Ch-3 Current electricity

Q.3.1 Emf of car battery $E = 12V$

Internal resistance $R = 0.4\Omega$

Max current is $= I$

Acc, Ohm's law

$E = IR$

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

$\Rightarrow I = \frac{12V}{0.4\Omega} = 30A$

$\therefore$ Max current drawn, $I = 30A$.

Q.3.2. Emf of battery $E = 10V$

Internal resistance $R = 3\Omega$

Current in circuit $I = 0.5A$

Resistance of resistor $= r$

$I = \frac{E}{R+r} = \frac{10}{3+r}$

$\Rightarrow \frac{10}{3+r} = \frac{5}{10}$

$\Rightarrow 15+5r = 100$

$\Rightarrow 5r = 85$

$\Rightarrow r = \frac{85}{5} = 17\Omega$

Hence, the resistance of resistor is $= 17\Omega$

Let terminal Voltage be V.

$V = IR$

$\Rightarrow V = 0.5 \times 17$

$\Rightarrow V = 8.5V$

Hence, terminal voltage V is 8.5 V

(b) [illegible]

[illegible]

[illegible] 17 [illegible] V

$\Rightarrow V = 20V$

current in R_1,

$R_1 = 2\Omega$

$$I = \frac{V}{R_1} = \frac{V}{R_1} = \frac{20}{2} = 10A$$

current in R_2,

$R_2 = 4\Omega$

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

current in R_3,

$R_3 = 5\Omega$

$$I = \frac{V}{R_3} = \frac{20}{5} = 4A$$

$I_1 = 10A$, $I_2 = 5A$ and $I_3 = 4A$

Total current drawn $I = I_1 + I_2 + I_3 = 19A$

3.5

5. Temperature $T = 27°C$

Resistance of heating element $R = 100\Omega$

Let increased temperature be T_1.

At T_1, the resistance R_1 is $= 117\Omega$

Temperature coefficient of the material $\alpha = 1.70 \times 10^{-4}$

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

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

$$\Rightarrow T_1 - 27 = 1000$$

$$\Rightarrow T_1 = 1027°C$$

Hence, resistance is 117Ω at a temperature of $1027°C$

Sol. $r_1 = 1\Omega$, $r_2 = 2\Omega$, $r_3 = 3\Omega$

r_1, r_2 and r_3 are in series

Total resistance $= (1+2+3)\,\Omega = 6\,\Omega$

Hence, total resistance of circuit $= 6\,\Omega$

(b) Let I be the current in circuit

emf of battery $E = 12\,V$

Total resistance $= 6\,\Omega$

By Ohm's law,

$$I = \frac{E}{R} = \frac{12}{6} = 2\,A$$

Hence, current I is 2 A.

Let potential drop across $1\Omega = V_1$

potential drop across $2\Omega = V_2$

value of $V_2 = 2 \times 2 = 4V$

Value of $V_1 = 2 \times 1 = 2V$

Let potential drop across $3\Omega = V_3$

Value of $V_3 = 3 \times 2 = 6V$

Hence, potential drops are $V_1 = 2V$, $V_2 = 4V$ and $V_3 = 6V$.

Q. 3. 4. (a) $r_1 = 2\Omega$ $r_2 = 4\Omega$ $r_3 = 5\Omega$

r_1, r_2 and r_3 are in parallel.

Total resistance $= R$

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \Rightarrow \frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5}$$

$$\Rightarrow \frac{1}{R} = \frac{10+5+4}{20}$$

$$\Rightarrow \frac{1}{R} = \frac{19}{20}$$

$$\Rightarrow R = \frac{20}{19}$$

6. Length of wire = 15 m

Area of cross-section $a = 6.0 \times 10^{-7} m^2$

Resistance $R = 5.0 \Omega$

Resistivity of the material ρ

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

$$\Rightarrow \rho = \frac{R \times A}{L} = \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}$$

