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NCERT EXERCISE :

3.1 Here $E = 12V$, $r = 0.4\,\Omega$

The current drawn from the battery will be maximum when the external resistance in the circuit is zero, i.e., $R = 0$

$$\therefore I_{max} = \frac{E}{r} = \frac{12}{0.4} = 30A$$

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

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

$$R = \frac{E}{I} - r = \frac{10}{0.5} - 3 = 17\,\Omega$$

Terminal voltage,

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

3.3 a) $R_s = R_1 + R_2 + R_3 = 6\,\Omega$

b) Current in the circuit, $I = \frac{E}{R} = \frac{12}{6} = 2A$

$\therefore$ Potential drops across different resistors are
$V_1 = IR_1 = 2 \times 1 = 2V$; $V_2 = IR_2 = 2 \times 2 = 4V$; $V_3 = IR_3 = 2 \times 3 = 6V$

3.4 a) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20}$

$R_p = \frac{20}{19}\ \Omega$

b) Current drawn through different resistors are

$I_1 = \frac{E}{R_1} = \frac{20}{2} = 10A$, $I_2 = \frac{E}{R_2} = \frac{20}{4} = 5A$, $I_3 = \frac{E}{R_3} = \frac{20}{5} = 4A$

Total current drawn from the battery,
$I = I_2 + I_3 + I_{(4)} = 10 + 5 + 4 = 19A$

3.5 Here $R_1 = 100\ \Omega$, $R_2 = 117\ \Omega$, $t_1 = 27^\circ C$,
$\alpha = 1.70 \times 10^{-4}\ {}^\circ C^{-1}$

As $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

$\therefore t_2 - t_1 = \frac{R_2 - R_1}{R_1 \alpha} = \frac{117 - 100}{100 \times 1.70 \times 10^{-4}} = 1000$

$\Rightarrow t_2 = 1000 + t_1 = 1000 + 27 = 1027^\circ C$

3.6 Here $l = 15m$, $A = 6.0 \times 10^{-7}\ m^2$, $R = 5.0\ \Omega$

Restivity, $\rho = \frac{RA}{l} = \frac{5.0 \times 6.0 \times 10^{-7}}{15} = 2.0 \times 10^{-7}\ \Omega m$

3.7 Here $R_1 = 2.1\ \Omega$, $t_1 = 27.5°C$, $R_2 = 2.7\ \Omega$, $t_2 = 100°C$

Temperature coefficient or resistivity of silver,

$$\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)} = \frac{2.7 - 2.1}{2.1(100 - 27.5)} = \frac{0.6}{2.1 \times 72.5} = 0.00394°C^{-1}$$

3.8 Here $V = 230\ V$, $I_1 = 3.2A$, $I_2 = 2.8A$, $\alpha = 1.70 \times 10^{-4}\ °C^{-1}$

Resistance at room temperature,

$$R_1 = \frac{V}{I_1} = \frac{230}{3.2} = 71.875\ \Omega$$

Resistance at steady temperature,

$$R_2 = \frac{V}{I_2} = \frac{230}{2.8} = 82.143\ \Omega$$

Now, $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

$$\therefore t_2 - t_1 = \frac{R_2 - R_1}{R_1 \alpha} = \frac{82.143 - 71.875}{71.875 \times 1.70 \times 10^{-4}} = 840.35°C$$

$$\Rightarrow t_2 = 840.37 + 27 = 867.35°C$$

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3.9 I = Current flowing through the outer circuit,
I_1 = Current flowing through branch AB
I_2 = Current flowing through branch AD
I_3 = Current flowing through branch BD
$I_2 + I_3$ = Current flowing through branch CD
$I_1 - I_3$ = Current flowing through branch BC

