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CH-3 Current Electricity

EXERCISE

3.1) Emf of the battery, $E = 12V$
Internal resistance of the battery, $r = 0.4\,\Omega$
Max. current drawn from the battery $= I$
Acc. to Ohm's Law,

$$E = Ir$$

$$I = \frac{E}{r}$$

$$= \frac{12}{0.4} = 30A$$

Ans

3.2) Emf of the battery, $E = 10V$
Internal resistance of the battery, $r = 3\,\Omega$
Current in the circuit, $I = 0.5A$
Resistance of the resistor $= R$
The relation for current using Ohm's law is,

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

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

$$= \frac{10}{0.5} = 20\,\Omega$$

$\therefore R = 20 - 3 = 17\,\Omega$

Terminal voltage of the resistor $= V$
According to Ohm's law,

$$V = IR$$

$$= 0.5 \times 17$$

$$= 8.5V$$

Ans

3.3)

(a) Three resistors of resistances 1Ω, 2Ω, 3Ω are combined in series. Total resistance of the combination is given by the algebraic sum of individual resistances

Total resistance = 1 + 2 + 3 = 6 Ω Ans

(b) Current flowing through the circuit = I
Emf of the battery, E = 12 V
Total resistance of the circuit, R = 6 Ω
The relation for current using Ohm's law is,

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

$$= \frac{12}{6} = 2\,A$$

Potential drop across 1Ω resistor = V_1
From Ohm's law, the value of V_1 can be obtained as
$V_1 = 2 \times 1 = 2V$ —— ①

Potential drop across 2Ω resistor = V_2
From Ohm's law, the value of V_2 can be obtained as
$V_2 = 2 \times 2 = 4V$ — ②

Potential drop across 3Ω resistor = V_3
From Ohm's law, the value of V_3 can be obtained as
$V_3 = 2 \times 3 = 6V$ —— ③

∴ Potential drop across 1Ω, 2Ω, 3Ω resistors are 2V, 4V and 6V respectively.

3.4)

(a) There are three resistors of resistances, $R_1 = 2\Omega$, $R_2 = 4\Omega$ and $R_3 = 5\Omega$.
They are connected in parallel. Hence, total resistance (R) of the combination is given by,

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

$$= \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{10+5+4}{20} = \frac{19}{20}$$

$\therefore R = \frac{20}{19}\Omega$

Ans

(b) Emf of the battery, $V = 20V$
Current (I_1) flowing through resistor R_1 is given by,

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

$$= \frac{20}{2} = 10A$$

Current (I_2) flowing through resistor R_2 is given by.

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

$$= \frac{20}{4} = 5A$$

Current (I_3) flowing through resistor R_3 is given by.

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

$$= \frac{20}{5} = 4A$$

Total current, $I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19A$

$\therefore$ Current flowing through each resistor is 10A, 5A and 4A respectively and the total current is 19A

3.5) Room temperature, $T = 27°C$
Resistance of the heating element at T, $R = 100\,\Omega$
Let T_1 is the increased temperature of the filament.
Resistance of the heating element at T_1, $R_1 = 117\,\Omega$

Temperature co-efficient of the material of the filament
$\alpha = 1.70 \times 10^{-4}\,°C^{-1}$
α is given by the relation

$$\alpha = \frac{R_1 - R}{R(T_1 - T)}$$

$$T_1 - T = \frac{R_1 - R}{R\alpha}$$

$$T_1 - 27 = \frac{117 - 100}{100(1.7 \times 10^{-4})}$$

$$T_1 - 27 = 1000$$

$$T_1 = 1027°C$$

∴ At 1027°C, the resistance of the element is $117\,\Omega$.