Hence, resistivity of the material is 2×10^{-7}

7. Silver wire's resistance $R = 2.1 \Omega$ at $27.5°C$ (T) and resistance R_1 is 2.7Ω at $100°C$ (T_1)

$R = 2.1 \Omega$ at T

~~R~~ = Increased temperature $R_1 = 2.7 \Omega$ at T_1

$T = 27.5°C$ & $T_1 = 100°C$

Temperature coefficient of resistivity of silver is α

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

$$\Rightarrow \alpha = \frac{2.7 - 2.1}{2.1(100 - 27.5)}$$

$$\Rightarrow \alpha = \frac{0.6}{2.1(72.5)} = \frac{6}{10} \times \frac{1}{\frac{21}{10} \times \frac{725}{100}} = \frac{6}{10} \times \frac{1000}{21 \times 725}$$

$$\Rightarrow \alpha = \frac{8}{29} °C^{-1} = 0.0039 °C^{-1}$$

∴ Temperature coefficient of resistivity of silver is $0.0039°C^{-1}$.

8. Supply voltage $V = 230V$

Initial current $I_1 = 3.2 A$

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

$$\Rightarrow R_1 = \frac{230}{3.2} = 71.87 \Omega$$

Current at steady state $I_2 = 2.8A$

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

Temp. coefficient of nichrome $= 1.70 \times 10^{-4} C^{-1}$

Initial temp. of nichrome, $T_1 = 27.0°C$

Steady temp. $T_2 = ?$

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

$$\Rightarrow T_2 - 27 = \frac{82.14 - 71.87}{71.87 \times (1.7 \times 10^{-4})}$$

$$\Rightarrow T_2 - 27 = 840.5$$

$$\Rightarrow T_2 = 867.5°C$$

Hence, steady temperature T_2 is $= 867.5°C$

10.(a) Let L_1 be the balance

$L_1 = 39.5$ cm

Resistance of resistor $S = 12.5\,\Omega$

$$\frac{R}{S} = \frac{100 L_1}{L_1}$$

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

∴ Calculated resistance $R_1 = 8.2\,\Omega$

~~(b) $l = 100 - 39.5 =$~~

(b) If R and S are interchanged, then the lengths will also be interchanged.

Hence, length modifies to

$l = 100 - 39.5 = 60.5$ cm

(c) If the galvanometer and the cell are interchanged, ~~the~~ ~~then~~ the position of the balance point remains unchang[ed]. Therefore, the galvanometer will show no current.

11. Emf $\varepsilon = 8.0$ V

Internal resistance $r = 0.5\,\Omega$

DC voltage $V = 120$ V

Resistance of resistor $R = 15.5\,\Omega$

Effective voltage : V'

~~$V' = $~~ $V' = V - E$

$V' = 120 - 8 = 112$ V

Current : I

$$I = \frac{V_1}{R + r}$$

$$\Rightarrow I = \frac{112}{15.5 + 0.5}$$

$$\Rightarrow I = \frac{112}{16}$$

$$\Rightarrow I = 7\,A$$

Voltage across resistor = I×R = 7×15.5 = 108.5 V

This is a series combination. Current would be [illegible] dangerous in its absence

12. ~~Em~~

Q. 12. Emf of cell $E = 1.25V$

Balance point of potentiometer $l_1 = 35cm$

Cell replaced by another emf E_2.

New balance point $l_2 = 63cm$

Balance condition is given by the relations

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

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

$$\Rightarrow E_2 = 1.25 \times \frac{63}{35} = 2.25V$$

13. Number density of free electrons $n = 8.5 \times 10^{28} m^{-3}$

Length of copper wire $l = 3.0m$

Area of cross-section $A = 2.0 \times 10^{-6} m^2$

Current carried by wire, $I = 3.0A$

$I = nAeV_d$

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

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

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

$$t = \frac{n \times A \times e \times l}{I}$$

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

$= 2.7 \times 10^{4}$ seconds

14. Surface charge density of earth $\sigma = 10^{-9}\ cm^{-2}$
$V = 400\ kV$
Current over globe $I = 1800\ A$
Radius of earth $r = 6.37 \times 10^6\ m$
Surface area $A = 4\pi r^2$
$= 4 \times 3.14 \times (6.37 \times 10^6)^2 = 5.09 \times 10^{14}\ m^2$
Charge on earth surface, $q = \sigma A = 10^{-9} \times 5.09 \times 10^{14}$
$= 5.09 \times 10^5\ C$
Time taken to neutralize the earth's surface,
$\Rightarrow t = q/I$
$\Rightarrow t = 5.09 \times 10^5 / 1800 = 283\ s$
∴ Time taken is 283 s or 4 mins 43 secs.

