Numerical Problems

Important formulas

- **Electric Current** $Current = \frac{Charge}{Time} \Rightarrow I = \frac{Q}{t}$
- **Ohm's Law** $V = IR$
- **Electric Power** $Electric\ power = \frac{electric\ energy}{time}$

$$\Rightarrow P = \frac{W}{t}\ or\ P = I^2R\ or\ P = IV$$

- **Electrical Energy** $W = QV$
- **Joule's Law (Energy Supplied By Q Charge)**

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

- **Equivalent Resistance of Series Circuit**

$R_e = R_1 + R_2$

- **Equivalent Resistance of Parallel Circuit**

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

- **The amount of energy in kilowatt-hour**

$$Energy\ in\ kWh = \frac{Power(Watt) \times time\ (hours)}{1000}$$

- **Electricity price**

$$E.P = \frac{Power(Watt) \times time\ (hours) \times (unit\ price)}{1000}$$

- **Monthly bill**

Bill$= \frac{Power(Watt) \times time\ (hours) \times (unit\ price) \times 30}{1000}$

14.1. A current of 3mA is flowing through a wire for 1 minute. What is the charge flowing through the wire? *(ALP)*

Given Data

$$Current = I = 3\ mA$$
$$I = 3 \times 10^{-3}\ A$$
$$Time = t = 1\ min.$$
$$t = 60\ s$$

To Find

$$charge = Q = ?$$

Solution

By using formula of current

$$I = \frac{Q}{t}$$
$$Q = It$$
$$Q = (3 \times 10^{-3})(60)$$
$$\boldsymbol{Q = 0.18\ C = 180 \times 10^{-3}\ C}$$

14.2. At$100,000\ \Omega$, how much current flows through your body if you touch the terminals of a $12\ V$ battery? If your skin is wet, so that your resistance is only $1000\ \Omega$, how much current would your receive from the same battery? *(ALP)*

Given Data

$$Dry\ skin\ resistance = R_1 = 100{,}000\ \Omega$$
$$Wet\ skin\ resistance = R_2 = 1000\ \Omega$$
$$Voltage = V = 12\ V$$

To Find

$$Current\ through\ dry\ skin = I_1 = ?$$
$$Current\ through\ wet\ skin = I_2 = ?$$

Solution

By using ohm's law

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

For dry skin

$$I_1 = \frac{V}{R_1}$$
$$I_1 = \frac{12}{100{,}000}$$
$$\boldsymbol{I_1 = 1.2 \times 10^{-4}\ A}$$

For wet skin

$$I_2 = \frac{V}{R_2}$$
$$I_2 = \frac{12}{1000}$$
$$\boldsymbol{I_2 = 1.2 \times 10^{-2}\ A}$$

14.3. The resistance of a conductor wire is $10\ M\Omega$. If a potential difference of $100\ volts$ is applied across its ends, then find the value of current passing through it in mA. *(ALP)*

Given Data

$$Resistance = R = 10\ M\Omega$$
$$R = 10 \times 10^6\ \Omega$$
$$Potential\ difference = V = 100\ V$$

To Find

$$Current = I = ?$$

Solution

By using ohm's law

$$V = IR$$
$$I = \frac{V}{R}$$
$$I = \frac{100}{10 \times 10^6}$$
$$I = 1 \times 10^{-5}\ A$$
$$I = 10^{-2} \times 10^{-3}\ A$$
$$I = 10^{-2}\ mA$$
$$\boldsymbol{I = 0.01\ mA}$$

14.4. By applying a potential difference of $10\ V$ across a conductor, a current of $1.5\ A$ passes through it. How much energy would be obtained from the current in $minutes$? *(ALP)*

Given Data

$$Potential\ difference = V = 10\ V$$
$$Current = I = 1.5\ A$$
$$time = t = 2\ min$$
$$t = 2 \times 60\ s$$
$$t = 120\ s$$

To Find

$$Energy = W = ?$$

Solution

By using joule's law

$$W = I^2Rt$$
$$W = I(IR)t$$
$$W = I(V)t$$
$$W = (1.5)(10)(120)$$
$$\boldsymbol{W = 1800\ J}$$

14.5. Two resistances of $2\ k\Omega$ and $8\ k\Omega$ are joined in series, if a $10\ V$ battery is connected across the ends of this combination, find the following quantities: *(ALP)*

(i) The equivalent resistance of the series combination.

