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1. Emf of the battery = E = 12V
Internal resistance of the battery, $r = 0.4\Omega$
Maximum current drawn from the battery = I
According to Ohm's law,

$$\varepsilon = Ir$$

$$I = \frac{\varepsilon}{r} = \frac{12}{0.4} = 30\,A$$

The maximum current drawn from the given battery is 30 A.

2. Emf of the battery, $\varepsilon = 10V$
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

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

$$R + r = \frac{\varepsilon}{I} = \frac{10}{0.5} = 20\Omega$$

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

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

$$V = IR$$

$$= 0.5 \times 17 = 8.5\,V$$

$\therefore$ Resistance of the resistor is 17Ω and voltage is 8.5 V.

3. (a) Three resistors of resistances 1Ω, 2Ω and 3Ω are combined in series.
Total resistance = $1 + 2 + 3 = 6\Omega$

(b) Current flowing through the circuit = I

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Emf of the battery, $E = 12V$
Total resistance of circuit = 6Ω
Using Ohm's law, $I = \frac{E}{R} = \frac{12}{6} = 2A$

Potential drop across 1Ω resistor = V_1
From Ohm's law, $V_1 = 2 \times 1 = 2V \rightarrow (1)$

Potential drop across 2Ω resistor = V_2
From Ohm's law, $V_2 = 2 \times 2 = 4V \rightarrow (2)$

Potential drop across 3Ω resistor = V_3
From Ohm's law, $V_3 = 2 \times 3 = 6V \rightarrow (3)$

$\therefore$ Potential drops across resistors are 2V, 4V and 6V.

4. (a) $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 5\Omega$
They connected in parallel. So, total resistance of combination =

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

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

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

(b) Emf of the battery = 20V
Current flowing through resistor R_1 =

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

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

Current flowing through resistor R_2 =

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

current flowing through resistor R_3 is given by -

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

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

5. Room temperature = $27°C$

Resistance at $T = 100\Omega = R$

Let T_1 be the increased temperature of filament.

Resistance of ath $T_1 = 117\Omega = R_1$

Temperature co-efficient of the material of filament,

$$\alpha = 1.70 \times 10^{-4} °C^{-1}$$

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

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

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

$$T_1 - 27 = 1000$$

$$T_1 = 1000 + 27$$

$$\boxed{T_1 = 1027°C}$$

∴ At $1027°C$, the resistance of element is 117Ω

6. Length of wire = $15m$

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

Resistance of the material = 5Ω

Resistivity of " $= \rho$

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

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

7. Temperature $= 27.5^\circ C = T_1$
Resistance of silver wire at $T_1 = 2.1\Omega = R_1$

$T_2 = 100^\circ C$
Resistance of wire at $T_2 = 2.7\Omega = R_2$
Temperature coeffecient of silver $= \alpha$

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} = \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039^\circ C^{-1}$$

$$\boxed{\alpha = 0.0039^\circ C^{-1}}$$

8. Supply voltage $= 230V$
Initial current drawn $= 3.2A = I_2$

$$R_1 = \frac{V}{I} = \frac{230}{3.2} = 71.87\,\Omega$$

Steady state value of current, $I_2 = 2.8A$
Resistance at the steady state =

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

Temperature co-efficient of nichrome $= T_2$

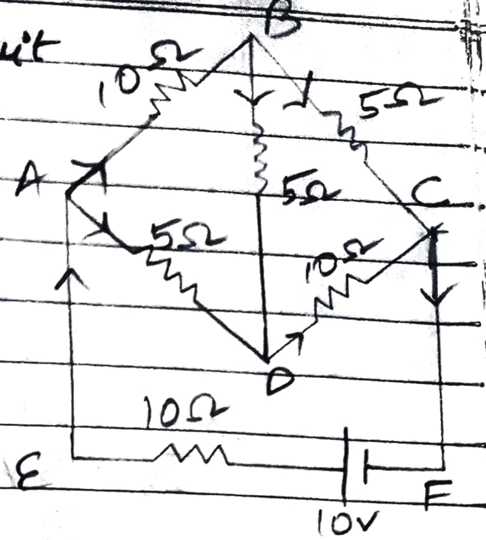
$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

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

$$T_2 = 840.5 + 27$$

$$\boxed{T_2 = 867.5^\circ C}$$

9. I_1 = Current through outer circuit
I_2 = " " branch AB
I_3 = " " " AD
$I_2 - I_4$ = " " " BC
$I_3 + I_4$ = " " " CD
I_4 = " " " BD



