I = 2.5 \text{ mA}$

$$(1\text{mA} = 10^{-3} \text{ A})$$

$$I = 2.5 \times 10^{-3} \text{ A}$$

Resistance = ?

Using Ohm's law,

$$V = IR$$

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

$$= \frac{12}{2.5 \times 10^{-3}} = 4.8 \times 10^3$$

$$= 4800 \, \Omega = 4.8 \text{ k } \Omega$$

Q. The potential difference between the terminals of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is increased to 120 V?
(NCERT Page 208 Ex: 12.4)

Potential difference, $V = 60 \text{ V}$

Current, $I = 4 \text{ A}$

Resistance = ?

Using Ohm's law, $V = IR$

$$R = \frac{V}{I} = \frac{60}{4} = 15 \, \Omega$$

When the potential difference, V is increased to 120 V, Resistance will remain same i.e. $15 \, \Omega$

$$\text{Therefore, the current is given by, } I = \frac{V}{R} = \frac{120}{15} = 8 \text{ A}$$

OR

Current, $I = 4 \text{ A}$,

Potential difference, $V = 60 \text{ V}$

New Potential difference $V' = 120 \text{ V}$; i.e. potential difference has doubled

Using Ohm's law, $V = IR$

$V \propto I$ (for a given resistance)

Since potential difference has doubled, therefore the current will also get doubled

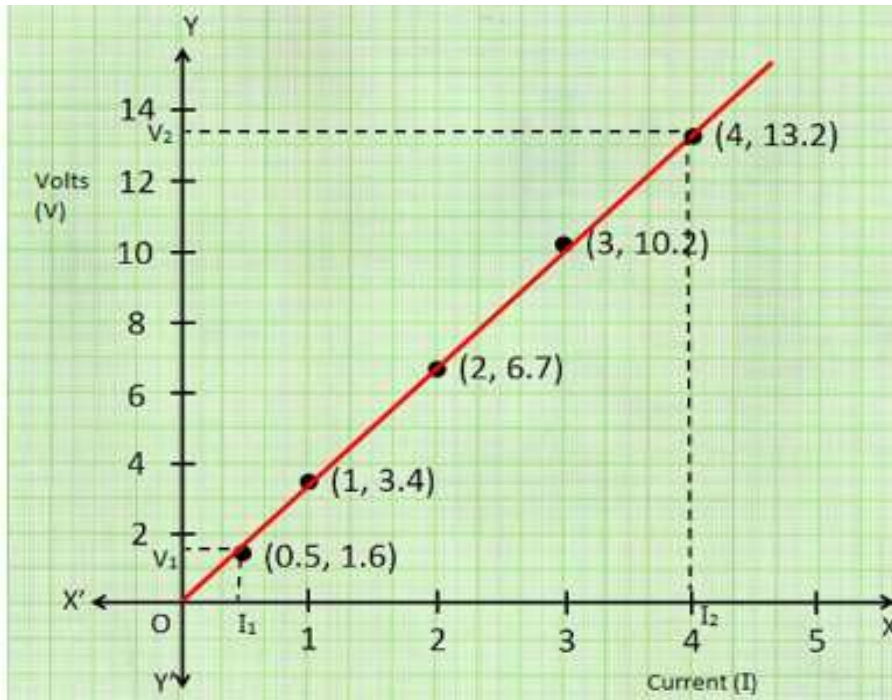
So, $I' = 4 I$

$$= 4 \times 2 = 8 \text{ A}$$

Q. The values of current I flowing in a given resistor for the corresponding values of potential difference V across the resistor are given below – (NCERT Back Exercise Q7)

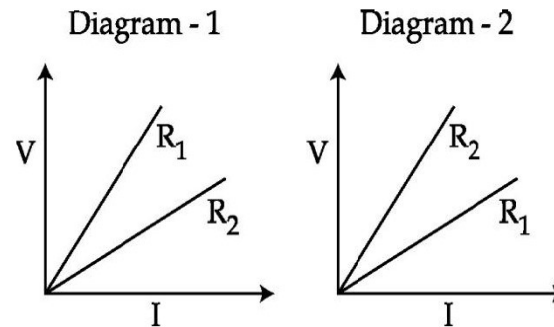
I (amperes)	0.5	1.0	2.0	3.0	4.0
V (volts)	1.6	3.4	6.7	10.2	13.2

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



$$\begin{aligned}
 \text{Resistance, } R &= \text{slope} = \frac{V_2 - V_1}{I_2 - I_1} \\
 &= \frac{13.2 - 1.6}{4 - 0.5} \\
 &= \frac{11.6}{3.5} \\
 &= 3.3 \, \Omega
 \end{aligned}$$

Q. Two students perform experiments on two given resistors R_1 and R_2 and plot the $V - I$ graphs shown by diagram 1 and 2. If $R_1 > R_2$, which of two diagrams correctly represent the situation on the plotted curves? Justify your answer.



We know, slope of V-I graph gives resistance R .

So greater the slope or inclination, greater the resistance.

Given, $R_1 > R_2$,

hence diagram 1 is correct as R_1 is greater,

so the slope of V-I graph (V/I) is greater in diagram 1.

The upcoming numericals are based on Resistance and Resistivity

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

Where ρ = resistivity of the conductor (in $\Omega \text{ m}$)
 L = length of conductor (in m)
 A = Area of cross section of conductor (in m^2)

- Resistance depend on length, area of cross-section, nature and temperature
- Resistivity does not depend on length, shape and area of cross-section. It depends only on nature and temperature.

Q. A wire of given material having length l and area of cross-section A has a resistance of $4\ \Omega$. What would be the resistance of another wire of the same material having length $l/2$ and area of cross-section $2A$?

