NCERT Exercises

CHAPTER 3

Current Electricity

1 The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0.4 Ω, what is the maximum current that can be drawn from the battery?

Ans. We have E = 12 V; r = 0.4 Ω the battery will be the maximum when no external resistance is connected to it.

$$I_{max} = \frac{E}{r + R_{min}} = \frac{E}{r} = \frac{12}{0.4} = 30 \text{ A}$$

2. A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0.5 A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

Ans. Given E = 10 V; r = 3 Ω; R = ?; I = 0.5 A

We have $$I = \frac{E}{R+r} \Rightarrow R + r = \frac{E}{I} = \frac{10}{0.5} = 20$$

$$\therefore \quad R = 20 - r = 20 - 3 = 17\ \Omega.$$

Terminal voltage = $E - Ir$ = 10 – (.5) (3) = 8.5 V.

3. (*a*) Three resistors 1 Ω, 2 Ω and 3 Ω are combined in series. What is the total resistance of the combination?

(*b*) If the combination is connected to a battery of emf 12 V and negligible internal resistance, obtain the potential drop across each resistor.

Ans. (*a*) We have R_1 = 1 Ω; R_2 = 2 Ω; R_3 = 3 Ω

In series combination R_S = 1 + 2 + 3

$= R_1 + R_2 + R_3 = 6\ \Omega.$

(*b*) With E = 12 V; $$I = \frac{E}{R_S} = \frac{12}{6} = 2 \text{ A}$$

$$\therefore \quad V_1 = IR_1 = 2 \times 1 = 2 \text{ V};$$

$$V_2 = IR_2 = 2 \times 2 = 4 \text{ V}; \quad V_3 = IR_3 = 2 \times 3 = 6 \text{ V}.$$

4. (*a*) Three resistors 2 Ω, 4 Ω and 5 Ω are combined in parallel. What is the total resistance of the combination?

(*b*) If the combination is connected to a battery of emf 20 V and negligible internal resistance, determine the current through each resistor, and the total current drawn from the battery.

Ans. (*a*) Given $R_1 = 2\ \Omega$; $R_2 = 4\Omega$; $R_3 = 5\ \Omega$; $E = 20$ V

For parallel combination $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} =$

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

$$\therefore \quad R_p = \frac{20}{19}\,\Omega$$

(*b*) In parallel combination, potential difference across each resistance will be the same *i.e.* 20 V

$$I_1 = \frac{V}{R_1} = \frac{20}{2} = 10\text{ A};\ I_2 = \frac{V}{R_2} = \frac{20}{4} = 5\text{ A};$$

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

$$\therefore \quad I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19\text{ A.}$$

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CHAPTER 3

Current Electricity

5. At room temperature (27.0°C) the resistance of a heating element is 100 Ω What is the temperature of the element if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the resistor is 1.70×10^{-4} °C^{-1}.

Ans. We have $T_1 = 27°C$; $R_1 = 100\ \Omega$; $R_2 = 117\ \Omega$ and $\alpha = 1.7 \times 10^{-4} °C^{-1}$

Using $$R_2 = R_1 [1 + \alpha(T_2 - T_1)]$$

$$117 = 100 [1 + 1.7 \times 10^{-4}(T_2 - 27)]$$

$$\therefore \quad 1.7 \times 10^{-4}(T_2 - 27) = 0.17$$

$$T_2 - 27 = \frac{0.17}{1.7 \times 10^{-4}} = 1000 \text{ or } T_2 = 1027°C.$$

6. A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 Ω. What is the resistivity of the material at the temperature of the experiment?

Ans. Given $l = 15$ m $A = 6 \times 10^{-7}$ m^2; $R = 5.0\ \Omega$; $\rho = ?$

Using $$R = \frac{\rho l}{A}; \text{ we get } \rho = \frac{RA}{l} = 5 \times \frac{6 \times 10^{-7}}{15}$$

$$= 2 \times 10^{-7}\ \Omega\ \text{m}$$

7. A silver wire has a resistance of 2.1 Ω at 27.5 °C, and a resistance of 2.7 Ω at 100 °C. Determine the temperature coefficient of resistivity of silver.