For loop ABDA,

$$10I_1 + 5I_3 - 5I_2 = 0$$

For loop BCDB,

$$5(I_1 - I_3) - 10(I_2 + I_3) - 5I_3 = 0$$

For loop ADCFGA,

$$5I_2 + 10(I_2 + I_3) + 10(I_1 + I_2) = 10$$

$$10I_1 - 5I_2 + 5I_3 = 0 \quad \text{--- (1)}$$

$$5I_1 - 10I_2 - 20I_3 = 0 \quad \text{--- (2)}$$

$$10I_1 + 25I_2 + 10I_3 = 0 \quad \text{--- (3)}$$

Solving equations (1), (2) and (3), we get

$I_1 = \frac{4}{17}$ A, $I_2 = \frac{6}{17}$ A, $I_3 = \frac{-2}{17}$ A

Currents in different branches are

$I_{AB} = I_1 = \frac{4}{17} A$, $I_{BC} = I_1 - I_3 = \frac{6}{17} A$

$I_{DC} = I_2 + I_3 = \frac{4}{17} A$

$I_{AD} = I_2 = \frac{6}{17} A$, $I_{BD} = I_3 = \frac{-2}{17} A$

Total current,

$I = I_1 + I_2 = \frac{10}{17} A$

3.10 a) Here $l = 35.9 cm$, $R = X = ?$, $S = Y = 12.5 \Omega$

As $S = \frac{100 - l}{l} \times R$ $\therefore$ $12.5 = \frac{100 - 39.5}{39.5} \times R$

$R = \frac{12.5 \times 39.5}{60.5} = 8.16 \Omega$

Connections are made by thick copper strips to minimise the resistances of connections which are not accounted for in the above formula

b) When X and Y are interchanged,

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$R = Y = 12.5\ \Omega$, $S = X = 8.16\ \Omega$, $l = ?$

As $S = \frac{100-l}{l} \times R$ $\therefore$ $8.16 = \frac{100-l}{l} \times 12.5$

$\Rightarrow 8.16\,l = 1250 - 12.5\,l$

$\Rightarrow l = \frac{1250}{20.66} = 60.5$ cm, from end A.

c) When the galvanometer and cell are interchanged at the balance point, the conditions of the balance bridge are still satisfied and so again the galvanometer will not show any current.

3.11 When the storage battery of 8.0V is charged with a dc supply of 120V, the net emf in the circuit will be

$E' = 120 - 8.0 = 112$ V

Current in the circuit during charging,

$I = \frac{E'}{R+r} = \frac{112}{15.5+0.5} = 7$ A

The terminal voltage of the battery during charging,

$V = E + Ir = 8.0 \times 7 \times 0.5 = 11.5$ V

The series resistor limits the current drawn from the external source. In its absence, the current will be dangerously high.

3.12 Here $E_1 = 12.5V$, $l_1 = 35.0 \text{ cm}$, $l_2 = 63.0 \text{cm}$

$$E_2 = \frac{l_2}{l_1} \times E_1 = \frac{63 \times 1.25}{35} = 2.25V$$

3.13 Here $n = 8.5 \times 10^{28} m^{-3}$, $l = 3 m$, $A = 2.0 \times 10^{-6} m^2$, $e = 1.6 \times 10^{-19} C$, $I = 3.0 A$

Drift speed,

$$v_d = \frac{I}{enA} = \frac{3}{1.6 \times 10^{-19} \times 8.5 \times 10^{28} \times 2 \times 10^{-6}} m/s$$

$$= \frac{3}{16 \times 85 \times 2 \times 10} m/s = 1.1 \times 10^{-4} m/s$$

Required time,

$$t = \frac{l}{v_d} = \frac{3}{1.1 \times 10^{-4}} = 2.73 \times 10^4 s \simeq 7.57h$$

3.14 Surface charge density, $\sigma = 10^{-9} Cm^{-2}$

Radius of the earth, $R = 6.37 \times 10^6 m$

Current, $I = 1800 A$

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Total charge of the globe,

$$q = 4\pi R^2 \sigma$$
$$= 4.314 \times (6.37 \times 10^6)^2 \times 10^{-9}$$
$$= 509.65 \times 10^3 \ C$$

Required time,

$$t = \frac{q}{I} = \frac{509.65 \times 10^3}{1800} = 283.13s \simeq 283s$$

3.15 a) Here $E = 2V$, $r = 0.015 \ \Omega$, $R = 8.5 \ \Omega$, $n = 6$

When the cells are joined in series, the current is

$$I = \frac{nE}{R + nr} = \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} A \simeq 1.4 A$$

Terminal voltage, $V = IR = 1.4 \times 8.5 = 11.9 V$

b Here $E = 1.9V$, $r = 380 \ \Omega$

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

This secondary cell cannot drive the starting motor of a car because that requires a large current of about 100 A for a few seconds.