(NCERT Page 209 Ex: 12.6)

OR

A $4\ \Omega$ resistance wire is doubled on itself calculate the new resistance of the wire

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

where l = length of wire

A = area of cross section

For another wire of same material,
it will have same resistivity ρ

New length, $l' = l/2$

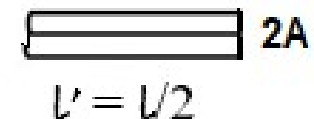
New area of cross section, $A' = 2A$

Resistance of another wire, $R' = \rho \frac{l'}{A'} = \rho \frac{l/2}{2A} = \frac{\rho l}{4A} = \frac{R}{4}$

It is given $R = 4\ \Omega$

Resistance of another wire, $R' = R/4$
 $= 4/4 = 1\ \Omega$

Concept Insight: - When a wire is folded on itself, length becomes half and area of cross section doubles.



Q. We have a copper wire of resistance R. This wire is pulled so that its length is doubled (temperature remains constant). Find the new resistance and resistivity.

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

where l = length of wire

A = area of cross section

For another wire of same material, it will have same resistivity ρ

Concept Insight: - To understand, pulling or stretching of wire imagine stretching of a rubber band, where length increases and area of cross section decreases by the same factor

New length, $l' = 2l$

New area of cross section, $A' = A/2$

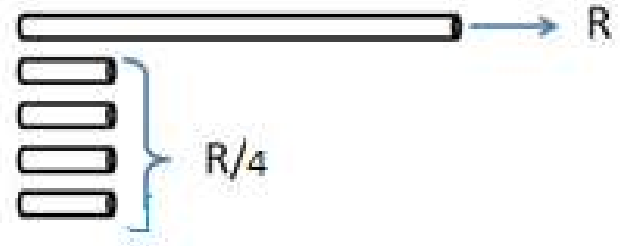
Resistance of another wire, $R' = \rho \frac{l'}{A'} = \rho \frac{2l}{A/2} = 4 \rho \frac{l}{A} = 4R$

Resistivity will not change as it is independent of length and area of cross section.

Q. You have a resistance of $5\ \Omega$. You cut it into four equal parts. What is the resistance of each part?

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

$$R = 5\ \Omega$$



$R \propto l$ (On cutting the wire, Area of cross section of each part and resistivity remains constant)

So new length, $l' = l/4$.

Therefore, resistance of each part of wire is $R/4 = 5/4\ \Omega$

Q. A copper wire has diameter 0.5 mm and resistivity of $1.6 \times 10^{-8} \Omega \text{ m}$. What will be the length of this wire to make its resistance 10Ω ? How much does the resistance change if the diameter is doubled?
(NCERT Back Exercise Q6)

Resistance, $R = 10 \Omega$

resistivity, $\rho = 1.6 \times 10^{-8} \Omega \text{ m}$

Diameter of wire = $0.5 \text{ mm} = \frac{0.5 \text{ m}}{1000} = 5 \times 10^{-4} \text{ m}$

Radius of wire, $r = \frac{\text{diameter}}{2} = \frac{5 \times 10^{-4} \text{ m}}{2} = 2.5 \times 10^{-4} \text{ m}$

$$A = \pi r^2 = \frac{22}{7} \times (2.5 \times 10^{-4})^2 = \frac{22}{7} \times (2.5)^2 \times (10^{-4})^2 = \frac{22}{7} \times 6.25 \times 10^{-8}$$

$$= \frac{22}{7} \times \frac{625}{100} \times 10^{-8} = \frac{13750}{7} \times 10^{-10} = 1964.28 \times 10^{-10} \text{ m}^2 = 1.964 \times 10^{-7} \text{ m}^2$$

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

$$l = \frac{1964 \times 10^{-7}}{16 \times 10^{-8}} \times \frac{100}{1000}$$

$$l = R \left(\frac{A}{\rho} \right)$$

$$l = \frac{491}{4} \times 10^{-7 - (-8)} \times \frac{1}{10}$$

$$l = \frac{10 \times 1.964 \times 10^{-7}}{1.6 \times 10^{-8}}$$

$$l = \frac{122.7 \times 10^{-7+8}}{10}$$

$$l = \frac{10 \times 1964 \times 10^{-7}}{16 \times 10^{-8}} \times \frac{10}{1000}$$

$$l = \frac{122.7 \times 10}{10} = 122.7 \text{ m}$$

When diameter is doubled

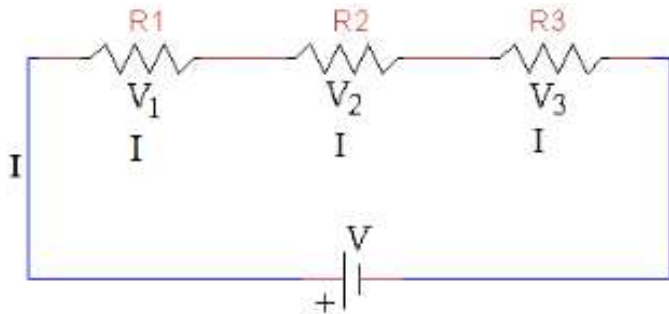
Radius also gets doubled i.e. new radius, $r' = 2r$

New area, $A' = \pi (r')^2 = \pi (2r)^2 = 4\pi r^2 = 4A$

Thus, new resistance, $R' = \rho \frac{l}{R} = \rho \frac{l}{4A} = \frac{1}{4} R$

