

Numerical Problems**Important formulas**

- **Electric Current** $\text{Current} = \frac{\text{Charge}}{\text{Time}} \Rightarrow I = \frac{Q}{t}$
- **Ohm's Law** $V = IR$
- **Electric Power** $\text{Electric power} = \frac{\text{electric energy}}{\text{time}}$
 $\Rightarrow P = \frac{W}{t}$ or $P = I^2 R$ or $P = IV$
- **Electrical Energy** $W = QV$
- **Joule's Law (Energy Supplied By Q Charge)**
 $W = I^2 R t = \frac{V^2 t}{R}$
- **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**
 $\text{Energy in kWh} = \frac{\text{Power(Watt)} \times \text{time (hours)}}{1000}$
- **Electricity price**
 $E.P = \frac{\text{Power(Watt)} \times \text{time (hours)} \times (\text{unit price})}{1000}$
- **Monthly bill**
 $\text{Bill} = \frac{\text{Power(Watt)} \times \text{time (hours)} \times (\text{unit price}) \times 30}{1000}$

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

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

To Find

$$\text{charge} = Q = ?$$

Solution

By using formula of current

$$\begin{aligned}I &= \frac{Q}{t} \\ Q &= It \\ Q &= (3 \times 10^{-3})(60) \\ Q &= 0.18 \text{ C} = 180 \times 10^{-3} \text{ C}\end{aligned}$$

14.2. At 100,000 Ω, 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 Ω, how much current would you receive from the same battery? (ALP)

Given Data

$$\begin{aligned}\text{Dry skin resistance} &= R_1 = 100,000 \Omega \\ \text{Wet skin resistance} &= R_2 = 1000 \Omega \\ \text{Voltage} &= V = 12 \text{ V}\end{aligned}$$

To Find

$$\begin{aligned}\text{Current through dry skin} &= I_1 = ? \\ \text{Current through wet skin} &= I_2 = ?\end{aligned}$$

Solution

By using ohm's law

$$V = IR$$

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

For dry skin

$$\begin{aligned}I_1 &= \frac{V}{R_1} \\ I_1 &= \frac{12}{100,000} \\ I_1 &= 1.2 \times 10^{-4} \text{ A}\end{aligned}$$

For wet skin

$$\begin{aligned}I_2 &= \frac{V}{R_2} \\ I_2 &= \frac{12}{1000} \\ I_2 &= 1.2 \times 10^{-2} \text{ A}\end{aligned}$$

14.3. The resistance of a conductor wire is 10 MΩ. 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

$$\begin{aligned}\text{Resistance} &= R = 10 \text{ M}\Omega \\ R &= 10 \times 10^6 \Omega \\ \text{Potential difference} &= V = 100 \text{ V}\end{aligned}$$

To Find

$$\text{Current} = I = ?$$

Solution

By using ohm's law

$$\begin{aligned}V &= IR \\ I &= \frac{V}{R} \\ I &= \frac{100}{10 \times 10^6} \\ I &= 1 \times 10^{-5} \text{ A} \\ I &= 10^{-2} \times 10^{-3} \text{ A} \\ I &= 10^{-2} \text{ mA} \\ I &= 0.01 \text{ mA}\end{aligned}$$

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

$$\begin{aligned}\text{Potential difference} &= V = 10 \text{ V} \\ \text{Current} &= I = 1.5 \text{ A} \\ \text{time} &= t = 2 \text{ min} \\ t &= 2 \times 60 \text{ s} \\ t &= 120 \text{ s}\end{aligned}$$

To Find

$$\text{Energy} = W = ?$$

Solution

By using joule's law

$$\begin{aligned}W &= I^2 R t \\ W &= I(IR)t \\ W &= I(V)t \\ W &= (1.5)(10)(120) \\ W &= 1800 \text{ J}\end{aligned}$$

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

- The equivalent resistance of the series combination.
- Current passing through each of the resistances.
- The potential difference across each resistance.

