Current Electricity   Chp-3

1\. Given, emf = 12V ; internal resistance $r = 0.4\Omega$

$\therefore$ Current drawn from the battery $I = \frac{E}{R+r}$

In case of maximum current $R = 0$.

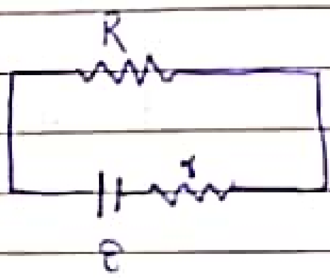
$$I_{max} = \frac{E}{r}$$

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

2\. Given, emf of battery, $E = 10V$

Internal resistance $r = 3\Omega$

Current in circuit $I = 0.5A$



The current in the circuit

$$= \frac{\text{emf}}{\text{Total resistance of the circuit}}$$

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

$$0.5 = \frac{10}{R+3} \quad \text{or} \quad R+3 = 20$$

$$R = 17\Omega.$$

When the circuit is closed, the terminal voltage

$V = E - Ir \Rightarrow 10 - 0.5 \times 3 = 10 - 1.5 = 8.5V$.

Then, the resistance in the circuit is 17Ω and terminal voltage of the battery when the circuit is closed is $8.5V$.

3\. a) $R_1 = 1\Omega$, $R_2 = 2\Omega$ and $R_3 = 3\Omega$

Resultant resistance in series

$$R_s = R_1 + R_2 + R_3$$

$$= 1 + 2 + 3 = 6\Omega.$$

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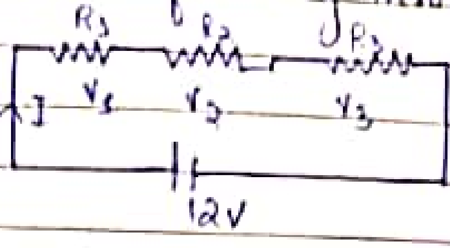
b. The potential drop across each resistor is different when two or more resistors are connected in series combination. Let V_1, V_2, V_3 be the potential drops across resistance R_1, R_2 and R_3 resp. and the current flowing through the circuit is I

$$I = \frac{V}{R_S} = \frac{12}{6} = 2A.$$

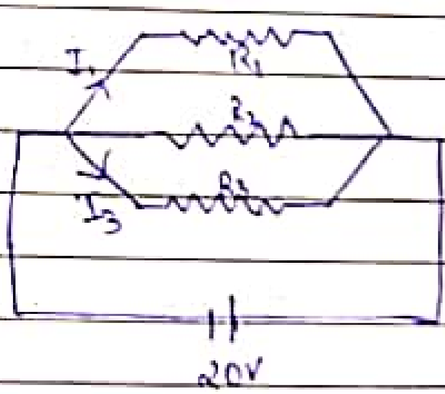


Current is same through each resistor as they are in series.
Potential drop across resistance R_1, $V_1 = IR_1 = 2\times1 = 2V$
Potential drop across resistance R_2, $V_2 = IR_2 = 2\times2 = 4V$.
Potential drop across resistance R_3, $V_3 = IR_3 = 2\times3 = 6V$.
Thus the potential drop across resistance 1Ω is 2V. resistance 2Ω is 4V and resistance 3Ω is 6V.

4. a) Given, $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 5\Omega$.
Resultant resistance in parallel

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{10+5+4}{20} = \frac{19}{20}.$$

$$R_P = \frac{20}{19}\ \Omega.$$



b. $V = 20V$.
Current through resistance R_1

$$I_1 = \frac{V}{R_1} = \frac{20}{2} = 10A.$$

Current through resistance R_2

$$I_2 = \frac{V}{R_2} = \frac{20}{4} = 5A.$$

Current through R_3 = $I_3 = \frac{V}{R_3} = \frac{20}{5} = 4A$.

Total current drawn = $10+5+4 = 19A$.

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Thus, current drawn from the Battery is 17A.