Series and Parallel Combination of Resistors

SERIES



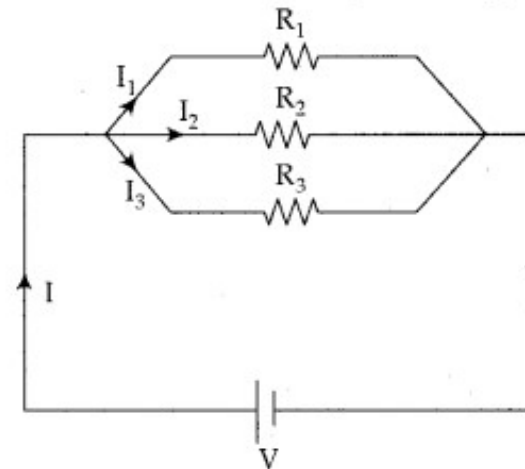
$$R = R_s = R_1 + R_2 + R_3$$

- Current is same in each resistor
- Potential difference is not same

$$\text{and } V = V_1 + V_2 + V_3$$

R = Net resistance or Equivalent resistance or Effective Resistance

PARALLEL

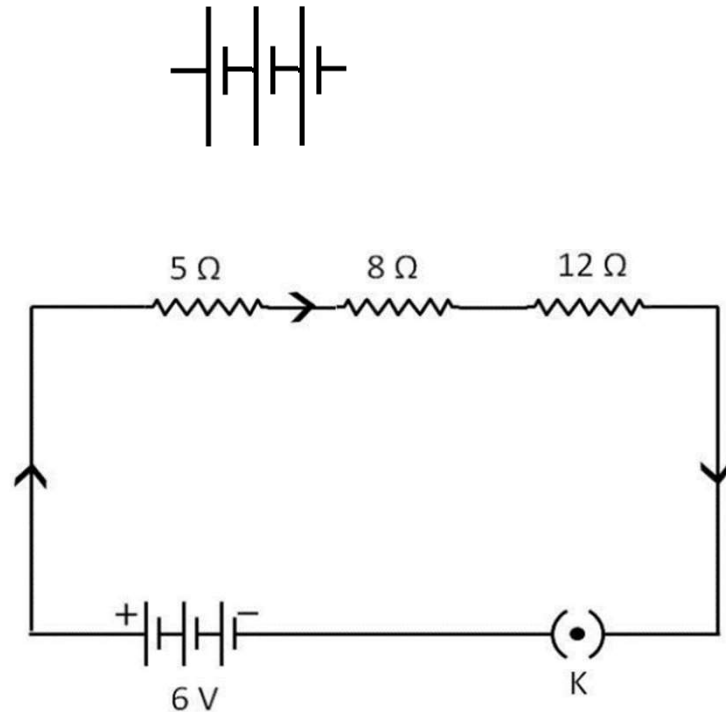


$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- Potential difference is same across each resistor
- Current is not same

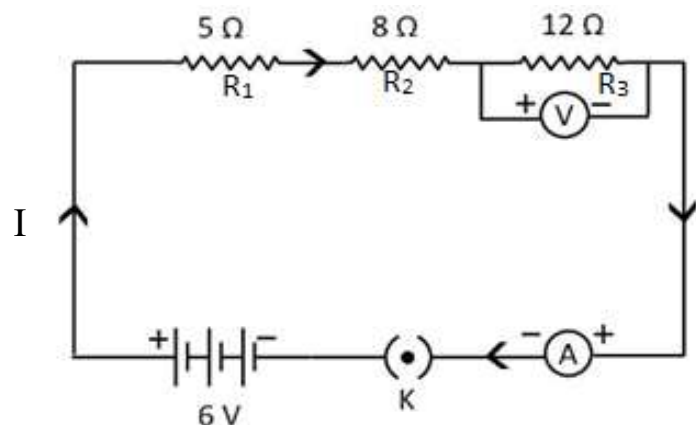
$$\text{and } I = I_1 + I_2 + I_3$$

Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.
(NCERT Page 213 Q1)



Redraw the circuit of Question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the $12\ \Omega$ resistor. What would be the readings in the ammeter and the voltmeter?

(NCERT Page 213 Q2)



For ammeter reading (Current, I)

Potential difference, $V = 6\text{ V}$

Resistance, $R = 25\ \Omega$

Using Ohm's law, $V = IR$

$$I = V/R$$

$$= 6/25 = 0.24\text{ A}$$

Concept Insight: In a series combination, current flowing through all the components of the circuit is same.

Resistors are in series, $R_s = 5\ \Omega + 8\ \Omega + 12\ \Omega = 25\ \Omega$

For voltmeter reading (potential difference across $12\ \Omega$ resistor)

Resistance, $R_3 = 12\ \Omega$

Current, $I = 0.24\text{ A}$

Using Ohm's law, $V = IR$

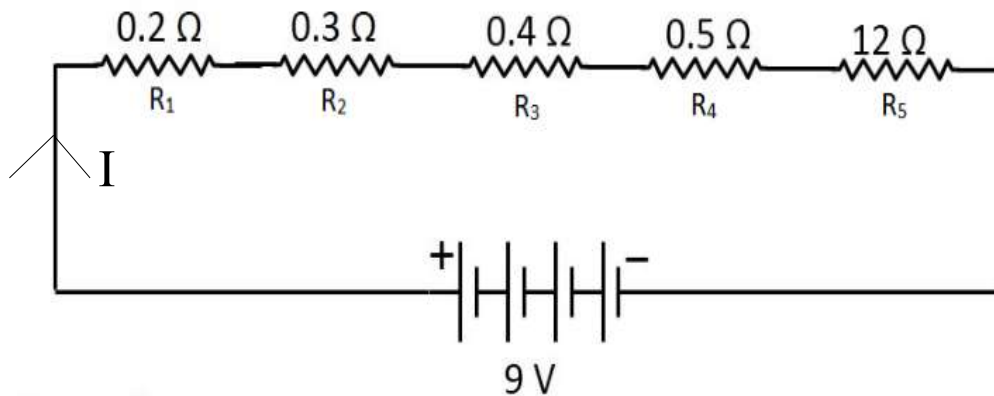
V across $12\ \Omega$, $V_3 = IR_3$

$$= 0.24 \times 12 = 2.88\text{ V}$$

A battery of 9 V is connected in series with resistors of $0.2\ \Omega$, $0.3\ \Omega$, $0.4\ \Omega$, $0.5\ \Omega$ and $12\ \Omega$, respectively. How much current would flow through the $12\ \Omega$ resistors? (NCERT Back Exercise Q9)

Concept Insight: In a series combination, current flowing through all the components of the circuit is same.