(ii) Current passing through each of the resistances.

(iii) The potential difference across each resistance.

Given Data

$$R_1 = 2\ k\Omega$$
$$R_2 = 8\ k\Omega$$
$$V = 10\ V$$

To Find

$$R_{eq} = ?$$
$$I_1 = ?, \quad I_2 = ?$$
$$V_1 = ?, \quad V_2 = ?$$

Solution

By using formula of equivalent resistance for series combination

$$R_{eq} = R_1 + R_2$$
$$R_{eq} = 2\ k\Omega + 8\ k\Omega$$
$$\boldsymbol{R_{eq} = 10\ k\Omega}$$

Current will be same for each resistance in series combination, so $I = I_1 = I_2$

$$I = \frac{V}{R_{eq}}$$
$$I = \frac{10\ V}{10\ k\Omega}$$
$$I = \frac{10\ V}{10 \times 10^3\ \Omega}$$
$$I = 1 \times 10^{-3}\ A$$
$$\boldsymbol{I = 1\ mA}$$

Potential difference across 1st resistance

$$V_1 = I_1 R_1$$
$$V_1 = (1\ mA)(2\ k\Omega)$$
$$V_1 = (1 \times 10^{-3} A)(2 \times 10^3\ \Omega)$$
$$\boldsymbol{V_1 = 2\ V}$$

Potential difference across 2nd resistance

$$V_2 = I_2 R_2$$
$$V_2 = (1\ mA)(8\ k\Omega)$$
$$V_2 = (1 \times 10^{-3} A)(8 \times 10^3\ \Omega)$$
$$\boldsymbol{V_2 = 8\ V}$$

14.6. Two resistances of $6\ k\Omega$ and $12\ k\Omega$ are connected in parallel. A $6\ V$ battery is connected across its ends; find the values of the following quantities: *(ALP)*

(i) Equivalent resistance of the parallel combination.

(ii) Current passing through each of the resistances.

(iii) Potential difference across each of the resistance.

Given Data

$$R_1 = 6\ k\Omega$$
$$R_2 = 12\ k\Omega$$
$$V = 6\ V$$

To Find

$$R_{eq} = ?$$
$$I_1 = ?, \quad I_2 = ?$$
$$V_1 = ?, \quad V_2 = ?$$

Solution

By using formula of equivalent resistance for parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\frac{1}{R_{eq}} = \frac{1}{6k\Omega} + \frac{1}{12k\Omega}$$
$$\frac{1}{R_{eq}} = \frac{2+1}{12k\Omega}$$
$$\frac{1}{R_{eq}} = \frac{3}{12k\Omega}$$
$$\frac{1}{R_{eq}} = \frac{1}{4k\Omega}$$
$$\boldsymbol{R_{eq} = 4\ k\Omega}$$

As we know potential difference (voltage) will be same for each resistance in parallel combination, so

$$\boldsymbol{V = V_1 = V_2 = 6\ V}$$

Current through 1st resistance

$$I_1 = \frac{V_1}{R_1}$$
$$I_1 = \frac{6\ V}{6\ k\Omega}$$
$$I_1 = \frac{6\ V}{6 \times 10^3\ \Omega}$$
$$I_1 = 1 \times 10^{-3}\ A$$
$$\boldsymbol{I_1 = 1\ mA}$$

Current through 2nd resistance

$$I_2 = \frac{V_2}{R_2}$$
$$I_2 = \frac{6\ V}{12\ k\Omega}$$
$$I_2 = \frac{6\ V}{12 \times 10^3\ \Omega}$$
$$I_2 = 0.5 \times 10^{-3}\ A$$
$$\boldsymbol{I_2 = 0.5\ mA}$$