Ans

3.6) Length of the wire, $l = 15\,m$
Area of cross-section of the wire, $a = 6.0 \times 10^{-7}\,m^2$
Resistance of the material of the wire, $R = 5.0\,\Omega$
Resistivity of the material of the wire $= \rho$
~~Resistivity~~ Resistance is related with the resistivity as

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

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

$$= \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}\,\Omega m$$

Ans

3.7) Temperature, $T_1 = 27.5°C$
Resistance of the silver wire at T_1, $R_1 = 2.1\,\Omega$
Temperature, $T_2 = 100°C$
Resistance of the silver wire at T_2, $R_2 = 2.7\,\Omega$
Temperature coefficient of silver $= \alpha$
It is related with temperature and resistance as

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

$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039°C^{-1}$$

Ans

3.8) Supply voltage, $V = 230V$
Initial current drawn, $I_1 = 3.2A$
Initial resistance $= R_1$, which is given by the relation

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

$$= \frac{230}{3.2} = 71.87\,\Omega$$

Steady state value of the current, $I_2 = 2.8A$
Resistance at the steady state $= R_2$, which is given by

$$R_2 = \frac{230}{2.8} = 82.14\,\Omega$$

Temperature co-efficient of nichrome, $\alpha = 1.70 \times 10^{-4}°C^{-1}$
Initial temperature of nichrome, $T_1 = 27.0°C$
Study state temperature reached by nichrome $= T_2$
T_2 can be obtained by the relation for α,

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

$$T_2 - 27^\circ C = \frac{82.14 - 71.87}{71.87 \times 1.7 \times 10^{-4}} = 840.5$$

$T_2 = 840.5 + 27 = 867.5^\circ C$ Ans

3.10)

(a) Balance point from end A, $l_1 = 39.5$ cm

Resistance of the resistor $Y = 12.5\,\Omega$.

Condition for the balance is given as,

$$\frac{X}{Y} = \frac{100 - l_1}{l_1}$$

$$X = \frac{100 - 39.5}{39.5} \times 12.5 = 8.2\,\Omega$$

⇒ The connection b/w resistors in a wheatstone or metre bridge is made of thick copper strip to minimize the resistance in & is not taken into consideration in the bridge formula.

(b) If X and Y are interchanged, then l_1 and $100 - l_1$ get interchanged.

The balance point of the bridge will be $100 - l_1$ from A.

$100 - l_1 = 100 - 39.5 = 60.5$ cm

∴ The balance point is 60.5 cm from A.

(c) When the galvanometer and cell are interchanged at the balance point of the bridge, the galvanometer will show no deflection. Hence, no current would flow through the galvanometer.

3.11) Emf of the storage battery, $E = 8.0V$
Internal resistance of the battery, $r = 0.5\Omega$
DC supply voltage, $V = 120V$
Resistance of the resistor, $R = 15.5\Omega$
Effective voltage in the circuit $= V'$

R is connected to the storage battery in series.
Hence, it can be written as $V' = V - E$
$V' = 120 - 8 = 112V$

Current flowing in the circuit $= I$, which is given by the relation,

$$I = \frac{V'}{R + r}$$

$$= \frac{112}{15.5 + 5} = \frac{112}{16} = 7A$$

Voltage across resistor R given by the product, is
$IR = 7 \times 15.5 = 108.5V$
DC supply voltage = Terminal voltage of battery + voltage drop across R

Terminal voltage $= 120 - 108.5 = 11.5V$
A series resistor in a charging circuit limits the current drawn from the external source. The current will be extremely high in its absence. This is very dangerous.

3.12) Emf of the cell $E_1 = 1.25V$
Balance point of the potentiometer, $l_1 = 35cm$
The cell is replaced by another cell of emf E_2,

New balance point of the potentiometer $l_2 = 63$ cm

The balance condition is given by the relation,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$E_2 = E_1 \times \frac{l_2}{l_1}$$

$$= 1.25 \times \frac{63}{35} = 2.25V$$

Ans

3.13) No. density of free electrons in a copper conductor $n = 8.5 \times 10^{28}\ m^{-3}$ Length of the copper wire, $l = 3.0$ m

Area of cross-section of the wire, $A = 2.0 \times 10^{-6} m^2$
Current carried by the wire, $I = 3.0$ A, which is given by the relation,

$I = nAeV_d$

Where,

e = Electric charge $= 1.6 \times 10^{-19}$ C

V_d = Drift velocity = $\frac{\text{Length of wire } (l)}{\text{Time taken to cover } l (t)}$

$$I = nAe\frac{l}{t}$$

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

$$= \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$$

$= 2.7 \times 10^4$ s

Ans