- So a current I i.e. total current in the circuit will flow through $12\ \Omega$ resistor.
- While calculating current, $I = V/R$ (R should be equivalent resistance R_s not R_5 ($12\ \Omega$))



Current through $12\ \Omega$ = current (I)

Potential difference, $V = 9\ \text{V}$

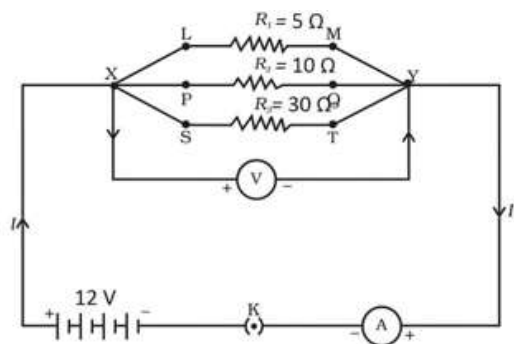
Resistance, $R = 13.4\ \Omega$

Using Ohm's law, $V = IR$

$$I = V/R = 9/13.4 = 0.24\ \text{A}$$

Resistors are in series, $R_s = 0.2 + 0.3 + 0.4 + 0.5 + 12 = 13.4\ \Omega$

In the circuit diagram given in Fig. 12.10, suppose the resistors R_1 , R_2 and R_3 have the values $5\ \Omega$, $10\ \Omega$, $30\ \Omega$, respectively, which have been connected to a battery of 12 V . Calculate (a) the current through each resistor, (b) the total current in the circuit, and (c) the total circuit resistance. (NCERT Page 214 Ex: 12.8)



(b) In parallel combination,

$$\begin{aligned}\text{Total current, } I &= I_1 + I_2 + I_3 \\ &= 2.4 + 1.2 + 0.4 = 4\text{ A}\end{aligned}$$

(c) In parallel connection,

Total resistance is given by

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

$$\frac{1}{R} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30}$$

$$\frac{1}{R} = \frac{6 + 3 + 1}{30}$$

$$\frac{1}{R} = \frac{10}{30}$$

$$R = \frac{30}{10} = 3\ \Omega$$

$$\begin{aligned}\text{OR } R &= \frac{V}{I} \\ R &= \frac{12}{4} = 3\ \Omega\end{aligned}$$

(a)

$$R_1 = 5\ \Omega$$

$$I_1 = \frac{V}{R_1}$$

$$= \frac{12}{5}$$

$$= 2.4\text{ A}$$

$$R_2 = 10\ \Omega$$

$$I_2 = \frac{V}{R_2}$$

$$= \frac{12}{10}$$

$$= 1.2\text{ A}$$

$$R_3 = 30\ \Omega$$

$$I_3 = \frac{V}{R_3}$$

$$= \frac{12}{30}$$

$$= 0.4\text{ A}$$

What is the total resistance of n resistors each of resistance R connected in (i)series and (ii)parallel?

Series combination:

Net resistance = $R + R + R + \dots n \text{ times}$

$$\Rightarrow \text{Net resistance} = n \times R = nR$$

Parallel combination:

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \dots n \text{ times}$$

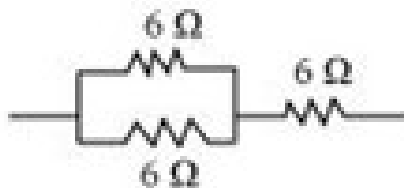
$$\Rightarrow \frac{1}{R_p} = \frac{n}{R}$$

$$\Rightarrow R_p = \frac{R}{n}$$

Show how you would connect three resistors, each of resistance $6\ \Omega$, so that the combination has a resistance of (i) $9\ \Omega$, (ii) $4\ \Omega$.

(NCERT Back Exercise Q11)

(i) $9\ \Omega$



Two $6\ \Omega$ resistors are connected in parallel.

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

$$R' = 3\ \Omega$$

The third $6\ \Omega$ resistor is in series with $3\ \Omega$

$$R = 6 + 3 = 9\ \Omega$$



(ii)



Two $6\ \Omega$ resistors are connected in series.

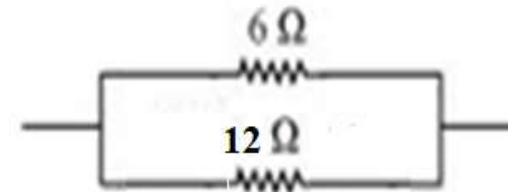
$$R' = 6 + 6 = 12\ \Omega$$

The third $6\ \Omega$ resistor is in parallel with $12\ \Omega$

$$\frac{1}{R} = \frac{1}{6} + \frac{1}{12}$$

$$= \frac{2}{12} + \frac{1}{12} = \frac{3}{12} = \frac{1}{4}$$

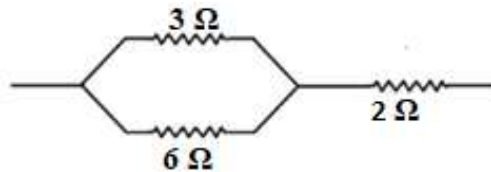
$$R = 4\ \Omega$$



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

(NCERT Page 216 Q4)