14.7. An electric bulb is marked with $220\ V, 100\ W$. Find the resistance of the filament of the bulb. If the bulb is used $5\ hours$ daily, find the energy in kilowatt-hour consumed by the bulb in one month ($30\ days$). *(ALP)*

Given Data

$$Voltage\ of\ bulb = V = 220\ V$$
$$Power = P = 100\ W$$
$$Daily\ use\ of\ bulb = t = 5\ h$$
$$No.\ of\ days = 30\ days$$

To Find

$$Resistance\ of\ bulb = R = ?$$
$$Energy\ in\ kWh = E = ?$$

Solution

By using formula of power

$$P = I^2 R$$

$$P = \left(\frac{V}{R}\right)^2 \times R \qquad \because I = \frac{V}{R}$$
$$P = \frac{V^2}{R^2} \times R$$
$$P = \frac{V^2}{R}$$
$$R = \frac{V^2}{P}$$
$$R = \frac{(220)^2}{100}$$
$$\boldsymbol{R = 484\ \Omega}$$

Total time in 30 days

$$time\ taken = 30 \times 5 = 150\ hours$$

By using formula of energy in kWh

$$Energy\ in\ kWh = \frac{Power(Watt) \times time\ (hours)}{1000}$$
$$Energy\ in\ kWh = \frac{100\ watt \times 150\ h}{1000}$$
$$\boldsymbol{Energy\ in\ kWh = 15\ kWh}$$

14.8. An incandescent light bulb with an operating resistance of $95\ \Omega$ is labeled "$150\ W$." Is this bulb designed for use in a $120\ V$ circuit or a $220\ V$ circuit?

Given Data

$$Resistance = R = 95\ \Omega$$
$$Power = P = 150\ W$$

To Find

$$Voltage = V = ?$$

Solution

By using formula of power

$$P = \frac{V^2}{R}$$
$$V^2 = P \times R$$
$$V^2 = 150 \times 95$$
$$V^2 = 14250$$
$$\sqrt{V^2} = \sqrt{14250}$$
$$V = 119.3\ V$$
$$\boldsymbol{V \approx 120\ V}$$

This bulb is designed for $120\ V$

14.9. A house is installed with

(a) 10 bulbs of 60 W each of which are used 5 hours daily.
(b) 4 fans of 75 W each of which run 10 hours daily.
(c) One T.V. of 100 W which is used for 5 hours daily.
(d) One electric iron of 1000 W which is used for 2 hours daily.

If the cost of one unit of electricity is Rs.4. Find the monthly expenditure of electricity (one month =30 days).

Given Data

$Power\ of\ 10\ bulb$	=	$60\ W \times 10$	=	$600\ W$	t	= $5\ h$
$Power\ of\ 4\ fans$	=	$75\ W \times 4$	=	$300\ W$	t	= $10\ h$
$Power\ of\ 1\ T.V$	=	$100\ W \times 1$	=	$100\ W$	t	= $5\ h$
$Power\ of\ 1\ iron$	=	$1000\ W \times 1$	=	$1000\ W$	t	= $2\ h$
$One\ unit\ price$	=	$Rs.4$				

To Find

$$Monthly\ cost\ of\ electricity\ (30\ days) = ?$$

Solution

$$Monthly\ electricity\ cost\ of\ bulb = \frac{Power(W) \times time\ (h) \times (\ price) \times 30}{1000}$$
$$= \frac{600 \times 5 \times 4 \times 30}{1000}$$
$$= 360\ Rs.$$

$$Monthly\ electricity\ cost\ of\ fans = \frac{Power(W) \times time\ (h) \times (\ price) \times 30}{1000}$$
$$= \frac{300 \times 10 \times 4 \times 30}{1000}$$
$$= 360\ Rs.$$