5. Given, the resistance of heating element at temp. 27°C.

$$= R_{27} = 100\,\Omega.$$

Resistance of heating element at temp. $t°C = R_t = 117\,\Omega$.
Temp. coefficient of resistance $\alpha = 1.70 \times 10^{-4}/°C$.
Temp. coefficient of resistance

$$\alpha = \frac{R_t - R_{27}}{R_{27}(t - 27)}$$

$$1.70 \times 10^{-4} = \frac{117 - 100}{100(t - 27)}$$

$$t - 27 = \frac{17}{100 \times 1.70 \times 10^{-4}}$$

$$t = 1000 + 27 = 1027°C.$$

Thus, the temp. of element is 1027°C when resistance is 117 Ω.

6. Given, area of cross-section of wire $(A) = 6.0 \times 10^{-7}\,m^2$
Length of the wire $l = 15\,m$.
Resistance of wire $R = 5\,\Omega$.
Resistance of the wire $R = \rho \frac{l}{A}$

$$\rho = \frac{RA}{L} = \frac{5 \times 6.0 \times 10^{-7}}{15} = 2 \times 10^{-7}\,\Omega m.$$

7. Given, resistance of silver wire at 27.5°C $= R_{27.5} =$
Resistance of silver wire at 100°C $= R_{100} = 2.7\,\Omega$.
Let the temp. coefficient of silver be α.

$$\alpha = \frac{R_{t_2} - R_{t_1}}{R_1(t_2 - t_1)}$$

$$\alpha = \frac{R_{100} - R_{27.5}}{R_{27.5}(100 - 27.5)} = \frac{2.7 - 2.1}{2.1 \times 72.5} \Rightarrow \alpha = 0.0039/°C$$

8. Given, Potential difference = 230 V
Initially current at 27°C = $I_{27°C}$ = 3.2A
Final current at t°C = $I_{t°C}$ = 2.8 A.
Room temp. = 27°C.
Temp coefficient of resistance
$\alpha = 1.70 \times 10^{-4} /°C$

Resistance at 27°C, $R_{27°C} = \frac{V}{I_{27°C}} = \frac{230}{3.2} = \frac{2300}{32}\ \Omega$.

Resistance at t°C = $R_{t°C} = \frac{V}{I_{t°C}} = \frac{230}{2.8} = \frac{2300}{28}\ \Omega$

Temp. of coefficient of resistance

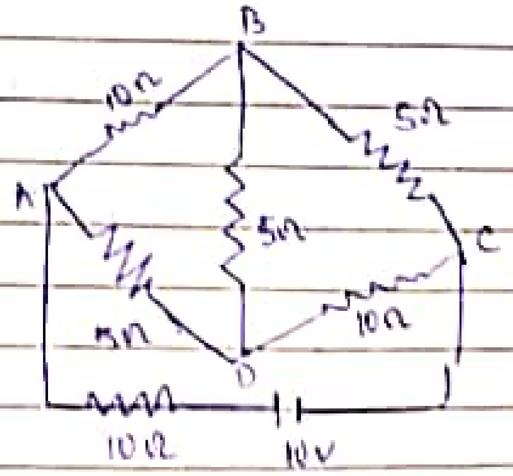
$$\alpha = \frac{R_t - R_{27}}{R_{27}(t - 27)}$$

$$1.7 \times 10^{-4} = \frac{\frac{2300}{28} - \frac{2300}{32}}{\frac{2300}{32}(t - 32)}$$

$$\Rightarrow t - 27 = \frac{82.143 - 71.875}{71.875 \times 1.7 \times 10^{-4}} = 840.347$$

$$t = 840.3 + 27$$
$$= 867.3°C.$$

9. From Kirchoff's 1st law ie loop law
$\Sigma V = \Sigma IR$



In loop ABDA, Distributing the current

$$10I_1 + 5I_2 - 5(I - I_1) = 0$$
$$2I_1 + I_2 - I + I_1 = 0$$
$$3I_1 + I_2 = I.$$

In loop BCDB
$$5(I_1 - I_2) - 10(I - I_1 + I_2) - 5I_2 = 0.$$

$I_1 - I_2 - 2I + 2I_1 - 2I_2 - I_2 = 0$

$$3I_1 - 4I_2 = 2I \quad - (ii)$$

By solving the eq (i) and eq (ii) we get

$$I_1 = \frac{2I}{5} \quad \text{and} \quad I_2 = -\frac{I}{5} \quad - (iii)$$

In loop ABCEFA.

