Chapter 11: Electric Current Through Conductors

EXERCISES [PAGES 219 - 220]

Exercises | Q 1. (i) | Page 219

Choose the correct alternative.
You are given four bulbs of 25 W, 40 W, 60 W, and 100 W of power, all operating at 230 V. Which of them has the lowest resistance?

1. 25 W
2. 40 W
3. 60 W
4. **100 W**

SOLUTION

100 W

Explanation:

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

Since all the bulbs are operating at the same volt.

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

∴ The bulb with the highest power will have the lowest resistance. i.e., 100 W bulb

Exercises | Q 1. (ii) | Page 219

Choose the correct alternative.
Which of the following is an ohmic conductor?

1. transistor
2. vacuum tube
3. electrolyte
4. **nichrome wire**

SOLUTION

Nichrome wire

Exercises | Q 1. (iii) | Page 219

Choose the correct alternative.
A rheostat is used

1. to bring on a known change of resistance in the circuit to alter the current
2. **to continuously change the resistance in any arbitrary manner and thereby alter the current**
3. to make and break the circuit at any instant
4. neither to alter the resistance nor the current

SOLUTION

To continuously change the resistance in any arbitrary manner and thereby alter the current

Exercises | Q 1. (iv) | Page 219

Choose the correct alternative.

The wire of length L and resistance R is stretched so that its radius of cross-section is halved. What is its new resistance?

1. 5R
2. 8R
3. 4R
4. **16R**

SOLUTION

16R

Explanation:

let r, and l, be their initial radius of the wire and r_2 and l_2 be their final radius of the wire.

∴ Initial volume = Final volume

$$\pi r_1^2 l_1 = \pi r_2^2 l^2$$

$$\therefore \frac{l_1}{l_2} = \left(\frac{r_2}{r_1}\right)^2$$

Since $r_2 = \frac{r_1}{2}$

$$\therefore \frac{r_2}{r_1} = \frac{1}{2} \text{ ....(i)}$$

$$\therefore \frac{l_1}{l_2} = \frac{1}{4} \text{ ....(ii)}$$

$$\therefore \text{Resistance, } R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$$

$$\therefore \frac{R_1}{R_2} = \frac{\frac{\rho l_1}{\pi r_1^2}}{\frac{\rho l_2}{\pi r_2^2}} = \frac{l_1}{l_2} \times \left(\frac{r_2}{r_1}\right)^2$$

$$= \frac{1}{4} \times \left(\frac{1}{2}\right)^2 = \frac{1}{16}$$

$\therefore R_2 = 16\ R_1$

Exercises | Q 1. (v) | Page 219

Choose the correct alternative.

Masses of three pieces of wires made of the same metal are in the ratio 1:3:5 and their lengths are in the ratio 5:3:1. The ratios of their resistances are

1. 1:3:5
2. 5:3:1
3. 1:15:125
4. **125:15:1**

SOLUTION

125:15:1

Explanation:

$$R = \frac{\rho l}{A} = \frac{\rho l \times l}{A \times l} = \frac{\rho l^2}{V}$$

Since, $V = \frac{m}{d}$

$$\therefore R = \frac{\rho l^2}{m/d}$$

$$\therefore R \propto \frac{l^2}{m}$$

$$\therefore R_1 : R_2 : R_3 = \frac{l_1^2}{m_1} : \frac{l_2^2}{m_2} : \frac{l_3^2}{m_3}$$

$$= \frac{5^2}{1} : \frac{3^2}{3} : \frac{1^2}{5}$$

= 125:15:1

Exercises | Q 1. (vi) | Page 219

Choose the correct alternative.

The internal resistance of a cell of emf 2V is 0.1Ω it is connected to resistance of 0.9Ω. The voltage across the cell will be

1. 0.5 V
2. **1.8 V**
3. 1.95 V
4. 3 V

SOLUTION

1.8 V

Explanation:

E = I (r + R)

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

$$= \frac{2}{0.1 + 0.9}$$

I = 2 A

∴ V = IR

= 2 × 0.9

= 1.8 V

Exercises | Q 1. (vii) | Page 219

Choose the correct alternative.