For ABDA, potential is zero,
i.e. $I_3 = 2I_2 + I_4 \rightarrow (1)$
For BCDB, potential is zero, i.e.
$I_2 = 2I_3 + 4I_4 \rightarrow (2)$
For ABCFEA, potential is zero. i.e.
$3I_2 + 2I_1 - I_4 = 2 \rightarrow (3)$

For eq (1) and (2), we get →
$I_3 = 2(I_3 + 4I_4) + I_4$
$I_3 = 4I_3 + 8I_4 + I_4$
$-3I_3 = 9I_4$
$I_3 = -3I_4 \rightarrow (4)$

Putting eq (4) in (1), we get →
$I_3 = 2I_2 + I_4$
$-4I_4 = 2I_2$
$I_2 = -2I_4 \rightarrow (5)$
$I_1 = I_3 + I_2 \rightarrow (6)$

Putting eq (6) in (1), we get →
$3I_2 + 2(I_3 + I_2) - I_4 = 2$
$5I_2 + 2I_3 - I_4 = 2 \rightarrow (7)$

Putting eq (4), (5) in (7), we get →
$5(-2I_4) + 2(-3I_4) - I_4 = 2$

$$-10I_4 - 6I_4 - I_4 = 2$$
$$17I_4 = -2$$
$$I_4 = \frac{-2}{17}$$
$$\boxed{BD = \frac{-2}{17}}$$

$$I_3 = -3I_4$$
$$I_3 = \frac{6}{17}A$$
$$\boxed{AD = \frac{6}{17}A}$$

$$I_2 = -2(I_4)$$
$$= \frac{4}{17}A$$
$$\boxed{AB = \frac{4}{17}A}$$

$$I_2 - I_4 = \frac{6}{17}A$$
$$\boxed{BC = \frac{6}{17}A}$$

$$\boxed{I_1 = \frac{10}{17}A}$$

$$I_3 + I_4 = \frac{4}{17}A$$
$$\boxed{CD = \frac{4}{17}A}$$

10. 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

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

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

$$\boxed{X = 8.2\,\Omega}$$

The connection between resistors in a Wheatstone or metre bridge is made up of thick copper strips to minimize the resistance, which is not taken into consideration in the bridge formula.

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(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.

$$100 - l_1 = 100 - 39.5 = 60.5 \text{ cm}$$

$\therefore$ balance point from A is 60.5 cm.

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

(11) Emf of the storage battery, $\mathcal{E} = 8$ V
Internal resistance of the battery, $r = 0.5\,\Omega$
DC supply voltage, $V = 120$ V
Resistance of the resistor, $R = 15.5\,\Omega$
Effective voltage in the circuit $= V_1$

R is connected to the storage battery in series.
So, $V_1 = V - E$

$$V_1 = 120 - 8 = 112 \text{ V}$$

Current flowing in the circuit $= I$

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

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

$$IR = 7 \times 15.5 = 108.5 \text{ V}$$

DC supply voltage = terminal voltage of battery + voltage drop across R.

Terminal voltage of battery $= 120 - 108.5 = 11.5$ V

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A series resistor in a charging circuit limits the current drawn from the external source. The current will be extermely high in its absence. This is very dangerous.

(12) Emf of the cell, $\varepsilon_1 = 1.25\ V$
Balance point of the potentiometer = $l_1 = 35\ cm$
The cell is replaced by another cell of emf ε_2.
New balance point of the potentiometer, $l_2 = 63\ cm$

The balance condition is given by the relation $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$

$$\varepsilon_2 = \varepsilon_1 \times \frac{l_2}{l_1}$$

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

Therefore, emf of second cell = $2.25\ V$

(13) Number density of free electrons in a copper conductor, $n = 8.5 \times 10^{28}\ m^{-3}$
Length of the copper, $l = 3\ m$
Area of cross-section of wire, $A = 2 \times 10^{-6}\ m^2$
Current carried by wire, $I = 3\ A$

$$I = nAev_d$$

where, $e = 1.6 \times 10^{-19}\ C$

$$v_d = \frac{l}{t}$$

$$I = nA\frac{el}{t} \Rightarrow t = \frac{nAel}{I} = \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3}$$

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

$\therefore \boxed{t = 2.7 \times 10^4 s}$

(14) $\sigma = 10^{-9} C m^{-2}$

$I = 1800 A$

$r = 6.37 \times 10^6 m$

$A = 4\pi r^2$

$= 4\pi \times (6.37 \times 10^6)^2$

$= 5.09 \times 10^{14} m^2$

time taken to neutralise the earth's surface = t

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

$t = \frac{q}{I} = \frac{5.09 \times 10^5}{1800} = 282.77 s$

$= 4.72 min (approx.)$

$\therefore$ time taken to neutralise earth's surface is 4.72 mins.