$$10 = 10I + 10I_1 + 5(I_1 - I_2)$$

$$2 = 2I + 3I_1 - I_2 \quad --(iv)$$

Putting the value of I_1, and I_2 from eq (iii) and eq (iv) we get.

$$2 = 2I + 3\left(\frac{2I}{5}\right) - \left(\frac{-I}{5}\right)$$

$$2 = \frac{17}{5} I$$

$$I = \frac{10}{17} A.$$

Current in branch AB $I_1 = \frac{2}{5} \times \frac{10}{7} = \frac{4}{17}$ A.

and $I_2 = \frac{-I}{5} = \frac{-2}{17}$ A.

Current in branch AB is $I_1 = \frac{4}{17}$ A

Current in branch BC is $I_1 - I_2 = \frac{4}{17} - \left(\frac{-2}{17}\right) = \frac{6}{17}$ A.

Current in branch AD is $I - I_1 = \frac{10}{17} - \frac{4}{17} = \frac{6}{17}$ A.

Current in branch DC is $(I - I_1) + I_2 = \frac{6}{17} + \left(\frac{-2}{17}\right) = \frac{4}{17}$ A

10.

a. Balance point from end A

$$l = 39.5 \text{ cm}.$$

Resistance of resistor $Y = 12.5\Omega$.
Resistance of resistor $X = ?$
Acc. to the condition of balanced wheatstone bridge.

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

$$X = \frac{l}{100-l} \cdot Y$$

$$X = \frac{39.5 \times 12.5}{100 - 39.5} = 8.16\Omega.$$

The resistance of resistor X is 8.16Ω

(b) If X and Y are interchanged, then the balanced length will also interchanged. Thus, the balance length becomes
$100 - 39.5 = 60.5$ cm

(c) If the galvanometer and cell are interchanged at the balanced point of the bridge. The balance point is not obtained. The galvanometer shows no deflection.

11. EMF of the battery $e = 8V$, emf of DC supply $V = 120V$
Since, the battery is being charged, so effective emf in the circuit

$$E = V - e = 120 - 8 = 112V.$$

Current in circuit

$$I = \frac{\text{Effective emf}}{\text{Total resistance}} = \frac{E}{r+R}$$

$$= \frac{112}{0.5+15.5} = \frac{112}{16} = 7A.$$

12. Given, $E_1 = 1.25V$, $l_1 = 35$ cm, $l_2 = 63$ cm.
As we know that in case of potentiometric the potential gradient remain constant.

ie $E \propto l$

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

$$\frac{1.25}{E} = \frac{35}{63}$$

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

13. Given, number density of e^- $n = 8.5 \times 10^{28}/m^3$
length of wire = 3m.
Current $I = 3A$. charge of $e^- = 1.6 \times 10^{-19}$ C.
Time taken by e^- to drift from one end to another of the wire

$$t = \frac{\text{length of the wire}}{\text{Drift velocity}} = \frac{l}{V_d} \quad \ldots (i)$$

Using the relation, $I = neAV_d$
or $V_d = \frac{I}{neA}$ $\quad \ldots (ii)$

Putting the value in eq (ii) from eq (i)

$$t = \frac{l\,neA}{I} = \frac{3 \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 2 \times 10^{-6}}{3}$$

$$t = 2.72 \times 10^4\,s = 7h\,33\,min.$$

14. Given, radius of earth $R = 6.37 \times 10^6$ m.
Negative surface charge density $\sigma = 10^{-9}\,C/m^2$
Potential difference $V = 400\,kV = 400 \times 10^3\,V$
Current on the globe $I = 1800\,A$
Surface area of earth $A = 4\pi R^2 = 4 \times 3.14 \times (6.37 \times 10^6)^2$
$= 509.64 \times 10^{12}\,m^2$

Charge on earth surface q = Area of earth surface $\times$ Surface charge density

$Q = AG = 507.64 \times 10^{12} \times 10^{-9}$
$= 507.64 \times 10^{3} C.$

We know that $Q = It$.