(a) $4\ \Omega$



$3\ \Omega$ and $6\ \Omega$ are connected in parallel

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

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

$$\frac{1}{R_p} = \frac{3}{6}$$

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

$$R_p = 2\ \Omega$$

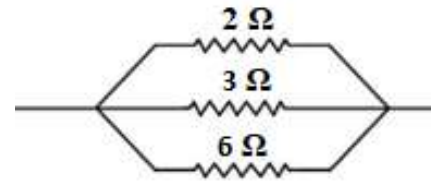


R_p and $2\ \Omega$ are in series

$$R = R_p + R_1$$

$$R = 2 + 2 = 4\ \Omega$$

(b) $1\ \Omega$



$2\ \Omega$, $3\ \Omega$ and $6\ \Omega$ are connected in parallel

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

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

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

$$R = 1\ \Omega$$

A piece of wire of resistance R is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R' , then the ratio R/R' is –

- (a) $1/25$ (b) $1/5$ (c) 5 (d) 25**

(NCERT Back Exercise Q1)

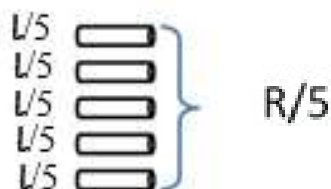


$$R = \rho \frac{L}{A}$$

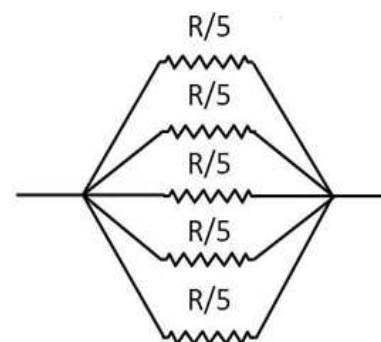
$R \propto L$ (On cutting the wire, Area of cross section of each part and resistivity remains constant)

So new length, $L' = L/5$

Therefore, resistance of each part of wire is $R/5$



All these 5 parts are now connected in parallel



For parallel combination, equivalent resistance R' is given by

$$\frac{1}{R'} = \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5}$$

$$\frac{1}{R'} = \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} = \frac{5+5+5+5+5}{R}$$

$$\frac{1}{R'} = \frac{25}{R}$$

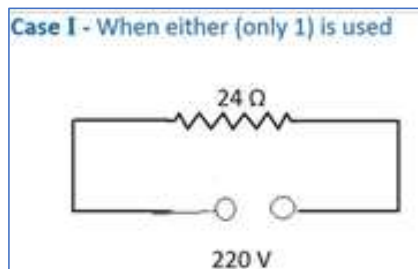
$$\frac{R}{R'} = 25$$

Therefore, the ratio $\frac{R}{R'}$ is 25.

A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of $24\ \Omega$ resistance, which may be used separately, in series, or in parallel. What are the currents in the three cases?

(NCERT Back Exercise Q13)

Potential difference, $V = 220\text{V}$



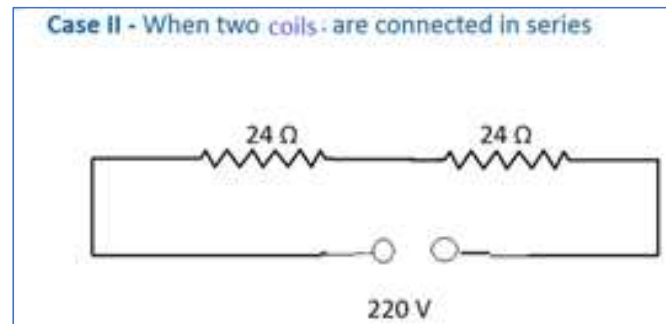
Using Ohm's law

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

$$I = \frac{220}{24}$$

$$I = \frac{55}{6}$$

$$I = 9.2\text{ A}$$



In series combination

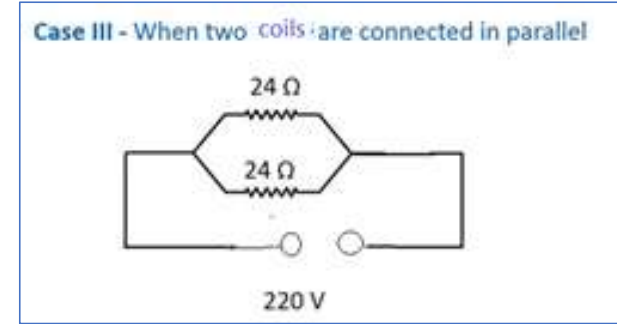
$$R_s = R_1 + R_2$$

$$R_s = 24 + 24$$

$$R_s = 48\ \Omega$$

Using Ohm's law

$$\text{Now, } I = \frac{V}{R_s} = \frac{220}{48} = 4.6\text{ A}$$



In parallel combination

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

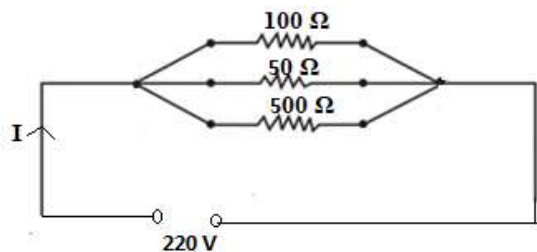
$$\frac{1}{R_p} = \frac{1}{24} + \frac{1}{24} = \frac{2}{24} = \frac{1}{12}$$

$$R_p = 12\ \Omega$$

Using Ohm's law

$$\text{Now, } I = \frac{V}{R_p} = \frac{220}{12} = 18.3\text{ A}$$

An electric lamp of $100\ \Omega$, a toaster of resistance $50\ \Omega$, and a water filter of resistance $500\ \Omega$ are connected in parallel to a $220\ \text{V}$ source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?
(NCERT Page 216 Q2)



In parallel combination:

$$\begin{aligned}\frac{1}{R} &= \frac{1}{100} + \frac{1}{50} + \frac{1}{500} \\ &= \frac{5+10+1}{500} = \frac{16}{500} \\ R &= \frac{500}{16}\ \Omega\end{aligned}$$

Using Ohm's law

$$\begin{aligned}I &= V/R \\ I &= \frac{220}{\frac{500}{16}} \\ &= 220 \div \frac{500}{16} \\ &= \frac{220 \times 16}{500} \\ &= \frac{3520}{500} \\ \therefore I &= 7.04\ \text{A}\end{aligned}$$

7.04 A of current is drawn by all the three given appliances.

Therefore, current drawn by an electric iron to the same voltage source of $220\ \text{V}$ is $7.04\ \text{A}$.