Given Data

$$\begin{aligned} R_1 &= 2\text{ k}\Omega \\ R_2 &= 8\text{ k}\Omega \\ V &= 10\text{ V} \end{aligned}$$

To Find

$$\begin{aligned} R_{eq} &= ? \\ I_1 &= ?, \quad I_2 = ? \\ V_1 &= ?, \quad V_2 = ? \end{aligned}$$

Solution

By using formula of equivalent resistance for series combination

$$\begin{aligned} R_{eq} &= R_1 + R_2 \\ R_{eq} &= 2\text{ k}\Omega + 8\text{ k}\Omega \\ R_{eq} &= 10\text{ k}\Omega \end{aligned}$$

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

$$\begin{aligned} I &= \frac{V}{R_{eq}} \\ I &= \frac{10\text{ V}}{10\text{ k}\Omega} \\ I &= \frac{10}{10 \times 10^3\text{ }\Omega} \\ I &= 1 \times 10^{-3}\text{ A} \\ I &= 1\text{ mA} \end{aligned}$$

Potential difference across 1st resistance

$$\begin{aligned} V_1 &= I_1 R_1 \\ V_1 &= (1\text{ mA})(2\text{ k}\Omega) \\ V_1 &= (1 \times 10^{-3}\text{ A})(2 \times 10^3\text{ }\Omega) \\ V_1 &= 2\text{ V} \end{aligned}$$

Potential difference across 2nd resistance

$$\begin{aligned} V_2 &= I_2 R_2 \\ V_2 &= (1\text{ mA})(8\text{ k}\Omega) \\ V_2 &= (1 \times 10^{-3}\text{ A})(8 \times 10^3\text{ }\Omega) \\ V_2 &= 8\text{ V} \end{aligned}$$

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

- Equivalent resistance of the parallel combination.
- Current passing through each of the resistances.
- Potential difference across each of the resistance.

Given Data

$$\begin{aligned} R_1 &= 6\text{ k}\Omega \\ R_2 &= 12\text{ k}\Omega \\ V &= 6\text{ V} \end{aligned}$$

To Find

$$\begin{aligned} R_{eq} &= ? \\ I_1 &= ?, \quad I_2 = ? \\ V_1 &= ?, \quad V_2 = ? \end{aligned}$$

Solution

By using formula of equivalent resistance for parallel combination

$$\begin{aligned} \frac{1}{R_{eq}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R_{eq}} &= \frac{1}{6\text{ k}\Omega} + \frac{1}{12\text{ k}\Omega} \\ \frac{1}{R_{eq}} &= \frac{2+1}{12\text{ k}\Omega} \\ \frac{1}{R_{eq}} &= \frac{3}{12\text{ k}\Omega} \\ \frac{1}{R_{eq}} &= \frac{1}{4\text{ k}\Omega} \\ R_{eq} &= 4\text{ k}\Omega \end{aligned}$$

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

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

Current through 1st resistance

$$\begin{aligned} I_1 &= \frac{V_1}{R_1} \\ I_1 &= \frac{6\text{ V}}{6\text{ k}\Omega} \\ I_1 &= \frac{6\text{ V}}{6 \times 10^3\text{ }\Omega} \\ I_1 &= 1 \times 10^{-3}\text{ A} \\ I_1 &= 1\text{ mA} \end{aligned}$$

Current through 2nd resistance

$$\begin{aligned} I_2 &= \frac{V_2}{R_2} \\ I_2 &= \frac{6\text{ V}}{12\text{ k}\Omega} \\ I_2 &= \frac{6\text{ V}}{12 \times 10^3\text{ }\Omega} \\ I_2 &= 0.5 \times 10^{-3}\text{ A} \\ I_2 &= 0.5\text{ mA} \end{aligned}$$

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

$$\begin{aligned} \text{Voltage of bulb} &= V = 220\text{ V} \\ \text{Power} &= P = 100\text{ W} \\ \text{Daily use of bulb} &= t = 5\text{ h} \\ \text{No. of days} &= 30\text{ days} \end{aligned}$$

To Find

$$\begin{aligned} \text{Resistance of bulb} &= R = ? \\ \text{Energy in kWh} &= E = ? \end{aligned}$$

Solution

By using formula of power

$$\begin{aligned} P &= I^2 R \\ P &= \left(\frac{V}{R}\right)^2 \times R & \therefore I &= \frac{V}{R} \end{aligned}$$

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

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

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

$$R = \frac{(220)^2}{100}$$

$$R = 484 \Omega$$

Total time in 30 days

$$\text{time taken} = 30 \times 5 = 150 \text{ hours}$$

By using formula of energy in kWh

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

$$\text{Energy in kWh} = \frac{100 \text{ watt} \times 150 \text{ h}}{1000}$$

$$\text{Energy in kWh} = 15 \text{ kWh}$$

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

Given Data

$$\text{Resistance} = R = 95 \Omega$$

$$\text{Power} = P = 150 \text{ W}$$

To Find

$$\text{Voltage} = V = ?$$

Solution

By using formula of power

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

$$V^2 = P \times R$$

$$V^2 = 150 \times 95$$

$$V^2 = 14250$$

$$\sqrt{V^2} = \sqrt{14250}$$

$$V = 119.3 \text{ V}$$

$$V \approx 120 \text{ V}$$

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

$$\text{Power of 10 bulb} = 60 \text{ W} \times 10 = 600 \text{ W} \quad t = 5 \text{ h}$$