Ans. We have $T_1 = 27.5°C$ $R_1 = 2.1\ \Omega$; $T_2 = 100°C$; $\alpha = ?$

$$\therefore \quad \alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} = \frac{2.7 - 2.1}{2.1(100 - 27.5)}$$

$$= \frac{0.6}{2.1 \times 72.5} = 0.0039°C^{-1}$$

8. A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27.0°C? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is 1.70 × 10^{-4}°C.

Ans. Given V= 230 V; At T_1 = 27°C; I_1 = 3.2 A;
At T_2; I_2 = 2.8 A and $\alpha = 1.7 \times 10^{-4}\,°\text{C}^{-1}$

$$\therefore \qquad R_1 = \frac{V}{I_1} = \frac{230}{3.2} = \frac{2300}{32}\,\Omega$$

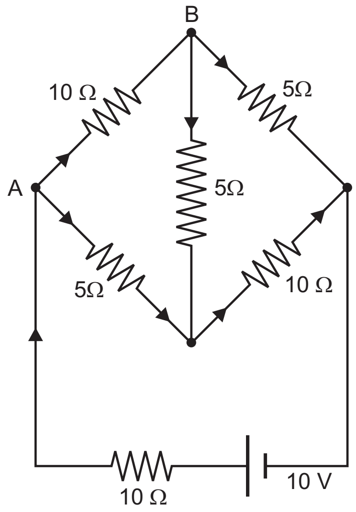
Similarly at T_2; $R_2 = \dfrac{V}{T_2} = \dfrac{2300}{28}\,\Omega$

As $$R_2 = R_1[1 + \alpha(T_2 - T_1)]$$

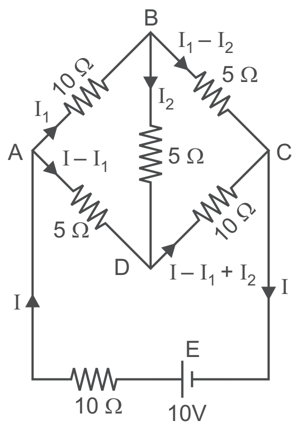
$$\therefore \qquad T_2 - T_1 = \frac{R_2 - R_1}{R_1\,\alpha} = \frac{\dfrac{2300}{28} - \dfrac{2300}{32}}{\dfrac{2300}{32} \times 1.7 \times 10^{-4}} = 840.$$

$$\Rightarrow \qquad T_2 = T_1 + 840 = 27 + 840 = 867°\text{C}.$$

9. Determine the current in each branch of the network shown in Fig. below



Ans. The current distribution in the circuit in terms of I, I_1 and I_2 applying junction rule is as shown.



Using loop rule in $ABDA$, $10I_1 + 5I_2 - 5(I - I_1) = 0$

or $5I - 15I_1 - 5I_2 = 0$ ...(1)

By loop rule in $BCDB$,

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

or $10I - 15I_1 + 20I_2 = 0$ ...(2)

In loop ABCEA, $10I_1 + 5(I_1 - I_2) - 10 + 10I = 0$

or $10I + 15I_1 - 5I_2 = 10$ ...(3)

From (1) $10I = 30I_1 + 10I_2$ ...(4)

From (2) $10I = 15I_1 - 20I_2$ ...(5)

From (3) $10I = -15I_1 + 5I_2 + 10$ ...(6)