100 cells each of emf 5V and internal resistance 1Ω are to be arranged so as to produce maximum current in a 25Ω resistance. Each row contains equal number of cells. The number of rows should be

1. **2**
2. 4
3. 5
4. 100

SOLUTION

2

Explanation:

let, m = Number of rows

n = Number of cells in a row

$\therefore m \times n = 100$ .....(i)

Resistance is series = nr

Resistance in parallel = $\frac{m}{nr}$

For maximum current, R = $\frac{nr}{m}$

$25 = \frac{n}{m}$ ....(r = 1Ω) ....(ii)

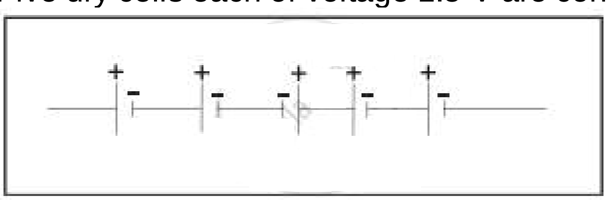
From equations (i) and (ii),

m = 2

Exercises | Q 1. (viii) | Page 219

Choose the correct alternative.

Five dry cells each of voltage 1.5 V are connected as shown in the diagram



What is the overall voltage with this arrangement?

1. 0 V
2. **4.5 V**
3. 6.0 V
4. 7.5 V

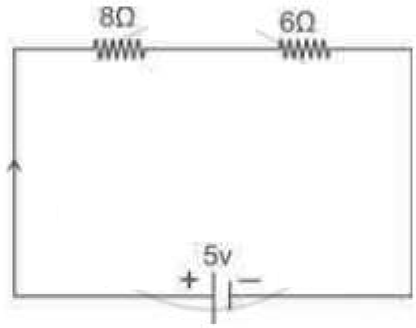
SOLUTION

4.5 V

Exercises | Q 2. (i) (a) | Page 219

Give reason/short answer.

In the given circuit diagram two resistors are connected to a 5V supply.



Calculate potential difference across the 8Ω resistor.

SOLUTION

Total current flowing through the circuit,

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

$$= \frac{5}{8+6}$$

$$= \frac{5}{14} = 0.36\ A$$

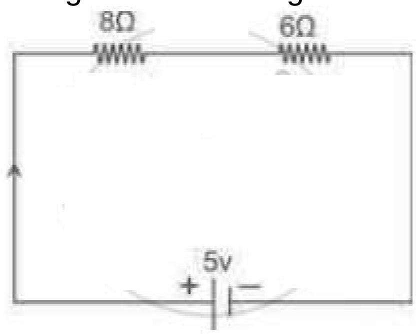
∴ Potential difference across 8Ω (V_1) = 0.36 × 8

= 2.88 V

Exercises | Q 2. (i) (b) | Page 219

Give reason/short answer.

In the given circuit diagram two resistors are connected to a 5V supply.

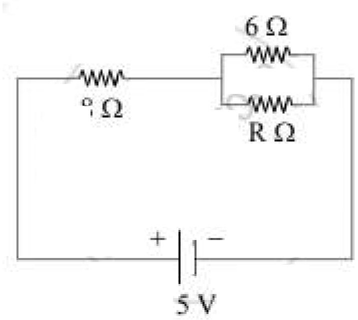


A third resistor is now connected in parallel with 6Ω resistor. Will the potential difference across the 8Ω resistor the larger, smaller, or the same as before? Explain the reason for your answer.

SOLUTION

Potential difference across 8Ω resistor will be larger.

Reason: As per the question, the new circuit diagram will be



When any resistor is connected parallel to 6Ω resistance. Then the resistance across that branch (6Ω and RΩ) will become less than 6Ω. i.e., the equivalent resistance of the entire circuit will decrease and hence current will increase. Since, V = IR, the potential difference across 8Ω resistor will be larger.

Exercises | Q 2. (ii) | Page 219

Give reasons/short answer.
Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

SOLUTION

1. Consider a part of conducting wire with its free electrons having the drift speed v_d in the direction opposite to the electric field $\vec{E}$.
2. All the electrons move with the same drift speed v_d and the current I is the same throughout the cross-section (A) of the wire.
3. Let L be the length of the wire and n be the number of free electrons per unit volume of the wire. Then the total number of free electrons in the length L of the conducting wire is nAL.
4. The total charge in the length L is,
   $q = nALe$......(1)
   where e is the charge of electron.
5. Equation (1) is the total charge that moves through any cross-section of the wire in a certain time interval t.
   $\therefore t = \frac{L}{v_d}$ ....(2)
6. Current is given by,
   $I = \frac{q}{t} = \frac{nALe}{L/v_d}$ .....[From equations (1) and (2)]
   $= n A v_d e$

Hence,

$$v_d = \frac{1}{n\,Ae}$$

$$= \frac{J}{ne} \ldots\ldots \left(\because J = \frac{1}{A}\right)$$

Hence for constant 'ne', current density of a metallic conductor is directly proportional to the drift speed of electrons, $J \propto v_d$.