$$Monthly\ electricity\ cost\ of\ T.V = \frac{Power(W) \times time\ (h) \times (price) \times 30}{1000}$$
$$= \frac{100 \times 5 \times 4 \times 30}{1000}$$
$$= 60\ Rs.$$

$$Monthly\ electricity\ cost\ of\ iron = \frac{Power(W) \times time\ (h) \times (price) \times 30}{1000}$$
$$= \frac{1000 \times 2 \times 4 \times 30}{1000}$$
$$= 240\ Rs.$$

$$Monthly\ cost\ of\ electricity = 360 + 360 + 60 + 240$$
$$= \boldsymbol{1020\ Rs.}$$

14.10. A $100\ W$ lamp bulb and a $4\ kW$ water heater are connected to a $250\ V$ supply. Calculate

(a) The current which flows in each appliance
(b) The resistance of each appliance when in use.

Given Data

$$Power\ of\ bulb = P_1 = 100\ W$$
$$Power\ of\ water\ heater = P_2 = 4\ kW$$
$$P_2 = 4 \times 10^3\ W$$
$$Voltage = V = 250\ V$$

To Find

(a) $I_1 = ?$ $\qquad I_2 = ?$
(b) $R_1 = ?$ $\qquad R_2 = ?$

Solution

Current in lamp

$$P_1 = I_1 V$$
$$I_1 = \frac{P_1}{V}$$
$$I_1 = \frac{100}{250}$$
$$\boldsymbol{I_1 = 0.4\ A}$$

Current in heater

$$P_2 = I_2 V$$
$$I_2 = \frac{P_2}{V}$$
$$I_2 = \frac{4 \times 10^3}{250}$$
$$\boldsymbol{I_2 = 16\ A}$$

Resistance in lamp

$$V = I_1 R_1$$
$$R_1 = \frac{V}{I_1}$$
$$R_1 = \frac{250}{0.4}$$
$$\boldsymbol{R_1 = 625\ \Omega}$$

Resistance in heater

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

$$R_2 = \frac{250}{16}$$
$$\boldsymbol{R_2 = 15.6\ \Omega}$$

14.11. A resistor of resistance $5.6\ \Omega$ is connected across a battery of $3.0\ V$ by means of a wire of negligible resistance. A current of $0.5\ A$ passes through the resistor. Calculate

(a) Power dissipated in the resistor.

(b) Total power produced by the battery.

(c) Give the reason of difference between these two quantities.

Given Data

$$Resistance\ of\ resistor = R = 5.6\ \Omega$$
$$Voltage = V = 3.0\ V$$
$$Current = I = 0.5\ A$$

To Find

$$Power\ dissipated = P_d = ?$$
$$Power\ of\ battery = P = ?$$

Solution

For power dissipated, we use

$$P_d = I^2R$$
$$P_d = (0.5)^2(5.6)$$
$$\boldsymbol{P_d = 1.4\ W}$$

For battery power, we use

$$P = IV$$
$$P = (0.5)(3.0)$$
$$\boldsymbol{P = 1.5\ W}$$

A little amount of power is lost due to internal resistance of battery.

Examples

14.1 If $0.5\ C$ charge passes through a wire in $10\ s$, then what will be the value of current flowing through the wire? *(ALP)*

Given Data

$$Charge = Q = 0.5\ C$$
$$Time = t = 10\ s$$

To Find

$$Current = I = ?$$

Solution

By using formula of current

$$I = \frac{Q}{t}$$
$$I = \frac{0.5}{10}$$
$$I = 0.05\ A$$
$$I = 50 \times 10^{-3}\ A$$
$$\boldsymbol{I = 50\ mA}$$

14.2 Reading on voltmeter connected across a heating element is $60\ V$. The amount of current passing through the heating element measured by an ammeter is $2\ A$. What is the resistance of the heating coil of the element? *(ALP)*