15. (a) Emf of secondary cells $\varepsilon = 2.0\ V$
No. of cells, $n = 6$
Total EMF, $E = n\varepsilon = 6 \times 2 = 12\ V$
Internal resistance $r = 0.015\ \Omega$
Resistance to which secondary cells are connected, $R = 8.5\ \Omega$
$R_{total} = nr + R = 6 \times 0.015 + 8.5 = 8.59\ \Omega$
Current drawn from supply, $I = E/R_{total} = 12/8.59$
$= 1.4\ A$
Terminal voltage, $V = IR = 1.4 \times 8.5 = 11.9\ V$

(b) Emf of secondary cell, $\varepsilon = 1.9\ V$
Internal resistance $r = 380\ \Omega$
Max current drawn $I = \varepsilon / r = 1.9/380 = 0.0$
To start motor 100 A current is required. Here 0.005 A current is produced, so the motor car cannot be started with this current.

16. Length of aluminium = l_1

Resistance of aluminium = R

Resistivity of aluminium, $\rho_{Al} = \rho_1 = 2.63 \times 10^{-8}\ \Omega m$

Relative density of aluminium, $d_1 = 2.7$

Area of cross-section = A_1

Length of copper = l_2

Resistance of copper = R_2

Resistivity of copper, $\rho_{cu} = \rho_2 = 1.72 \times 10^{-8}\ \Omega m$

Relative density of copper, $d_2 = 8.9$

Area of cross-section of copper = A_2

Therefore,

$$R_1 = \rho_1 \frac{l_1}{A_1} \quad \text{—— (i)}$$

$$R_2 = \rho_2 \frac{l_2}{A_2} \quad \text{—— (ii)}$$

Given, $R_1 = R_2$

Therefore,

$$\rho_1 \frac{l_1}{A_1} = \rho_2 \frac{l_2}{A_2}$$

~~Ex~~ Given, $l_1 = l_2$

$$\frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$$

$$\frac{A_1}{A_2} = \frac{\rho_1}{\rho_2} = (2.63 \times 10^{-8}) / (1.72 \times 10^{-8})$$

$$= 1.52$$

Mass of aluminium, m_1 = Volume × density

$= A_1 l_1 \times d_1$

Mass of copper: m_2 = Volume × density

$= A_2 l_2 \times d_2$

$= (A_1 d_1 / A_2 l_2 \times d_2)$

~~$m_1/m_2 = (A)($~~

$m_1/m_2 = (A_1 d_1 / A_2 d_2)$

$m_1/m_2 = (1.52) \times (2.7/8.9)$

$= (1.52) \times (0.303)$

$m_1/m_2 = 0.46$

The mass ratio of aluminium to copper is 0.46. Since, aluminium is lighter, it is preferred for long suspensions of cables.

17.

Current A	Voltage V	Current A	Voltage V
0.2	3.94	3.0	59.2
0.4	7.87	4.0	78.8
0.6	11.8	5.0	98.6
0.8	15.7	6.0	118.5
1.0	19.7	7.0	138.2
2.0	39.4	8.0	158.0

Ohm's law is valid to high accuracy. This m that the resistivity of the alloy manganin is nearly independent of temperature.

18. (a) Current is steady. Therefore, it is a constant. The current density, electric field, drift speed inversely depends on the area of cross section.

(b) No, examples of non-ohmic elements are vacuum diode, semiconductor diode etc.

(c) Because the maximum current drawn from a source $= \varepsilon / r$.

(d) If the circuit is shorted (accidentally), the current drawn will ~~safely exceed~~ exceed safety limits if internal resistance is not large.

19. (a) Alloys of metals usually have greater resistivity than that of their constituent metals.

(b) Alloys usually have much lower temp. coefficient of resistance than pure metals.

(c) The resistivity of the alloy manganin is nearly independent of temperature.

(d) The resistivity of a typical insulator (e.g. amber) is greater than that of a metal by a factor of the order of 10^{22}.