Exercises | Q 3. (i) | Page 219

Answer the following question.

Distinguish between Ohmic and non-ohmic substances; explain with the help of example.

SOLUTION

Ohmic substances	**Non-ohmic substances**
1. Substances which obey ohm's law are called ohmic substances	1. Substances which do not obey ohm's law are called non-ohmic substances.
2. Potential difference (V) versus current (I) curve is a straight line.	2. Potential difference (V) versus current (I) curve is not a straight line.
3. Resistance of these substances is constant i.e. they follow linear I-V characteristic.	3. Resistance of these substances is a function of V or I.
4. Expression for resistance is, R = $\frac{V}{I}$	4. Expression for resistance is, R = $\lim_{\Delta I \to 0} \frac{\Delta V}{\Delta I} = \frac{dV}{dI}$
5. **Examples:** Gold, silver, copper etc.	5. **Examples:** Liquid electrolytes, vacuum tubes, junction diodes, thermistors etc.

Exercises | Q 3. (ii) | Page 219

Answer the following question.

DC current flows in a metal piece of the non-uniform cross-section. Which of these quantities remains constant along the conductor: current, current density, or drift speed?

SOLUTION

Drift velocity and current density will change as it depends upon the area of cross-section whereas current will remain constant.

Exercises | Q 4. (i) | Page 220

Solve the following problem.

What is the resistance of one of the rails of a railway track 20 km long at 20° C? The cross-section area of the rail is 25 cm^2 and the rail is made of steel having resistivity at 20° C as 6×10^{-8} Ω m.

SOLUTION

Given: l = 20 km = 20×10^3 m, A = 25 cm^2 = 25×10^{-4} m^2, ρ = 6×10^{-8} Ω m

To find: Resistance of rail (R)

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

Calculation: From formula,

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

$$\therefore R = \frac{6 \times 10^{-8} \times 20 \times 10^3}{25 \times 10^{-4}} = \frac{6 \times 4}{5} \times 10^{-1}$$

= 0.48 Ω

The resistance of one of the rails of railway track is **0.48 Ω**.

Exercises | Q 4. (ii) | Page 220

Solve the following problem.

A battery after a long use has an emf 24 V and an internal resistance 380 Ω. Calculate the maximum current drawn from the battery? Can this battery drive starting motor of car?

SOLUTION

Given: E = 24 V, r = 380 Ω

To find: i. Maximum current (I_{max})

ii. Can battery start the motor?

Formula: $I_{max} = \frac{E}{r}$

Calculation: From formula,

$I_{max} = \frac{24}{380} = 0.063$ A

As the value of the current is very small compared to the required current to run a starting motor of a car, this battery cannot be used to drive the motor.

i. The maximum current drawn from the battery is **0.063 A**.
ii. The battery **cannot be used** to drive a starting motor of a car.

Exercises | Q 4. (iii) | Page 220

Solve the following problem.
A battery of emf 12 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0.5 A,

a. Calculate resistance of resistor.
b. Calculate terminal voltage of the battery when the circuit is closed.

SOLUTION

Given: E = 12 V, r = 3 Ω, I = 0.5 A

To find: a. Resistance (R)

b. Terminal voltage (V)

Formulae: i. E = I (r + R)

ii. V = IR

Calculation: From formula (i),

E = Ir + IR

$$\therefore R = \frac{E - Ir}{I}$$

$$= \frac{12 - 0.5 \times 3}{0.5}$$

= 21 Ω

From formula (ii),

V = 0.5 × 21

= 10.5 V

a. The resistance of a resistor is **21 Ω**.

b. The terminal voltage of the battery when the circuit is closed is **10.5 V**.

Exercises | Q 4. (iv) | Page 220

Solve the following problem.