From (4) and (5) $30I_1 + 10I_2 = 15I_1 - 20I_2 \Rightarrow I_1 = -2I_2$

From (5) and (6) $15I_1 - 20I_2 = -15I_1 + 5I_2 + 10$

or $30I_1 = 25I_2 + 10$

$30(-2I_2) = 25I_2 + 10$

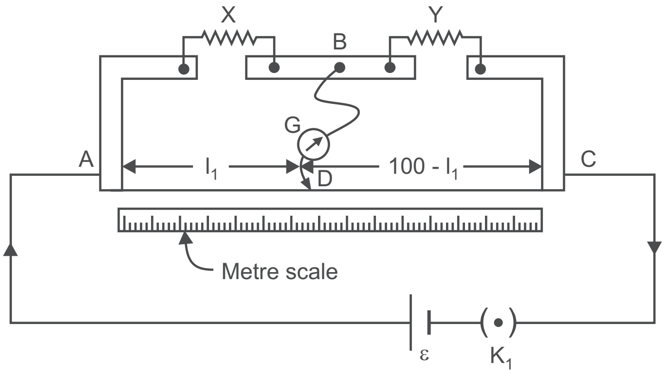
$-85I_2 = 10 \Rightarrow I_2 = -\frac{2}{17}\text{ A}.$

$\therefore \quad I_1 = -2\left(-\frac{2}{17}\right) = \frac{4}{17}\text{ A}$

and $$I = \frac{30I_1 + 10I_2}{10} = 3I_1 + I_2 = \frac{10}{17}\text{ A.}$$

$$\therefore \quad I_{BC} = \frac{6}{17}\text{ A}; \; I_{AD} = \frac{6}{17}\text{ A}; \; I_{DC} = \frac{4}{17}\text{ A}$$

10. (*a*) In a metre bridge [Fig. below], the balance point is found to be at 39.5 cm from the end *A*, when the resistor *Y* is of 12.50 Ω. Determine the resistance of *X*. Why are the connections between resistors in a Wheatstone or meter bridge made of thick copper strips?



(*b*) Determine the balance point of the bridge above if *X* and *Y* are interchanged.

(*c*) What happen if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

Ans. (*a*) We have $Y = 12.5\ \Omega$, $AD = l_1 = 39.5$ cm; $DC = 100 - l_1 = 60.5$ cm

For balanced bridge $$\frac{X}{Y} = \frac{l_1}{100 - l_1} \Rightarrow X = Y.\frac{l_1}{100 - l_1}$$

$$= \frac{12.5 \times 39.5}{60.5} = 8.2\ \Omega. \quad ...(1)$$

The resistances of the connecting wires are not taken into consideration while deriving balance condition in Wheatstone bridge. So their resistance should be very small to minimise errors. Hence thick copper strips are used.

(*b*) We have $$\frac{X}{Y} = \frac{39.5}{60.5} \; ...(1) \text{ and } \frac{Y}{X} = \frac{l_2}{100 - l_2} \quad ...(2)$$

(1) × (2) gives $$\left(\frac{l_2}{100 - l_2}\right)\frac{39.5}{60.5} = 1 \text{ or } l_2 = 60.5 \text{ cm.}$$

(*c*) Interchanging cell and galvanometer in a balanced bridge does not alter the balance condition.

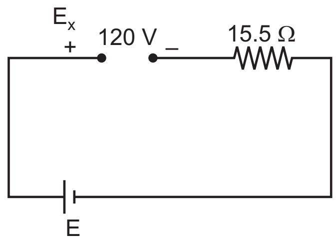
So the galvanometer will not show any deflection.

11. A storage battery of emf 8.0 V and internal resistance 0.5 Ω is being charged by a 120 V *dc* supply using a series resistor of 15.5 Ω. What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?

Ans. Here $E = 8$ V; $R = 15.5\ \Omega$; $r = 0.5\ \Omega$; $E_x = 120$ V

We have $E_x - E = I(R + r)$

$112 = 16\, I$ or $I = 7$A



Terminal voltage while charging = $E + Ir = 8 + 3.5 = 11.5$ V

The 15 Ω resistance introduced in the circuit limits the charging current which would otherwise be very high.

12. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shift to 63.0 cm, what is the emf of the second cell?

Ans. We have E_1 = 1.25 V; l_1 = 35.0 cm; l_2 = 63.0 cm; E_2 = ?

By principle of potentiometer $\frac{E_1}{E_2} = \frac{l_1}{l_2} \Rightarrow E_2 = E_1 \times \frac{l_2}{l_1} =$

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

13. The number density of free electrons in a copper conductor is 8.5 × 10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is 2.0 × 10^{-6} m^2 and it is carrying a current of 3.0 A.