20. (a) Total no. of resistors $= n$

Resistance of each resistor $= R$

i) The max effective resistance is got when the resistors are in series. & $R_{eff} = nR$

ii) Minimum effective resistance is got when the resistors are in parallel. R_{eff} $R_2 = R/n$

Ratio of max resistance to minimum resistance $= nR/(R/n) = n^2$

... are :- 1Ω, 2Ω, 3Ω

(i) 11/3 Ω

The resistors of resistance 1Ω and 2Ω are parallel. Effective resistance $\frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2}\right] = 3/2$

$\Rightarrow R' = 2/3$

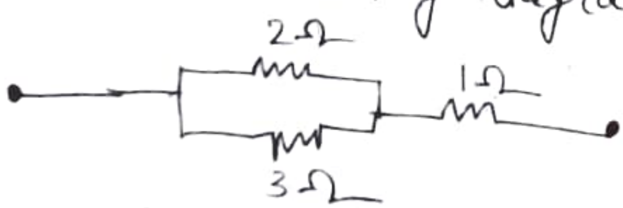
These resistors are connected in series with 3Ω

Effective resistance $R = R' + 3 = (2/3) + 3$

$= (11/3)\ \Omega$

(ii) 11/5 Ω

Consider following diagram:-



2Ω and 3Ω are in parallel.

$\frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{3}\right] = 5/6$

$\Rightarrow R' = 6/5\ \Omega$

These resistors with resistance 1Ω, 2Ω, 3Ω are connected in series the effective resista[nce] is given by 1Ω + 2Ω + 3Ω = 6Ω

(iii) 6 Ω

1 Ω, 2 Ω and 3 Ω are connected in series (with 6 Ω)

Effective resistance = 1 Ω + 2 Ω + 3 Ω = 6 Ω

(iv) (6/11) Ω

Resistors in parallel, effective resistance

$$= \frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2} + \frac{1}{3}\right] = 11/6\ \Omega$$

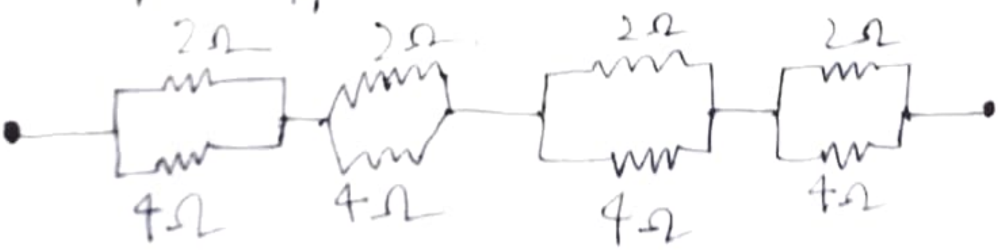
$R' = (6/11)\ \Omega$

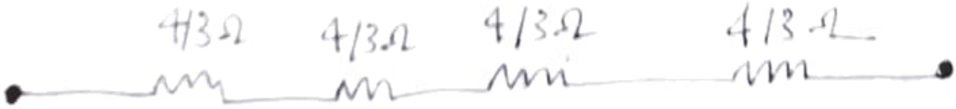
(c) (a) In all loops, two resistors of resistance 2 Ω are connected in series. Therefore, the effective resistance is (2+2) = 4 Ω.

2 Ω and 4 Ω are in parallel in all four loops.

Effective resistance $\frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{4}\right] = 3/4$

$R' = 4/3\ \Omega$

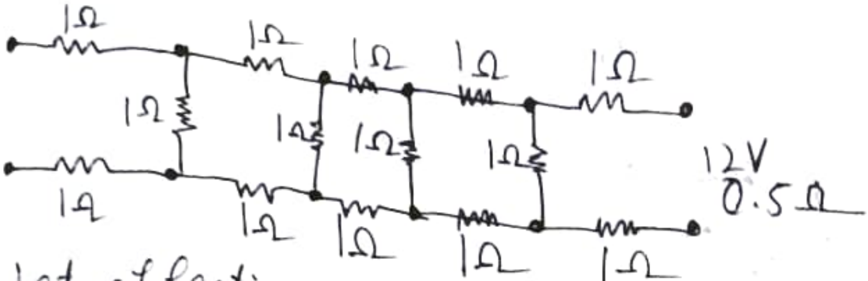




Equivalent resistance R each arc (4/3)×4 = 16/3 Ω

(b) Resistors are connected in series.