(15) (a) Number of secondary cells = n = 6

Emf of each cell = 2 V

resistance of each cell, r = 0.015 Ω

resistance of resistor = R = 8.5 Ω

$I = \frac{nE}{R + nr} = \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} = 1.39 A$

$V = IR = 1.39 \times 8.5 = 11.87 A$

$\therefore$ Current drawn from supply is 1.39 A and terminal voltage is 11.87 A.

(b) Emf of secondary cell, $\varepsilon = 1.9 V$

Internal resistance = 380 Ω

maximum current $= \frac{\varepsilon}{r} = \frac{1.9}{380} = 0.005 A$

Since a large current is required to start the motor of a car, the cell cannot be used to start a motor.

(16) Resistivity of aluminium = $2.63 \times 10^{-8} \Omega m$
Density of aluminium = $d_1 = 2.7$

Let l_1 be the length of Al wire and m_1 be the mass.
Resistance of Al wire = R_1
Area of cross section = A_1

Resistivity of Cu = $1.72 \times 10^{-8} \Omega m$
Relative density = $d_2 = 8.9$

Let l_1 be the length of Cu and m_2 be the mass.
Resistance = R_2
Area of cross-section = A_2

$R_1 = \rho_1 \frac{l_1}{A_1} \longrightarrow (1)$ $\qquad$ $R_2 = \rho_2 \frac{l_2}{A_2} \longrightarrow (2)$

$R_1 = R_2$ (given)

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

$l_1 = l_2$

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

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

$= \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}} = \frac{2.63}{1.72}$

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Mass of aluminium wire $= V \times d$
$= A_1 l_1 \times d_1$
$= A_1 l_1 d_1 \rightarrow (3)$

Mass of Cu wire $= V \times d$
$= A_2 l_2 \times d_2 = A_2 l_2 d_2 \rightarrow (4)$

Dividing (3) by (4), we get →

$$\frac{m_1}{m_2} = \frac{A_1 l_1 d_1}{A_2 l_2 d_2}$$

$$\Rightarrow \frac{m_1}{m_2} = \frac{A_1 d_1}{A_2 d_2} \quad (\because l_1 = l_2)$$

and $\frac{A_1}{A_2} = \frac{2.63}{1.72}$

$$\frac{m_1}{m_2} = \frac{2.63}{1.72} \times \frac{2.7}{8.9} = 0.46$$

So, m_1 is less than m_2. Hence, Al is lighter than Cu.
Since Al is lighter, it is preferred for overhead power cables over Cu.

(17) It can be inferred from the above table that the ratio of voltage with current is a constant which is 19.7. Hence, manganin is an ohmic conductor i.e. the alloy obeys Ohm's law. According to Ohm's law, the ratio of voltage with current is resistance of conductor. Hence, resistance of manganin is $19.7\ \Omega$.

(18) (a) When a steady current flows in a metallic conductor of non-uniform cross-section, the

current flowing through the conductor is constant. Current density, electric field and drift speed are inversely proportional to the area of cross-section. Therefore, they are not constant.

(b) No, Ohm's law is not universally applicable for all conducting elements. Vaccum diode semi-conductor is a non-ohmic conductor. Ohm's law is not valid for it.

(c) According to Ohm's law, the relation for the potential is $V = IR$

$$V \propto I$$

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

If V is low, then R is very low, so that high current can be drawn from the source.

(d) In order to prohibit the current from exceeding the safety limit, a high tension supply must have a very large internal resistance. If the internal resistance is not large, then the current drawn can exceed the safety limits in case of a short circuit.

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

(b) Alloys usually have lower temperature coefficients of resistance than pure metals.

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

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

(20) (a) Total number of resistors = n
Resistance of each resistor = R

(i) When n resistors are connected in series, effective resistance R_1 is the maximum, given by the product nR. Hence, max. resistance of combination, $R_1 = nR$.