The magnitude of current density in a copper wire is 500 A/cm^2. If the number of free electrons per cm^3 of copper is 8.47×10^{22} calculate the drift velocity of the electrons through the copper wire (charge on an e = 1.6×10^{-19} C)

SOLUTION

Given: J = 500 A/cm^2 = 500×10^4 A/m^2, n = 8.47×10^{22} electrons/cm^3 = 8.47×10^{28} electrons/m^3

e = 1.6×10^{-19} C

To find: Drift velocity (v_d)

Formula: $v_d = \frac{J}{ne}$

Calculation: From formula.

$$v_d = \frac{500 \times 10^4}{8.47 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$= \frac{500}{8.47 \times 1.6} \times 10^{-5}$$

$$= \{\text{antilog} [\log 500 - \log 8.47 - \log 1.6]\} \times 10^{-5}$$

$$= \{\text{antilog} [2.6990 - 0.9279 - 0.2041]\} \times 10^{-5}$$

$$= \{\text{antilog} [1.5670]\} \times 10^{-5}$$

$$= 3.690 \times 10^1 \times 10^{-5}$$

$$= 3.69 \times 10^{-4} \text{ m/s}$$

The drift velocity of electrons is **3.69×10^{-4} m/s**.

Exercises | Q 4. (v) | Page 220

Solve the following problem.

Three resistors 10 Ω, 20 Ω, and 30 Ω are connected in series combinations.

i. Find the equivalent resistance of series combination.
ii. When this series combination is connected to 12V supply, by neglecting the value of internal resistance, obtain potential difference across each resistor.

SOLUTION

Given: R_1 = 10 Ω, R_2 = 20 Ω, R_3 = 30 Ω, V = 12 V

To find: i. Series equivalent resistance(R_s)

ii. Potential difference across each resistor (V_1, V_2, V_3)

Formula: i. $R_s = R_1 + R_2 + R_3$

ii. V = IR

Calculation: From formula (i),

R_s = 10 + 20 + 30 = 60 Ω

From formula (ii),

$I = \frac{V}{R} = \frac{12}{60} = 0.2$ A

∴ Potential difference across R_1,

$V_1 = I \times R_1 = 0.2 \times 10 = 2$ V

∴ Potential difference across R_2,

$V_2 = 0.2 \times 20 = 4$ V

∴ Potential difference across R_3,

$V_3 = 0.2 \times 30 = 6$ V

i. The equivalent resistance of the series combination is **60 Ω**.

ii. Potential difference across 10 Ω, 20 Ω, and 30 Ω resistors are **2 V, 4 V**, and **6 V** respectively.

Exercises | Q 4.(vi) | Page 220

Solve the following problem.

Two resistors 1 kΩ and 2 kΩ are connected in parallel combination.

i. Find equivalent resistance of parallel combination
ii. When this parallel combination is connected to 9 V supply, by neglecting internal resistance calculate current through each resistor.

SOLUTION

Given: $R_1 = 1\ k\Omega = 10^3\ \Omega$, $R_2 = 2\ k\Omega = 2 \times 10^3\ \Omega$, $V = 9\ V$

To find: i. Parallel equivalent resistance (R_p)

ii. Current through 1 kΩ and 2 kΩ (I_1 and I_2)

Formula: i. $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

ii. $V = IR$

Calculation: From formula (i),

$$\frac{1}{R_p} = \frac{1}{10^3} + \frac{1}{2 \times 10^3}$$

$$= \frac{3}{2 \times 10^3}$$

$$\therefore R_p = \frac{2 \times 10^3}{3} = 0.66\ k\Omega$$

From formula (ii),

$$I_1 = \frac{V}{R_1} = \frac{9}{10^3}$$

$$= 9 \times 10^{-3}\ A$$

$$= 9\ mA$$

$$I_2 = \frac{V}{R_2} = \frac{9}{2 \times 10^3}$$

$$= 4.5 \times 10^{-3}\ A$$

$$= 4.5\ mA$$

i. The equivalent resistance of the parallel combination is **0.66 kΩ**.

ii. Current flowing through 1 kΩ and 2 kΩ resistances are **9 mA** and **4.5 mA** respectively.

Exercises | Q 4. (vii) | Page 220

Solve the following problem.

A silver wire has a resistance of 4.2 Ω at 27° C and resistance 5.4 Ω at 100° C. Determine the temperature coefficient of resistance.

SOLUTION

Given: R_1 = 4.2 Ω, R_2 = 5.4 Ω, T_1 = 27° C, T_2 = 100° C

To find: Temperature coefficient of resistance (α)

Formula: $\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$

Calculation: From the formula,

$$\alpha = \frac{5.4 - 4.2}{4.2(100 - 27)} = 3.91 \times 10^{-3}/° C$$

The temperature coefficient of resistance is **3.91×10^{-3}/° C**.