Effective resistance is R + R + R + R + R = 5R



Let effective resistance of infinite network be x.

Equivalent resistance of this network

$= R + $ (eq. resistance when X and R are parallel) + R

$= R + [XR/(X+R)] + R$

$R' = 2R + [XR/(X+R)]$

$R' = X$

$\Rightarrow 2R + [XR/(X+R)] = X$

$R = 1\Omega$, we get

$2\times 1 + [X\times 1/(X+1)] = X$

$X^2 - 2X - 2 = 0$

$$X = \frac{(-2) \pm \sqrt{(-2)^2 - 4\times 1\times(-2)}}{2}$$

$X = 1 \pm \sqrt{3}$

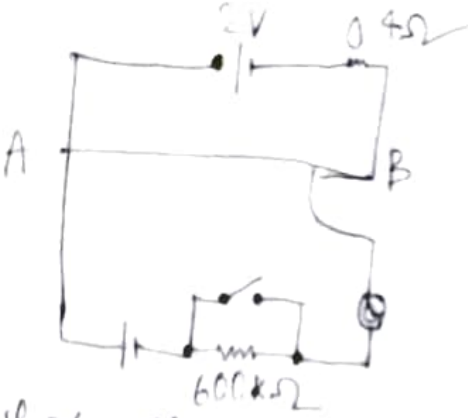
Resistance cannot be negative, so $X = 1+\sqrt{3} = 2.73$

$E = 12V$; $r = 0.5\,\Omega$

Current drawn $I = E/(X+r) = 12/(2.732+0.5) = 3$

$I = 3.713A$

22.



(a) Emf of cell ϵ_1 = 1.02 V

Balance point l_1 = 67.3 cm

Standard cell is replaced by cell of unknown emf, balance point changes to ~~67.8~~ 82.3 cm.

$\epsilon_1/l_1 = \epsilon/l$

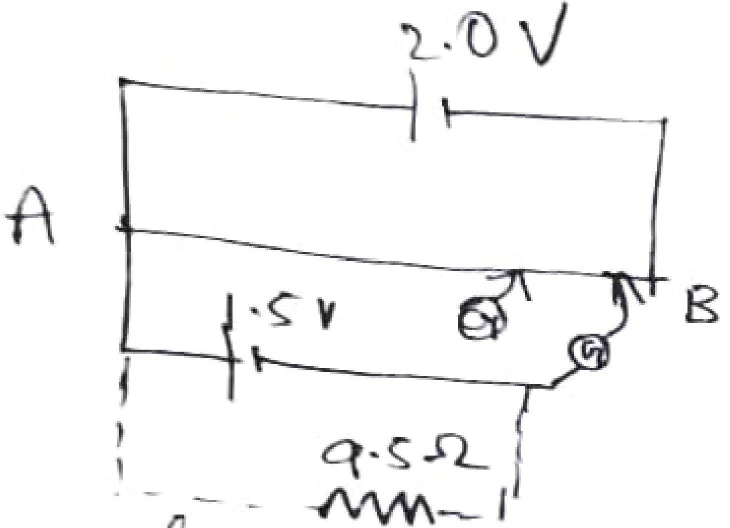
$\epsilon = (l \times \epsilon_1/l_1) = (82.3 \times 1.02)/67.3 = 1.247$ V

(b) The purpose of using high ~~temperature~~ resistance of 600 kΩ is to reduce current through the galvanometer when the movable contact is far from the balance point.

(c) No.

(d) No. If ϵ is greater than the emf of the driver cell of the potentiometer, there will be no balance point ~~at~~ on the wire AB.

(e) The circuit will not be suitable, because the balance point (for ϵ of the order of a few mV) will be very close to the end.



Internal resistance of the cell, r = 1.5 V cell
Balance point of the cell in open circuit, l = 76.3 cm
External resistance, R = 9.5 Ω
New balance point, l_1 = 64.8 cm
Expression for internal resistance is given as:

$r = R\left[\frac{l}{l_1} - 1\right]$ $r = 9.5\left[\frac{76.3}{64.8} - 1\right] = 1.69\ \Omega$