(ii) When n resistors are connected in parallel, the effective resistance (R_2) is min. given by the ratio $\frac{R}{n}$. Hence, min. resistance of the combination, $R_2 = \frac{R}{n}$

(iii) The ratio of the max. to min. resistance is

$$\frac{R_1}{R_2} = \frac{nR}{\frac{R}{n}} = n^2$$

(b) The resistance of given resistors is.
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$

(i) Equivalent resistance = $\frac{11}{3}\Omega$

(ii) Equivalent resistance = $\frac{11}{5}\Omega$

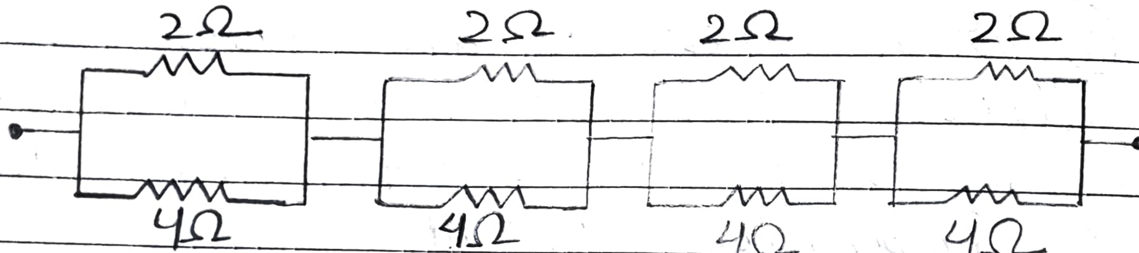
(iii) Equivalent resistance = $1+2+3 = 6\Omega$

(iv) Equivalent resistance = $\frac{6}{11}\Omega$

Ⓒ ⓐ It can be observed from from given circuit that in the first small loop, two resistors of resistance 1Ω each are connected in series. Hence, their equivalent resistance $= 2\Omega$

2 resistors of resistance 2Ω each are also connected in series. Hence, their equivalent resistance $= 4\Omega$.

So, the new circuit can be



It can be observed that 2Ω and 4Ω resistors are connected in parallel in all four loops.
Hence, equivalent resistance $= \frac{4}{3}\Omega$

$\therefore$ Total equivalent resistance $= \frac{16}{3}\Omega$

ⓑ Equivalent resistance of circuit $= R+R+R+R+R$
$= 5R$

(21) Equivalent resistance =

$$R = 2 + \frac{R}{R+1}$$

$$(R)^2 - 2R - 2 = 0$$

$$R = \frac{2 \pm \sqrt{4+8}}{2}$$

$$= \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$$

(−)ve value cannot be accepted. So,
$R = 1 + \sqrt{3} = 1 + 1.73 = 2.73\,\Omega$

Internal resistance = 0.5Ω
Total resistance = $2.73 + 0.5\Omega = 3.23\Omega$
$V = 12V$
Current drawn from source is given by ratio
$$\frac{12}{3.23} = 3.72A$$

(22) (a) Constant emf of given standard cell = 1.02V
Balance point on the wire = 67.3cm

A cell of unknown emf, $\mathcal{E}$ replaced the standard cell. So, new balance point on the wire = 82.3 cm

$$\therefore \frac{\mathcal{E}_1}{l_1} = \frac{\mathcal{E}}{l} \Rightarrow \mathcal{E} = \frac{l}{l_1} \times \mathcal{E}_1$$
$$= \frac{82.3}{67.3} \times 1.02 = \underline{1.247\ V}$$

(b) The purpose of using the high resistance of $600k\Omega$ is to reduce the current through the galvanometer when the movable contact is far from the balance point.

(c) The balance point is not affected by the presence of high resistance.

(d) The method would not work if the driver cell of potentiometer had an emf of 1V instead of 2V. This is because if the emf of the driver cell of potentiometer is less than the emf of cell then there would be no balance point on wire

(e) The circuit would not work well for determining entremely small emf. As the circuit would be unstable, the balance point would be close to end A. Hence, there would be a large percentage of error.
The given circuit can be modified if a series resistance is connected with the wire AB. The potential drop across AB is slightly greater than the emf measured. The percentage error would be small.

(23) Internal resistance of cell = r
Balance point of cell = 76.3 cm
An external resistance is connected to the circuit with R = 9.5 Ω
New balance point = 64.8 cm

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

$$= \frac{76.3 - 64.8}{64.8} \times 9.5 = 1.68\,\Omega$$

∴ Internal resistance of cell is 1.68 Ω