Let R' be the resistance of electric iron.

Using Ohm's law

$$\begin{aligned}V &= IR' \\ R' &= \frac{V}{I} \\ &= \frac{220}{7.04} = 31.25\ \Omega\end{aligned}$$

The upcoming numericals are based on:

PHYSICAL QUANTITY (SYMBOL)	FORMULA	S.I UNIT
Power (P)	$P = \frac{\text{Energy}}{\text{time}} = \frac{E}{t} \text{ or } \frac{H}{t}$ $P = I^2 R = V I = \frac{V^2}{R}$	Watt (W)
Heat (H)	$H = I^2 R t = V I t = \frac{V^2 t}{R}$	Joule (J)
Energy (E)	$E = P \times t$ $1 \text{ J} = 1 \text{ W} \times 1 \text{ s}$	Joule (J) or watt sec (Ws)
Commercial unit of Energy (E)	$E = P \times t$ $1 \text{ kWh} = 1 \text{ kW} \times 1 \text{ h}$ $1 \text{ kW h} = 3.6 \times 10^6 \text{ J}$	Kilowatt hour (kWh)

An electric iron of resistance $20\ \Omega$ takes a current of 5 A . Calculate the heat developed in 30 s . (NCERT Page 218 Q3)

Resistance, $R = 20\ \Omega$

Current, $I = 5\text{ A}$

Time, $t = 30\text{ s}$

Using Joule's law of heating:

$$H = I^2 R t = V I t = \frac{V^2 t}{R}$$

$$H = I^2 R t$$

$$= (5)^2 \times 20 \times 30$$

$$= 15000\text{ J} = 1.5 \times 10^4\text{ J}$$

Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential difference of 50 V.
(NCERT Page 218 Q2)

Charge, $Q = 96000 \text{ C}$

Time, $t = 1 \text{ h}$

$$= 1 \times 60 \times 60 \text{ s}$$

Potential energy, $V = 50 \text{ V}$

$$\text{Current, } I = \frac{Q}{t}$$

$$= \frac{96000}{1 \times 60 \times 60} = \frac{80}{3} \text{ A}$$

$$H = VIt$$

$$H = 50 \times \frac{80}{3} \times 60 \times 60$$

$$= 4.8 \times 10^6 \text{ J}$$

$$H = I^2 R t = V I t = \frac{V^2 t}{R}$$

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 (NCERT Back Exercise Q4)

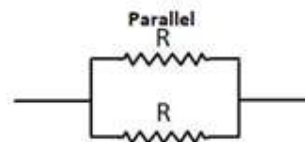
Both the wires have the same resistance because they are made of the same material and have equal lengths and diameters. Let the resistance be R .



$$\begin{aligned} R_s &= R_1 + R_2 \\ &= R + R \\ &= 2R \end{aligned}$$

Let the current through the series combination be I_s and heat produced in the circuit be H_s

$$\begin{aligned} H_s &= I_s^2 R_s t \\ &= \left(\frac{V}{2R} \right)^2 2R t \\ H_s &= \frac{V^2 t}{2R} \quad \text{--- (i)} \end{aligned}$$



$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R_p} &= \frac{1}{R} + \frac{1}{R} \\ \frac{1}{R_p} &= \frac{2}{R} \\ R_p &= \frac{R}{2} \end{aligned}$$

Let the current through the series combination be I_p and heat produced in the circuit be H_p

$$\begin{aligned} H_p &= I_p^2 R_p t = \left(\frac{V}{R/2} \right)^2 \frac{R}{2} t \\ H_p &= \frac{2V^2 t}{R} \quad \text{--- (ii)} \end{aligned}$$

$$\text{Hence, required ratio is } \frac{H_s}{H_p} = \frac{\frac{V^2 t}{2R}}{\frac{2V^2 t}{R}} = \frac{V^2 t}{2R} \times \frac{R}{2V^2 t} = \frac{1}{4}$$

Therefore, the ratio of heat produced in series and parallel combination is 1:4.

An electric heater of resistance $8\ \Omega$ draws $15\ \text{A}$ from the service mains in $2\ \text{h}$. Calculate the rate at which heat is developed in the heater.
(NCERT Back Exercise Q17)

Resistance, $R = 8\ \Omega$

Current, $I = 15\ \text{A}$

Time, $t = 2\ \text{h}$

Rate at which heat is produced = $\frac{\text{Heat}}{\text{time}}$ or $\frac{\text{Energy}}{\text{time}} = \text{Power}$

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

$$P = I^2R$$

$$= (15)^2 \times 8$$

$$= 1800\ \text{J/s or}$$

$$= 1800\ \text{W}$$

An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

(NCERT Page 220 Q2)

Current, $I = 5 \text{ A}$

Potential Difference, $V = 220 \text{ V}$

Time, $t = 2 \text{ h}$

$$= 2 \times 60 \times 60 = 7200 \text{ s}$$

Power, $P = ?$

Energy, $E = ?$

$$P = V I$$

$$= 220 \times 5 = 1100 \text{ W}$$

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

Energy consumed by the motor, $E = \text{Power} \times \text{time} = P t$

$$= 1100 \text{ W} \times 7200 \text{ s} = 7.92 \times 10^6 \text{ J}$$

An electric oven of 2 kW power rating is operated in a domestic electric circuit which has a current rating 5A. If the supply voltage is 220V, what result do you expect? Explain.