Given Data

$$Voltage = V = 60\ V$$
$$Current = I = 2\ A$$

To Find

$$Resistance = R = ?$$

Solution

By using ohm's law

$$V = IR$$
$$60 = (2)(R)$$
$$\frac{60}{2} = R$$
$$30 = R$$
$$\boldsymbol{R = 30\ \Omega}$$

14.3 If the length of copper wire is $1\ m$ and its diameter is $2\ mm$, then find the resistance of this copper wire.

Given Data

$$Length = L = 1\ m$$
$$Diameter = d = 2\ mm$$
$$Radius = r = \frac{2\ mm}{2}$$
$$r = 1\ mm$$
$$r = 1 \times 10^{-3} m$$
$$Specific\ resistance\ of\ copper = \rho = 1.69 \times 10^{-8} \Omega m$$

To Find

$$Resistance = R = ?$$

Solution

First, we find cross sectional area of the wire

$$A = \pi r^2$$
$$A = (3.14)(1 \times 10^{-3})^2$$
$$A = 3.14 \times 10^{-6}\ m^2$$

Now, for resistance

$$R = \frac{\rho L}{A}$$
$$R = \frac{(1.69 \times 10^{-8})(1)}{3.14 \times 10^{-6}}$$
$$\boldsymbol{R = 5.4 \times 10^{-3}\ \Omega}$$

14.4 If two resistors of $6\ k\Omega$ and $4\ k\Omega$ are connected in series across a $10\ V$ battery, then find the following quantities: *(ALP)*

(a) Equivalent resistance of the series combination.

(b) The current flowing through each of the resistance.

(c) Potential difference across each of the resistances.

Given Data

$$R_1 = 6\ k\Omega$$
$$R_2 = 4\ k\Omega$$
$$V = 10\ V$$

To Find

$$R_{eq} = ?$$
$$I_1 = ?, \quad I_2 = ?$$
$$V_1 = ?, \quad V_2 = ?$$

Solution

By using formula of equivalent resistance for series combination

$$R_{eq} = R_1 + R_2$$
$$R_{eq} = 6\ k\Omega + 4\ k\Omega$$
$$\boldsymbol{R_{eq} = 10\ k\Omega}$$

Current will be same for each resistance in series combination, so $I = I_1 = I_2$

$$I = \frac{V}{R_{eq}}$$
$$I = \frac{10\ V}{10\ k\Omega}$$
$$I = \frac{10\ V}{10 \times 10^3\ \Omega}$$
$$I = 1 \times 10^{-3}\ A$$
$$\boldsymbol{I = 1\ mA}$$

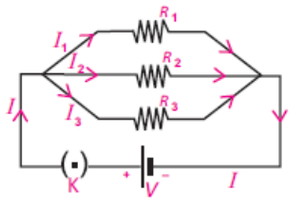
Potential difference across 1st resistance

$$V_1 = I_1 R_1$$
$$V_1 = (1\ mA)(6\ k\Omega)$$
$$V_1 = (1 \times 10^{-3} A)(6 \times 10^3\ \Omega)$$
$$\boldsymbol{V_1 = 6\ V}$$

Potential difference across 2nd resistance

$$V_2 = I_2 R_2$$
$$V_2 = (1\ mA)(4\ k\Omega)$$
$$V_2 = (1 \times 10^{-3} A)(4 \times 10^3\ \Omega)$$
$$\boldsymbol{V_2 = 4\ V}$$

14.5 If in the circuit (Figure), $R_1 = 2\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 6\ \Omega$, and $V = 6\ V$, then find the following quantities: *(ALP)*
(a) equivalent resistance of the circuit.
(b) current passing through each resistance.
(c) The total current of the circuit.