Exercises | Q 4. (viii) | Page 220

Solve the following problem.

A 6 m long wire has diameter 0.5 mm. Its resistance is 50 Ω. Find the resistivity and conductivity.

SOLUTION

Given: l = 6 m, D = 0.5 mm, r = 0.25 mm = 0.25×10^{-3} m, R = 50 Ω

To find: i. Resistivity (ρ)

Formula: i. $\rho = \frac{RA}{l} = \frac{R\pi r^2}{l}$

ii. $\sigma = \frac{1}{\rho}$

Calculation: From formula (i),

$$\rho = \frac{50 \times 3.142 \times \left(0.25 \times 10^{-3}\right)^2}{6}$$

$= \{\text{antilog}\ [\log 50 + \log 3.142 + 2\log 0.25 - \log 6]\} \times 10^{-6}$

$= \{\text{antilog}\ [1.6990 + 0.4972 + 2(\bar{1}.3979) - 0.7782]\} \times 10^{-6}$

$= \{\text{antilog}\ [2.1962 + \bar{2}.7958 - 0.7782]\} \times 10^{-6}$

$= \{\text{antilog}\ [0.9920 - 0.7782]\} \times 10^{-6}$

$= \{\text{antilog}\ [0.2138]\} \times 10^{-6}$

$= 1.636 \times 10^{-6}\ \Omega/\text{m}$

From formula (ii),

$$\sigma = \frac{1}{1.636 \times 10^{-6}}$$

$= 0.6157 \times 10^{6}$ ....(Using reciprocal from log table)

$= 6.157 \times 10^{5}\ \Omega/\text{m}$

i. The resistivity of the wire is $\mathbf{1.636 \times 10^{-6}\ \Omega/m}$.

ii. The conductivity of the wire is $\mathbf{6.157 \times 10^{5}\ \Omega/m}$

Exercises | Q 4. (ix) (1) | Page 220

Solve the following problem.
Find the value of resistance for the following colour code.
Blue Green Red Gold

SOLUTION

Given: Blue - Green - Red - Gold

To find: Value of resistance

Formula: Value of resistance
$= (xy \times 10^{z} \pm T\%)\ \Omega$

Calculation:

Colour	Blue (x)	Green (y)	Red (z)	Gold T%
Code	6	5	2	±5

From formula,
Value of resistance $= (65 \times 10^{2} \pm 5\%)\ \Omega$
Value of resistance $= 6.5\ \text{k}\Omega \pm 5\%$

Exercises | Q 4. (ix) (2) | Page 220

Solve the following problem.
Find the value of resistance for the following colour code.
Brown Black Red Silver

SOLUTION

Given: Brown - Black - Red - Silver

To find: Value of resistance

Formula: Value of resistance
= $(xy \times 10^z \pm T\%)\ \Omega$

Calculation:

Colour	Brown (x)	Black (y)	Red (z)	Silver T%
Code	1	0	2	±10

From formula,
Value of resistance = $(10 \times 10^2 \pm 10\%)\ \Omega$
Value of resistance = 1.0 k Ω ± 10%

Exercises | Q 4. (ix) (3) | Page 220

Solve the following problem.
Find the value of resistance for the following colour code.
Red Red Orange Gold

SOLUTION

Given: Red - Red - Orange - Gold

To find: Value of resistance

Formula: Value of resistance
= $(xy \times 10^z \pm T\%)\ \Omega$

Calculation:

Colour	Red (x)	Red (y)	Orange (z)	Gold T%
Code	2	2	3	±5

From formula,
Value of resistance = $(22 \times 10^3 \pm 5\%)\ \Omega$
Value of resistance = 22 k Ω ± 5%

Exercises | Q 4. (ix) (4) | Page 220

Solve the following problem.
Find the value of resistance for the following colour code.
Orange White Red Gold

SOLUTION

Given: Orange - White - Red - Gold

To find: Value of resistance

Formula: Value of resistance
$= (xy \times 10^z \pm T\%)\ \Omega$

Calculation:

Colour	Orange (x)	White (y)	Red (z)	Gold T%
Code	3	9	2	±5

From formula,
Value of resistance = $(39 \times 10^2 \pm 5\%)\ \Omega$
Value of resistance = 3.9 k Ω ± 5%