Ans. Given $n = 8.5 \times 10^{28}/m^3$; l = 3.0 m; $A = 2.0 \times 10^{-6}$ m^2; I = 3A.

$\therefore$ Drift velocity $v_d = \frac{I}{neA}$

$$= \frac{3}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 2 \times 10^{-6}} \simeq 1.1 \times 10^{-4} \text{ ms}^{-1}$$

Also Length of the conductor $(L) = v_d t \Rightarrow t = \frac{L}{v_d}$

$$= \frac{3}{1.1 \times 10^{-4}} = 2.7 \times 10^4 \text{ sec}$$

$$= \frac{27000}{60 \times 60} = 7.5 \text{ hours}$$

ADDITIONAL EXERCISES

14. The earth's surface has a negative surface charge density of 10^{-9} C m^{-2}. The potential difference of 400 kV between the top of the atmosphere and the surface results (due to the low conductivity of the lower atmosphere) in a current of only 1800 A over the entire globe. If there were no mechanism of sustaining atmospheric electric field, how much time (roughly) would be required to neutralise the earth's surface? (This never happens in practice because there is a mechanism to replenish electric charges, namely the continual thunderstorms and lightning in different parts of the globe). (Radius of earth = 6.37 × 10^6 m)

Ans. Given surface charge density $\sigma = 10^{-9}$ C m^{-2}

$R = 6.37 \times 10^6$ m; I = 1800 A

Total charge $Q = \sigma . 4\pi R^2 = I.t$

$$\therefore \quad t = \frac{\sigma . 4\pi R^2}{I} = \frac{10^{-9} \times 4\pi \times (6.37 \times 10^6)^2}{1800} = 283 \text{ s.}$$

15. (*a*) Six lead-acid type of secondary cells each of emf 2.0 V and internal resistance 0.015 Ω are joined in series to provide a supply to a resistance of 8.5 Ω. What is the current drawn from the supply and its terminal voltage?

(*b*) A secondary cell after long use has an emf of 1.9 V and a large internal resistance of 380 Ω. What maximum current can be drawn form the cell? Could the cell drive the starting motor of a car?

Ans (*a*) Given No. of cells = 6; emf of each cell = e = 2.0 V

$$r = 0.015\ \Omega;\ R = 8.5\ \Omega$$

Total *emf* $E = 6\ e = 12\ \text{V} = I(R + 6r)$

[∵ Internal resistance = $6r$]

$$I = \frac{12}{8.5 + .09} = \frac{12}{8.59} = 1.4\ \text{A}$$

Terminal voltage = $E - I(6r) = 12 - (1.4)(.09) \simeq 11.9$ V

(*b*) Solve as *Q* 3.1. The current 5 m *A* is too small to start a car.

16. Two wires of equal length, one of aluminium and the other of copper have the same resistance. Which of the two wires is lighter? Hence explain why aluminium wires are preferred for overhead power cables. (ρ_{Al} = 2.63 × 10^{-8} Ω m, ρ_{Cu} = 1.72 × 10^{-8} Ω m, Relative density of *Al* = 2.7, of *Cu* = 8.9.)

Ans. Given $R_{Al} = R_{Cu}$; $\rho_{Al} = 2.63 \times 10^{-8}$ Ωm; $\rho_{Cu} = 1.72 \times 10^{-8}$ Ωm

Relative density of *Al* = 2.7; Relative density of *Cu* = 8.9

As $R_{A\ell} = R_{Cu}$; we get $\frac{\rho_{Al}\, l_{Al}}{A_{Al}} = \frac{\rho_{Cu}\, l_{Cu}}{A_{Cu}}$ or $\frac{\rho_{Al}}{A_{Al}} = \frac{\rho_{Cu}}{A_{Cu}}$

$$\frac{A_{Al}}{A_{Cu}} = \frac{\rho_{Al}}{\rho_{Cu}} = \frac{2.63 \times 10^{-8}}{1.72 \times 10^{-8}} = \frac{263}{172}$$

$$\frac{\text{Mass of } Al \text{ wire}}{\text{Mass of } Cu \text{ wire}} = \frac{A_{Al}}{A_{Cu}} \cdot \frac{d_{Al}}{d_{Cu}} = \frac{263}{172} \times \frac{27}{89} = 0.47$$