3.16 Mass = volume × density = $Al\,d$

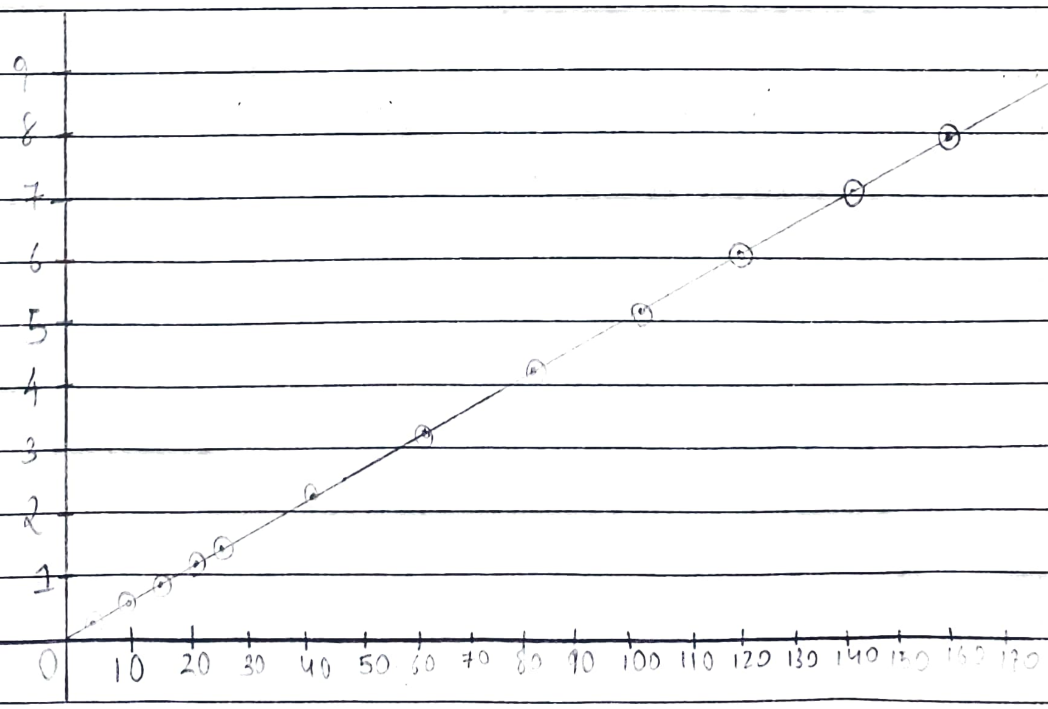
$$= \frac{\rho l}{R} \cdot l d = \frac{\rho d l^2}{R}$$

As the two wires are of equal length and have the same resistance, their mass ratio will be

$$\frac{M_{Cu}}{M_{Al}} = \frac{\rho_{Cu} d_{Cu}}{\rho_{Al} d_{Al}} = \frac{1.72 \times 10^{-8} \times 8.9}{2.63 \times 10^{-8} \times 2.7} = 2.1558 \simeq 2.2$$

i.e., copper wire is 2.2 times heavier than aluminium wire. Since aluminium is lighter, it is preferred for long suspension of cables otherwise heavy cable may sag down due to its own weight

3.17 We plot a graph between current I (along y-axis) and voltage V (along x-axis) as



Since the V-I graph is almost a straight line therefore, manganin resistor is an ohmic resistor for given ranges of voltage and current. As the current increases from 0 to 8A, the temperature increases but the resistance of ~~mang~~ manganin does not change. This indicates that the temperature coefficient of resistivity of manganin alloy is negligibly small.

3.18 a) Only current is constant because it is given to be steady. Other quantities: current density, electric field and drift speed vary inversely with area of cross-section.

b) No, Ohm's law is not universally applicable for all conducting elements. Examples of non-Ohmic elements are vacuum diode, semiconductor diode, thyristor, gas, discharge ~~the~~ tube, electrolytic solution, etc.

c) The maximum current that can ~~take~~ be drawn from a voltage supply is given by

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

Clearly, I_{max} will be large if r is small.

d) If the internal resistance is not very large, then the current will exceed the safety limits in case the circuit is short circuited accidentally.