Exercises | Q 4. (ix) (5) | Page 220
Solve the following problem.
Find the value of resistance for the following colour code.
Yellow Violet Brown Silver

SOLUTION

Given: Yellow - Violet - Brown - Silver

To find: Value of resistance

Formula: Value of resistance
$= (xy \times 10^z \pm T\%)\ \Omega$

Calculation:

Colour	Yellow (x)	Violet (y)	Brown (z)	Silver T%
Code	4	7	1	±10

From formula,
Value of resistance = $(47 \times 10 \pm 10\%)\ \Omega$
Value of resistance = 4.70 k Ω ± 10%

Exercises | Q 4. (x) (a) | Page 220

Solve the following problem.

Find the colour code for the following value of resistor having tolerance ± 10%
330 Ω

SOLUTION

Value of resistance	1st Band	2nd Band	Multiple	Tolerance	Colour code
330 Ω ± 10% = 33 × 10^1 Ω ± 10%	3 (Orange)	3 (Orange)	10^1 (Brown)	± 10% (Silver)	Orange - Orange - Brown - Silver

Exercises | Q 4. (x) (b) | Page 220

Solve the following problem.
Find the colour code for the following value of resistor having tolerance ± 10%
100 Ω

SOLUTION

Value of resistance	1st Band	2nd Band	Multiple	Tolerance	Colour code
100 Ω ± 10% = 10 × 10^1 Ω ± 10%	1 (Brown)	0 (Black)	10^1 (Brown)	± 10% (Silver)	Brown - Black - Brown - Silver

Exercises | Q 4. (x) (c) | Page 220

Solve the following problem.
Find the colour code for the following value of resistor having tolerance ± 10%
47 kΩ

SOLUTION

Value of resistance	1st Band	2nd Band	Multiple	Tolerance	Colour code
47 kΩ ± 10% = 47 × 10^3 Ω ± 10%	4 (Yellow)	7 (Violet)	10^3 (Orange)	± 10% (Silver)	Yellow - Violet - Orange - Silver

Exercises | Q 4. (x) (d) | Page 220

Solve the following problem.
Find the colour code for the following value of resistor having tolerance ± 10%
160 Ω
SOLUTION

Value of resistance	1st Band	2nd Band	Multiple	Tolerance	Colour code
160 Ω ± 10% = 16 × 10^1 Ω ± 10%	1 (Brown)	6 (Blue)	10^1 (Brown)	± 10% (Silver)	Brown - Blue - Brown - Silver

Exercises | Q 4. (x) (e) | Page 220

Solve the following problem.

Find the colour code for the following value of resistor having tolerance ± 10%
1 KΩ

SOLUTION

Value of resistance	1st Band	2nd Band	Multiple	Tolerance	Colour code
1 KΩ ± 10% = 10×10^2 Ω ± 10%	1 (Brown)	0 (Black)	10^2 (Red)	± 10% (Silver)	Brown - Black - Red - Silver

Exercises | Q 4. (xi) | Page 220

Solve the following problem.

A current 4A flows through an automobile headlight. How many electrons flow through the headlight in a time 2hrs?

SOLUTION

Given: I = 4 A, t = 2 hrs = 2 × 60 × 60 s

To find: Number of electrons (N)

Formula: $I = \frac{q}{t} = \frac{Ne}{t}$

Calculation: As we know, $e = 1.6 \times 10^{-9}$ C

From formula,

$$N = \frac{It}{e} = \frac{4 \times 2 \times 60 \times 60}{1.6 \times 10^{-19}} = 1.8 \times 10^{23}$$

Number of electrons flowing through the headlight in 2 hrs is $\mathbf{1.8 \times 10^{23}}$.

Exercises | Q 4. (xii) | Page 220

Solve the following problem.

The heating element connected to 230V draws a current of 5A. Determine the amount of heat dissipated in 1 hour (J = 4.2 J/cal.).

SOLUTION

Given: V = 230 V, I = 5 A, Δt = 1 hour = 60 × 60 sec

To find: Heat dissipated (H)

Formula: $H = \Delta U = I\Delta tV$

Calculation: From the formula,

H = 5 × 60 × 60 × 230

= 4.14×10^6 J

Heat dissipated in calorie,

$$H = \frac{4.14 \times 10^6}{4.2} = 985.7 \times 10^3 \text{ cal}$$

= 985.7 kcal

The amount of heat dissipated in 1 hour is **985.7 kcal**.