Power, $P = 2 \text{ kW}$

$$1 \text{ kW} = 1000 \text{ W}$$

$$= 2 \times 1000 \text{ W} = 2000 \text{ W}$$

Potential Difference, $V = 220 \text{ V}$

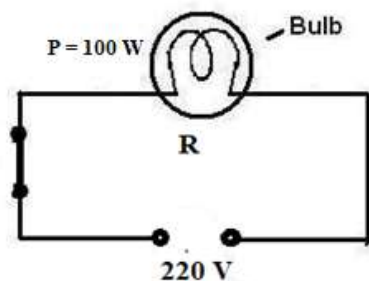
$$P = V \times I$$

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

$$= \frac{2000}{220} = 9.09 \text{ A}$$

Current drawn is very high (9.09A) but the fuse is only of 5A. The fuse wire will melt due to overloading and cut off the power supply in this circuit.

An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be – (a) 100 W (b) 75 W (c) 50 W (d) 25 W
(NCERT Back Exercise Q3)



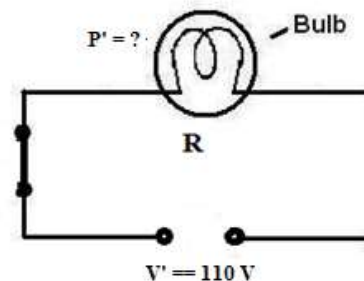
Potential difference, $V = 220 \text{ V}$

Power, $P = 100 \text{ W}$

Resistance, $R = ?$

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

$$R = \frac{V^2}{P} = \frac{(220)^2}{100} = 484 \Omega$$



If the supply voltage is reduced to 110 V, the resistance of the bulb remains.

Potential difference, $V' = 110 \text{ V}$

Resistance, $R = 484 \Omega$

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

$$= \frac{(110)^2}{484} = 25 \text{ W}$$

Therefore, the power consumed will be 25 W (d).

Which uses more energy, a 250 W TV set in 1 hr, or a 1200 W toaster in 10 minutes?

(NCERT Back Exercise Q16)

TV set

Power, $P_1 = 250 \text{ W}$

time, $t_1 = 1 \text{ h}$

$$= 1 \times 3600 \text{ s} = 3600 \text{ s}$$

$$\text{Energy} = P_1 \times t_1$$

$$= 250 \times 3600$$

$$= 900000 \text{ J}$$

$$= 9 \times 10^5 \text{ J}$$

Toaster

Power, $P_2 = 1200 \text{ W}$

time, $t_2 = 10 \text{ min}$

$$= 10 \times 60 \text{ s} = 600 \text{ s}$$

$$\text{Energy} = P_2 \times t_2$$

$$= 1200 \times 600$$

$$= 720000 \text{ J}$$

$$= 7.2 \times 10^5 \text{ J}$$

$\therefore$ Energy consumed by TV is more.

An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs 3.00 per kW h?
(NCERT Page 219 Ex 12.13)

$$\begin{aligned}\text{Power, } P &= 400 \text{ W} \\ &= \frac{400}{1000} \text{ kW} = 0.4 \text{ kW}\end{aligned}$$

Time to consume energy in one day, $t = 8 \text{ h}$

$$\begin{aligned}\text{Energy consumed in one day, } E_{1 \text{ days}} &= P \times t \\ &= 0.4 \text{ kW} \times 8 \text{ h} = 3.2 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\text{Energy consumed in 30 days, } E_{30 \text{ days}} &= 3.2 \text{ kWh} \times 30 \\ &= 96 \text{ kWh}\end{aligned}$$

$$\text{Cost of 1 kWh} = \text{Rs. } 3$$

$$\text{Cost of 96 kWh} = 96 \times 3 = \text{Rs. } 288$$

How many $176\ \Omega$ resistors (in parallel) are required to carry 5 A on a 220 V line? (NCERT Back Exercise Q10)

Current, $I = 5\text{ A}$

Potential difference, $V = 220\text{ V}$

Resistance of each resistor, $R = 176\ \Omega$

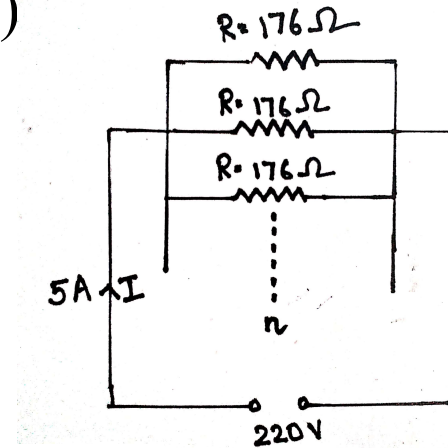
We need to find equivalent resistance R_p such that current of 5 A flows when potential difference of 220 V is applied.

Using Ohm's law

$$V = I R_p$$

$$R_p = \frac{V}{I} = \frac{220}{5} = 44\ \Omega$$

Let n resistors are connected in parallel



In parallel combination,

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \dots \dots n \text{ (times)}$$

$$\frac{1}{44} = \frac{1}{176} + \frac{1}{176} + \frac{1}{176} + \dots \dots n \text{ (times)}$$

$$\frac{1}{44} = n \times \frac{1}{176}$$

$$n = \frac{176}{44} = \frac{44}{11}$$

$$n = 4$$

Check

$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \\ &= \frac{1}{176} + \frac{1}{176} + \frac{1}{176} + \frac{1}{176} \\ &= \frac{4}{176} = \frac{1}{44} \\ R_p &= 44 \end{aligned}$$

Several electric bulbs designed to be used on a 220 V electric supply line, are rated 10 W. How many lamps can be connected in parallel with each other across the two wires of 220 V line if the maximum allowable current is 5 A? `
(NCERT Back Exercise Q12)

Potential difference, $V = 220 \text{ V}$

Power of each bulb, $P = 10 \text{ W}$

Current, $I = 5 \text{ A}$

Let R be resistor of each bulb

We know, $P = \frac{V^2}{R}$ (where)

R

$R = \frac{V^2}{P} = \frac{(220)^2}{10} = 4840 \Omega$

$P = 10$

Resistor of each bulb, $R = 4840 \Omega$

We need to find equivalent resistance R_p such that current of 5A flows when potential difference of 220V is applied.