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3.19 a) greater
b) lower
c) is nearly independent of
d) 10^{22}

3.20 a) For maximum effective resistance, all the n resistors must be connected in series.

∴ Maximum effective resistance, $R_s = nR$

For minimum effective resistance, all the n resistors must be connected in parallel. It is given by

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \ldots n \text{ terms} = \frac{n}{R}$$

∴ Minimum effective resistance, $R_p = \frac{R}{n}$

$$\frac{R_s}{R_p} = \frac{nR}{R/n} = \frac{n^2}{1} = n^2 : 1$$

b Here $R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$

i When parallel combination of 1Ω and 2Ω resistor is connected in series with 3Ω resistor the equivalent resistance is

$$R = R_p + R_3 = \frac{R_1 R_2}{R_1 + R_2} + R_3 = \frac{1\times2}{1+2} + 3 = \frac{2}{3} + 3 = \frac{11}{3}\Omega$$

ii When parallel combination of 2 Ω and 3 Ω resistors is connected in series with 1 Ω resi[stor], the equivalent resistance is

$$R = \frac{R_2 R_3}{R_2 + R_3} + R_1 = \frac{2 \times 3}{2+3} + 1 = \frac{6}{5} + 1 = \frac{11}{5}\ \Omega$$

iii When the three resistances are connected in series, the equivalent resistance is

$$R = R_1 + R_2 + R_3 = 1 + 2 + 3 = 6\ \Omega$$

iv When the three resistances are connected in parallel, the equivalent resistance is

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{11}{6}$$

$$R = \frac{6}{11}\ \Omega$$

e In figure (a):

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

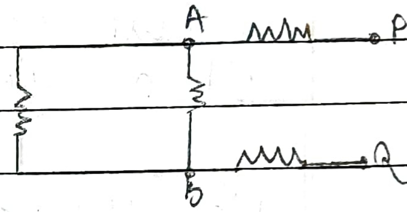
$$R = \frac{4}{3}$$

∴ Resistance of the total network $= \frac{4 \times 4}{3} = \frac{16}{3} \Omega$

In figure (b) :

$R = 5 \Omega$

3·21 Let the equivalent resistance of the infinite network be x. This network consists of infinite units of 3 resistors of $1\Omega, 1\Omega, 1\Omega$.



Resistance between A and B

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

Resistance between P and Q $= 1 + \frac{x}{x+1} + 1 = 2 + \frac{x}{x+1}$

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

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

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

As the value of resistance cannot be negative, so

$x = 1 + \sqrt{3} = 2.732 \Omega$

$I = \frac{E}{x+r} = \frac{12}{2.732+0.5} = 3.713 A$

3.22 a) $E_1 = 1.02\ V$, $l_1 = 67.3\ cm$, $E_2 = E = ?$, $l_2 = 82.3\ cm$

$$\frac{E_2}{E_1} = \frac{l_2}{l_1} \Rightarrow E = \frac{82.3}{67.2} \times 1.02 = 1.25\ V$$

b) High resistance of 600 kΩ protects the galvanometer for positions far away from th balance point, by decreasing current through

c) No, balance point is not affected by high resistance because no current flows through the standard cell at the balance point.

d) No, the arrangement will not work. If the E is greater than the emf of the driver cell of the potentiometer, there will be no balance point on the wire AB.

e) The circuit as it is would be unsuitable because the balance point (for E of the order of a few mV) will be very close to the end A and the percentage error in measurement will be very large. The circuit is modified by putting a suitable resistor R in series with wire AB so that potential drop across AB is only slightly greater than the emf to be measured. Then the balance point will be at larger length of the wire and the percentage error will be much smaller.

3.23 Here $l_1 = 76.3$ cm, $l_2 = 64.8$ cm, $R = 9.5\ \Omega$

The formula for the internal resistance of a cell by the potentiometer method is

$$r = R\left(\frac{l_1 - l_2}{l_2}\right) = 9.5\left(\frac{76.3 - 64.8}{64.8}\right) = \frac{9.5 \times 11.5}{64.8}$$

$$= 1.7\ \Omega$$