∴ Time required to neutralize the earth's surface

$$t = \frac{Q}{I} = \frac{507.64 \times 10^{3}}{1800}$$

$$t = 282.1 \, s \text{ or } t = 4 \min 43 s.$$

15.a) Six cells are joined in series

EMF of each cell $E = 2V$

Total emf of circuit $= n \times E = 6 \times 2 = 12V$.

No. of cells, $n = 6$.

Internal resistance of each cell $r = 0.015 \Omega$.

Total internal resistance $= n \times r = 6 \times 0.015 = 0.09 \Omega$.

External load $R = 8.5 \Omega$.

Current in the circuit

$$I = \frac{nE}{nr + R} = \frac{12}{0.09 + 8.5} = 1.4A.$$

The terminal voltage of battery $V = IR = 1.4 \times 8.5 = 11.9V$.

b. EMF of cell $E = 1.9V$.

Internal resistance of cell $r = 380 \Omega$

Maximum current can be drawn from the cell, if there is zero external resistance, Therefore

$$I_{max} = \frac{E}{r} = \frac{1.9}{380} = 0.005A.$$

15.c) Current does not depend on area of conductor. So current remains constant. Current density is inversely proportional to area of cross-section $(J \propto \frac{1}{A})$, electric field and drift speed also depend on area $(E \propto \frac{1}{A}$ and $V_d \propto \frac{1}{A})$ so current density, electric field and drift speed do not remain constant as area changes

b. No, Ohm's law is not universally applicable for all conducting elements. Vaccum tubes, semiconductor diodes, transistors, thermistors and electrolytes are the example of elements which do not obey ohm law.

c. For very high current, the internal resistance should be low by acc. to the formula $I_{max} = \frac{V}{r}$ As lesser be the value of r (internal resistance) more is the current.

d. A high tension supply must have a very large internal resistance because if the circuit is shorted the internal resistance is not large enough than current drawn will exceed the safe limit and will cause the damage.

19.

a. The resistivity of alloys of metals usually have greater ~~resistance~~ resistivity than that of their constituent metals.

b. Alloys usually have much lower temp. coefficients resistance than pure metals.

c. The resistivity of alloy manganin is nearly independent of increases of temp. Because the coefficient of resistance is very low and its resistivity ~~is~~ is quite large.

d. The resistivity of a typical insulator (mica and amber) is greater than that of a metal by a factor of the order of 10^{22}. Because insulator has maximum resistivity in comparision of metals and alloys.

20. a. To get the maximum effective resistance, we connect the n resistors in series combination

$$R_{max} = R + R + \dots + n \text{ times} = nR \quad \dots (i)$$

To get the minimum effective resistance, we connect the n resistors in parallel combination.

$$\frac{1}{R_{min}} = \frac{1}{R} + \frac{1}{R} + \dots + n \text{ times} = \frac{n}{R}$$

$$R_{min} = \frac{R}{n} \quad \dots (ii)$$

Ratio of maximum to minimum resistance

$$= \frac{R_{max}}{R_{min}} = \frac{nR \cdot n}{R} \quad \text{(From eq. (i) and (ii))}$$

$$= n^2$$

b. Given, $R_1 = 1\Omega$, $R_2 = 2\Omega$ and $R_3 = 3\Omega$.

(i) To get the equivalent resistance as $\frac{11}{3}\Omega$.

Here R_1 and R_2 in parallel ie

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = 1 + \frac{1}{2} = \frac{3}{2}$$

$$R_p = \frac{2}{3}\Omega.$$

Now, R_p and R_3 are in series, the resultant resistance

$$R = R_p + R_3 = 3 + \frac{2}{3} = \frac{11}{3}\Omega.$$

(ii) To get the equivalent resistance as $\frac{11}{5}\Omega$.

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The R_2 and R_3 are in parallel.