So Aluminium wire being lighter is used as overhead power cable. It is also cost effective

17. What conclusion can you draw from the following observations on a resistor made of alloy manganin?

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	98.8
0.8	15.7	6.0	118.5
1.0	19.7	7.0	138.2
2.0	39.4	8.0	158.0

Ans. The ratio $\frac{V}{I}$ for all observation is nearly 19.7 Ω. *i.e.* constant. The student may calculate $\frac{V}{I}$ for the observations given. Hence manganin is an ohmic resistor.

18. **Answer the following questions:**

(*a*) **A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities remain constant along the conductor: current, current density, electric field, drift speed?**

(*b*) **Is Ohm's law universally applicable for all conducting elements? If not, give examples of elements which do not obey Ohm's law.**

(*c*) **A low voltage supply from which one needs high currents must have very low internal resistance. Why?**

(*d*) **A high tension (HT) supply of, say, 6 kV must have a very large internal resistance. Why?**

Ans. (*a*) Current remains constant.

(*b*) No, it is not universal. Semiconductor diodes, electrolytes; discharge tube etc. do not obey Ohm's law.

(*c*) As $I_{max} = \frac{E}{r}$; for large current, r must be small.

(*d*) If a HT source has low r; short circuiting will imply dangerously large current damaging appliances and may even cause fire.

19. **Choose the correct alternative:**

(*a*) **Alloys of metals usually have (greater/less) resistivity than that of their constituent metals.**

(*b*) **Alloys usually have much (lower/higher)temperature coefficients of resistance than pure metals.**

(*c*) **The resistivity of the alloy managanin is *nearly independent of/ increases rapidly with* increase 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}/10^3).**

Ans. (*a*) Greater

(*b*) lower

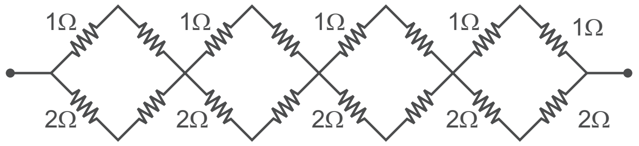
(*c*) nearly independent of

(*d*) 10^{22}.

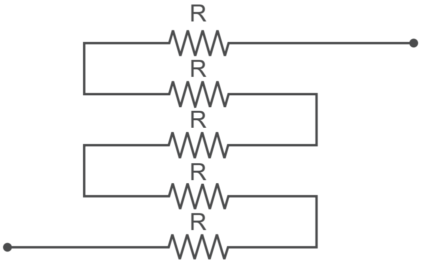
20. **(*a*)** **Given n resistors each of resistance R, how will you combine them to get the (*i*) maximum (*ii*) minimum effective resistance? What is the ratio of the maximum to minimum resistance?**

(*b*) **Given the resistances of 1 Ω, 2 Ω, 3 Ω, how will you combine them to get an equivalent resistance of (i) (11/3) Ω, (*ii*) (11/5) Ω, (*iii*) 6 Ω, (*iv*) (6/11) Ω?**

(*c*) **Determine the equivalent resistance of networks shown in (*a*) and (*b*).**



(a)



(b)

Ans. (*a*) (*i*) In series for maximum resistance. $R_s = nr$.

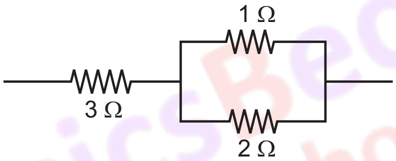
(*ii*) In parallel for minimum resistance $R_p = \dfrac{r}{n}$

and $\dfrac{R_s}{R_p} = n^2$.

(*b*) Given $R_1 = 1\Omega$; $R_2 = 2\ \Omega$; $R_3 = 3\ \Omega$.