$$\text{Power of 4 fans} = 75 \text{ W} \times 4 = 300 \text{ W} \quad t = 10 \text{ h}$$

$$\text{Power of 1 T.V.} = 100 \text{ W} \times 1 = 100 \text{ W} \quad t = 5 \text{ h}$$

$$\text{Power of 1 iron} = 1000 \text{ W} \times 1 = 1000 \text{ W} \quad t = 2 \text{ h}$$

$$\text{One unit price} = \text{Rs.4}$$

To Find

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

Solution

$$\text{Monthly electricity cost of bulb} = \frac{\text{Power(W)} \times \text{time (h)} \times (\text{price}) \times 30}{1000}$$

$$= \frac{600 \times 5 \times 4 \times 30}{1000}$$

$$= 360 \text{ Rs.}$$

$$\text{Monthly electricity cost of fans} = \frac{\text{Power(W)} \times \text{time (h)} \times (\text{price}) \times 30}{1000}$$

$$= \frac{300 \times 10 \times 4 \times 30}{1000}$$

$$= 360 \text{ Rs.}$$

$$\text{Monthly electricity cost of T.V.} = \frac{\text{Power(W)} \times \text{time (h)} \times (\text{price}) \times 30}{1000}$$

$$= \frac{100 \times 5 \times 4 \times 30}{1000}$$

$$= 60 \text{ Rs.}$$

$$\text{Monthly electricity cost of iron} = \frac{\text{Power(W)} \times \text{time (h)} \times (\text{price}) \times 30}{1000}$$

$$= \frac{1000 \times 2 \times 4 \times 30}{1000}$$

$$= 240 \text{ Rs.}$$

$$\text{Monthly cost of electricity} = 360 + 360 + 60 + 240$$

$$= 1020 \text{ Rs.}$$

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

$$\text{Power of bulb} = P_1 = 100 \text{ W}$$

$$\text{Power of water heater} = P_2 = 4 \text{ kW}$$

$$P_2 = 4 \times 10^3 \text{ W}$$

$$\text{Voltage} = V = 250 \text{ V}$$

To Find

$$(a) I_1 = ?$$

$$I_2 = ?$$

$$(b) R_1 = ?$$

$$R_2 = ?$$

Solution

Current in lamp

$$P_1 = I_1 V$$

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

$$I_1 = \frac{100}{250}$$

$$I_1 = 0.4 \text{ A}$$

Current in heater

$$P_2 = I_2 V$$

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

$$I_2 = \frac{4 \times 10^3}{250}$$

$$I_2 = 16 \text{ A}$$

Resistance in lamp

$$V = I_1 R_1$$

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

$$R_1 = \frac{250}{0.4}$$

$$R_1 = 625 \Omega$$

Resistance in heater

$$V = I_2 R_2$$

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

$$R_2 = \frac{250}{16}$$

$$R_2 = 15.6 \Omega$$

14.11. A resistor of resistance 5.6Ω 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

- Power dissipated in the resistor.
- Total power produced by the battery.
- Give the reason of difference between these two quantities.

Given Data

$$\text{Resistance of resistor} = R = 5.6 \Omega$$

$$\text{Voltage} = V = 3.0 V$$

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

To Find

$$\text{Power dissipated} = P_d = ?$$

$$\text{Power of battery} = P = ?$$

Solution

For power dissipated, we use

$$P_d = I^2 R$$

$$P_d = (0.5)^2 (5.6)$$

$$P_d = 1.4 W$$

For battery power, we use

$$P = IV$$

$$P = (0.5)(3.0)$$

$$P = 1.5 W$$

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

$$\text{Charge} = Q = 0.5 C$$

$$\text{Time} = t = 10 s$$

To Find

$$\text{Current} = I = ?$$

Solution

By using formula of current

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

$$I = \frac{0.5}{10}$$

$$I = 0.05 A$$

$$I = 50 \times 10^{-3} A$$

$$I = 50 mA$$

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

$$\text{Voltage} = V = 60 V$$

$$\text{Current} = I = 2 A$$

To Find

$$\text{Resistance} = R = ?$$

Solution

By using ohm's law

$$V = IR$$

$$60 = (2)(R)$$

$$\frac{60}{2} = R$$

$$30 = R$$

$$R = 30 \Omega$$

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

$$\text{Length} = L = 1 m$$

$$\text{Diameter} = d = 2 mm$$

$$\text{Radius} = r = \frac{2 mm}{2}$$

$$r = 1 mm$$

$$r = 1 \times 10^{-3} m$$

$$\text{Specific resistance of copper} = \rho = 1.69 \times 10^{-8} \Omega m$$

To Find

$$\text{Resistance} = R = ?$$

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

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

$$R = \frac{(1.69 \times 10^{-8})(1)}{3.14 \times 10^{-6}}$$

$$R = 5.4 \times 10^{-3} \Omega$$

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)