Given Data

$$R_1 = 2\ \Omega$$
$$R_2 = 3\ \Omega$$
$$R_3 = 6\ \Omega$$
$$V = 6\ V$$

To Find

$$R_{eq} = ?$$
$$V_1 = ?, V_2 = ?, V_3 = ?$$
$$I_1 = ?, I_2 = ?, I_3 = ?$$

Solution

By using formula of equivalent resistance for parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
$$\frac{1}{R_{eq}} = \frac{1}{2\Omega} + \frac{1}{3\Omega} + \frac{1}{6\Omega}$$
$$\frac{1}{R_{eq}} = \frac{3+2+1}{6\Omega}$$
$$\frac{1}{R_{eq}} = \frac{6}{6\Omega}$$
$$\frac{1}{R_{eq}} = \frac{1}{1\Omega}$$
$$\boldsymbol{R_{eq} = 1\ \Omega}$$

As we know potential difference (voltage) will be same for each resistance in parallel combination, so

$$\boldsymbol{V = V_1 = V_2 = V_3 = 6\ V}$$

Current through 1st resistance

$$I_1 = \frac{V_1}{R_1}$$
$$I_1 = \frac{6\ V}{2\ \Omega}$$
$$\boldsymbol{I_1 = 3\ A}$$

Current through 2nd resistance

$$I_2 = \frac{V_2}{R_2}$$
$$I_2 = \frac{6\ V}{3\ \Omega}$$
$$\boldsymbol{I_2 = 2\ A}$$

Current through 3rd resistance

$$I_3 = \frac{V_3}{R_3}$$
$$I_3 = \frac{6\ V}{6\ \Omega}$$
$$\boldsymbol{I_3 = 1\ A}$$

14.6 If a current of $0.5\ A$ passes through a bulb connected across a battery of $6\ V$ for $20\ seconds$, then find the rate of energy transferred to the bulb. Also find the resistance of the bulb.

Given Data

$$Current = I = 0.5\ A$$
$$Potential\ difference = V = 6\ V$$
$$time = t = 20\ s$$

To Find

$$Rate\ of\ energy\ transferred (Power) = P = ?$$
$$Resistance = R = ?$$

Solution

By using joule's law

$$W = I^2 Rt$$
$$W = I(IR)t$$
$$W = I(V)t$$
$$W = (0.5)(6)(20)$$
$$W = 60\ J$$

Now by using formula of power

$$P = \frac{W}{t}$$
$$P = \frac{60}{20}$$
$$\boldsymbol{P = 3\ watt}$$

Again by using joule's law

$$W = I^2 Rt$$
$$\frac{W}{I^2 t} = R$$
$$R = \frac{W}{I^2 t}$$
$$R = \frac{60}{(0.5)^2(20)}$$
$$\boldsymbol{R = 12\ \Omega}$$

14.7 The resistance of an electric bulb is $500\ \Omega$. Find the power consumed by the bulb when a potential difference of $250\ V$ is applied across its ends.

Given Data

$$Resistance\ of\ bulb = R = 500\ \Omega$$
$$Potential\ difference = V = 250\ V$$

To Find

$$Power = P = ?$$

Solution

By using formula of power

$$P = I^2R$$
$$P = \left(\frac{V}{R}\right)^2 \times R \qquad \because I = \frac{V}{R}$$
$$P = \frac{V^2}{R^2} \times R$$
$$P = \frac{V^2}{R}$$
$$P = \frac{(250)^2}{500}$$
$$\boldsymbol{P = 125\ W} \qquad (\boldsymbol{watt})$$

14.8 Calculate the one month cost of using $50\ W$ energy saver for 8 hours daily in your study room. Assume that the price of a unit is Rs. 12. *(ALP)*

Given Data

$$Power = P = 50\ W$$
$$Time\ in\ hours = t = 8\ h$$
$$One\ unit\ price = P = Rs.12$$

To Find

$$Monthly\ cost\ of\ electricity\ (30\ days) = ?$$

Solution

$$Monthly\ electricity\ cost\ of\ bulb = \frac{Power(W) \times time\ (h) \times (price) \times 30}{1000}$$
$$= \frac{50 \times 8 \times 12 \times 30}{1000}$$
$$= \boldsymbol{144\ Rs.}$$