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{3} = \frac{3+2}{6} = \frac{5}{6}$$

$$R_p = \frac{6}{5}\,\Omega$$

Now, R_p and R_1 in series, So resultant resistance

$$R = R_p + R_1 = \frac{6}{5} + 1 = \frac{11}{5}\,\Omega.$$

(iii) To get the equivalent resistance as $6\,\Omega$.
Resultant resistance

$$R_s = R_1 + R_2 + R_3 = 1+2+3 = 6\,\Omega.$$

(iv) To get the equivalent resistance as $\frac{6}{11}\,\Omega$.

$$\frac{1}{R_p} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6}$$

Resultant resistance $R_p = \frac{6}{11}\,\Omega$.

c) Here $1\,\Omega$ and $1\,\Omega$ are in series

$$\therefore R_s = 1+1 = 2\,\Omega.$$

and $2\,\Omega$ and $2\,\Omega$ are in series

$$R'_s = 2+2 = 4\,\Omega.$$

Now, R_s and R'_s in parallel

$$\frac{1}{R'} = \frac{1}{R_s} + \frac{1}{R'_s} = \frac{1}{2} + \frac{1}{4} = \frac{2+1}{4} = \frac{3}{4}$$

$\therefore$ Resultant resistance $R' = \frac{4}{3}\,\Omega$.

21. Let the effective resistance of the network is x. If one part of the network has resistance ($1\Omega, 1\Omega, 1\Omega$) is seperated as shown, the effective resistance remains x (as it is infinitely network) Here x and 1Ω are in parallel.

$$\frac{1}{R_p} = \frac{1}{x} + \frac{1}{1} = \frac{1+x}{x}$$

$$R_p = \frac{x}{1+x}$$

Now, resistance R_p, $1\,\Omega$ and $1\,\Omega$ are in series, so the resultant resistance

$$R = R_p + 1 + 1 = \frac{x}{1+x} + 1 + 1 = \frac{x}{1+x} + 2 \quad \cdots (i)$$

In case of infinite resistance, the value of R remains x

$$\therefore \quad x = \frac{x}{1+x} + 2$$

$$x(x+1) = x + 2 + 2x$$

$$x^2 - 2x - 2 = 0$$

$$x = \frac{-(-2) \pm \sqrt{4+8}}{2} = \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$$

The value of resistance can't be -ve, so the resistance of network

$$x = 1 + \sqrt{3} = 1 + 1.732$$

$$x = 2.732\,\Omega.$$

Total resistance of the circuit $= 2.732 + 0.5 = 3.232\,\Omega$.

current drawn from the supply

$$I = \frac{V}{3.232} = \frac{12}{3.232} = 3.72\,A.$$

22. a. Here $E_1 = 1.02\,V$, $l_1 = 67.3\,cm$, $E_2 = E = ?$ and $l_2 = 82.3\,cm$

$$E \propto l$$

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

$$\frac{1.02}{E} = \frac{67.3}{82.3}$$

$$E = \frac{1.02 \times 82.3}{67.3} = 12.47\,V.$$

b. The use of very high resistance of 600kΩ is to allow a very small current through the galvanometer when it is too far from the balance point.

c. No, the balance point is not affected by high resistance of 600 kΩ.

d. No, the balance point is not affected by the internal resistance of the driver cell.

e. If the emf of the driver cell is less than the driven cell, the method cannot work.

f. No, the circuit does not work for determining the extremely small emf of millivolt because in this situation, the balance point is very near to end. To modify, we use high resistance in series with the cell. This decreases the current in the potential gradient decreases.

23. Here $l_1 = 58.3$ cm, $l_2 = 68.5$ cm, $R = 10\Omega$,
Let I be the current in the potentiometer wire and E_1 and E_2 be the potential drops across R and X.
Then,

$$\frac{E_2}{E_1} = \frac{IX}{IR} = \frac{X}{R} \quad \text{---(i)}$$

$$\text{Or} \quad X = \frac{E_2}{E_1} \cdot R \quad \cdots \text{(ii)}$$

Acc. to the principle of potentiometer

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

From eq. (i), we get

$$r = \frac{l_2}{l_1} \cdot R = \frac{68.5}{58.3} \times 10 = 11.75\,\Omega.$$

24. Here balancing length when cell is in open circuit

$$l_1 = 76.3\,cm$$

Balancing length when cell is in closed-circuit

$$l_2 = 64.8\,cm.$$

and $R = 9.5\,\Omega$.

The internal resistance of the cell is given by

$$r = \left(\frac{l_1}{l_2} - 1\right) R$$

$$= \left(\frac{76.3}{64.8} - 1\right) \times 9.5 = 1.68\,\Omega.$$