- Equivalent resistance of the series combination.
- The current flowing through each of the resistance.
- 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

$$R_{eq} = R_1 + R_2$$

$$R_{eq} = 6 k\Omega + 4 k\Omega$$

$$R_{eq} = 10 k\Omega$$

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

$$I = \frac{V}{R_{eq}}$$

$$I = \frac{10 V}{10 k\Omega}$$

$$I = \frac{10 V}{10 \times 10^3 \Omega}$$

$$I = 1 \times 10^{-3} A$$

$$I = 1 mA$$

Potential difference across 1st resistance

$$V_1 = I_1 R_1$$

$$V_1 = (1 mA)(6 k\Omega)$$

$$V_1 = (1 \times 10^{-3} A)(6 \times 10^3 \Omega)$$

$$V_1 = 6 V$$

Potential difference across 2nd resistance

$$V_2 = I_2 R_2$$

$$V_2 = (1 mA)(4 k\Omega)$$

$$V_2 = (1 \times 10^{-3} A)(4 \times 10^3 \Omega)$$

$$V_2 = 4 V$$

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

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{2\Omega} + \frac{1}{3\Omega} + \frac{1}{6\Omega}$$

$$\frac{1}{R_{eq}} = \frac{3 + 2 + 1}{6\Omega}$$

$$\frac{1}{R_{eq}} = \frac{6}{6\Omega}$$

$$\frac{1}{R_{eq}} = \frac{1}{1\Omega}$$

$$R_{eq} = 1 \Omega$$

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

$$V = V_1 = V_2 = V_3 = 6 V$$

Current through 1st resistance

$$I_1 = \frac{V_1}{R_1}$$

$$I_1 = \frac{6 V}{2 \Omega}$$

$$I_1 = 3 A$$

Current through 2nd resistance

$$I_2 = \frac{V_2}{R_2}$$

$$I_2 = \frac{6 V}{3 \Omega}$$

$$I_2 = 2 A$$

Current through 3rd resistance

$$I_3 = \frac{V_3}{R_3}$$

$$I_3 = \frac{6 V}{6 \Omega}$$

$$I_3 = 1 A$$

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

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

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

$$\text{time} = t = 20 s$$

To Find

$$\text{Rate of energy transferred (Power)} = P = ?$$

$$\text{Resistance} = R = ?$$

Solution

By using joule's law

$$W = I^2 R t$$

$$W = I(I R) t$$

$$W = I(V) t$$

$$W = (0.5)(6)(20)$$

$$W = 60 J$$

Now by using formula of power

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

$$P = \frac{60}{20}$$

$$P = 3 \text{ watt}$$

Again by using joule's law

$$W = I^2 R t$$

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

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

$$R = \frac{60}{(0.5)^2 (20)}$$

$$R = 12 \Omega$$

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

Given Data

$$\text{Resistance of bulb} = R = 500 \Omega$$

$$\text{Potential difference} = V = 250 V$$

To Find

$$\text{Power} = P = ?$$

Solution

By using formula of power

$$P = I^2 R$$

$$P = \left(\frac{V}{R}\right)^2 \times R \quad \because I = \frac{V}{R}$$

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

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

$$P = \frac{(250)^2}{500}$$

$$P = 125 \text{ W} \quad (\text{watt})$$

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

$$\text{Power} = P = 50 \text{ W}$$

$$\text{Time in hours} = t = 8 \text{ h}$$

$$\text{One unit price} = P = \text{Rs. } 12$$

To Find

Monthly cost of electricity (30 days) =?

Solution

$$\begin{aligned} \text{Monthly electricity cost of bulb} &= \frac{\text{Power(W)} \times \text{time (h)} \times (\text{price}) \times 30}{1000} \\ &= \frac{50 \times 8 \times 12 \times 30}{1000} \\ &= \mathbf{144 \text{ Rs.}} \end{aligned}$$

Hira Science Academy – For Educational Use Only