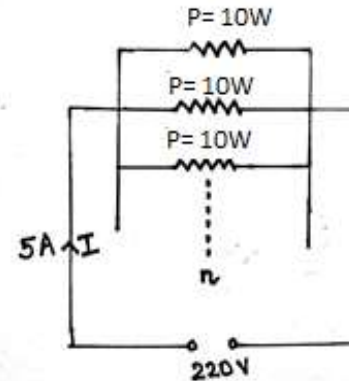
Using Ohm's law

$V = I R_p$

$R_p = \frac{V}{I} = \frac{220}{5} = 44 \Omega$

$I = 5$

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



Let n resistors are connected in parallel

In parallel combination,

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \dots \dots n \text{ (times)}$$

$$\frac{1}{R_p} = \frac{1}{4840} + \frac{1}{4840} + \frac{1}{4840} + \dots \dots (n \text{ times})$$

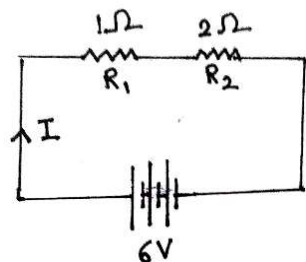
$$\frac{1}{44} = n \times \frac{1}{4840}$$

$$n = \frac{4840}{44} = \frac{1210}{11}$$

$$n = 110$$

Compare the power used in the $2\ \Omega$ resistor in each of the following circuits:

(i) a 6 V battery in series with $1\ \Omega$ and $2\ \Omega$ resistors, and (ii) a 4 V battery in parallel with $12\ \Omega$ and $2\ \Omega$ resistors.
(NCERT Back Exercise Q14)



(i) Potential difference, $V = 6\text{ V}$

$$R_1 = 1\ \Omega, R_2 = 2\ \Omega$$

$$\begin{aligned}\text{In series, } R_s &= R_1 + R_2 \\ &= 1 + 2 = 3\ \Omega\end{aligned}$$

In series combination current through each individual resistor is same as the current through circuit.

Using Ohm's law

$$V = IR$$

$$I = \frac{V}{R_s} = \frac{6}{3} = 2\text{ A}$$

To find power P_2 in resistor R_2

Current, I through $R_2 = 2\text{ A}$

Resistance, $R_2 = 2\ \Omega$

$$\begin{aligned}P_2 &= I^2 R_2 \\ &= (2)^2 \times 2 \\ &= 8\text{ W}\end{aligned}$$

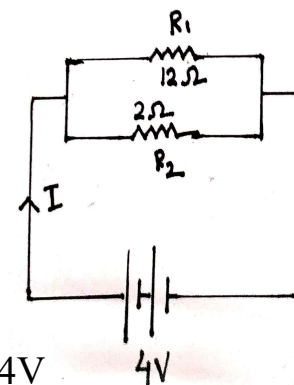
$$P = VI = \frac{V^2}{R} = I^2 R$$

(ii) Potential difference, $V = 4\text{ V}$

$$R_1 = 12\ \Omega, R_2 = 2\ \Omega$$

In parallel combination potential difference across each resistor is same as the total potential difference in the circuit.

Hence, potential difference across R_2 is 4 V



To find power P_2 in resistor R_2

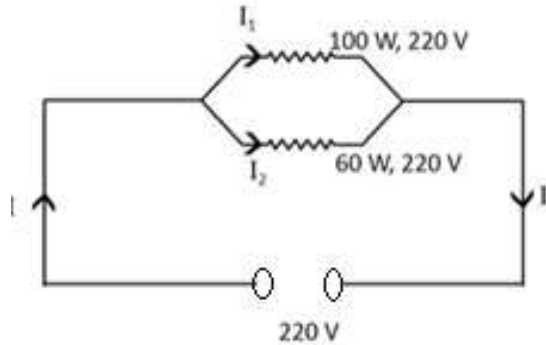
Potential difference, $V = 4\text{ V}$

Resistance, $R_2 = 2\ \Omega$

$$\begin{aligned}P_2 &= \frac{V^2}{R_2} \\ &= \frac{(4)^2}{2} = 8\text{ W}\end{aligned}$$

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

Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply. What current is drawn from the line if the supply voltage is 220 V? (NCERT Back Ex Q15)



Potential difference, $V = 220 \text{ V}$

Power of lamp 1 = $P_1 = 100 \text{ W}$

Power of lamp 2 = $P_2 = 60 \text{ W}$

In parallel combination current gets divided among the resistors, and net current $I = I_1 + I_2$

We know, $P = VI$

So, $I = \frac{P}{V}$

Lamp 1

$$I_1 = \frac{P_1}{V}$$

$$I_1 = \frac{100}{220}$$

$$I_1 = \frac{10}{22}$$

$$I_1 = \frac{5}{11} \text{ A}$$

Lamp 2

$$I_2 = \frac{P_2}{V}$$

$$I_2 = \frac{60}{220}$$

$$I_2 = \frac{6}{22}$$

$$I_2 = \frac{3}{11} \text{ A}$$

Net Current, $I = ?$

$$I = I_1 + I_2$$

$$I = \frac{5}{11} + \frac{3}{11}$$

$$I = \frac{8}{11}$$

$$I = 0.73 \text{ A}$$