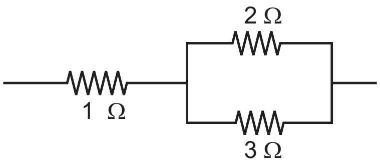
(*i*) $R_{net} = \dfrac{11}{3}\Omega\,; = 3\dfrac{2}{3}\Omega$ can be obtained by connecting parallel combination of 1 Ω and 2 Ω in series 3 Ω resistance as shown.

$$R_{net} = 3 + \frac{2 \times 1}{2+1} = 3 + \frac{2}{3} = \frac{11}{3}\ \Omega.$$



(*ii*) For $R_{net} = \dfrac{11}{5}\Omega$; one ohm in series with a parallel combination of 2 Ω and 3 Ω

$$R_{net} = 1 + \frac{3 \times 2}{3+2} = 1 + \frac{6}{5} = \frac{11}{5}\Omega.$$

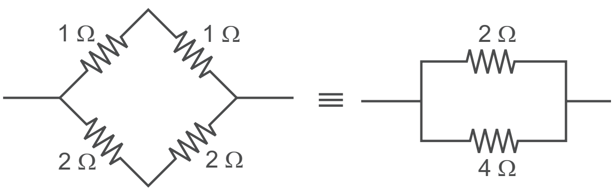


(*iii*) For $R_{net} = 6\ \Omega$; R_1; R_2 and R_3 in series

(*iv*) For $R_{net} = \dfrac{6}{11}\Omega < 1\ \Omega$; all three resistances in parallel

$$\because\ \frac{1}{R} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6} \Rightarrow R = \frac{6}{11}\ \Omega.$$

(*c*) (*i*)The circuit contains four identical elements connected in series.



For one element above shown

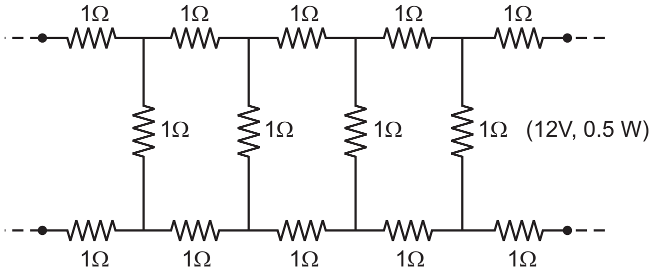
$R_{eff} = \frac{2 \times 4}{2+4} = \frac{8}{6} = \frac{4}{3}\,\Omega$ [parallel combination of 2 Ω and 4 Ω]

$\therefore \quad R_{net} = 4 \times R_{eff} = \frac{16}{3}\,\Omega$.

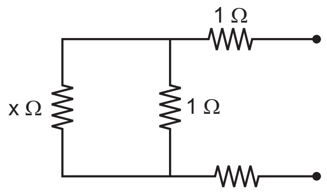
(*ii*) In fig (b) the combination has only one path for flow of current and is hence a series combination of five resistances

$\therefore\ R_{net} = 5$ R.

21. Determine the current drawn from a 12V supply with internal resistance 0.5Ω by the infinite network shown in Fig. below. Each resistor has 1 Ω resistance.



Ans. The given circuit can be redrawn as a combination of an infinite ladder of resistance *x* Ω with one repeating element as shown.



Effective resistance of *x* Ω and 1 Ω parallel combination = $\frac{x \times 1}{x+1} = \frac{x}{x+1}$

$$\therefore \quad R_{net} = \frac{x}{x+1} + 1 + 1 = 2 + \frac{x}{x+1} = \frac{3x+2}{x+1}$$

Addition of one element to an infinite ladder does not alter the resistance *i.e.*, it remains *x* Ω.

$$\therefore \quad x = \frac{3x+2}{x+1} \Rightarrow x^2 + x = 3x + 2$$

or $\quad x^2 - 2x - 2 = 0$

$$\therefore \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{2 \pm \sqrt{4+8}}{2}$$

$$= \frac{2 \pm 2\sqrt{3}}{2} = \left(1 \pm \sqrt{3}\right).$$

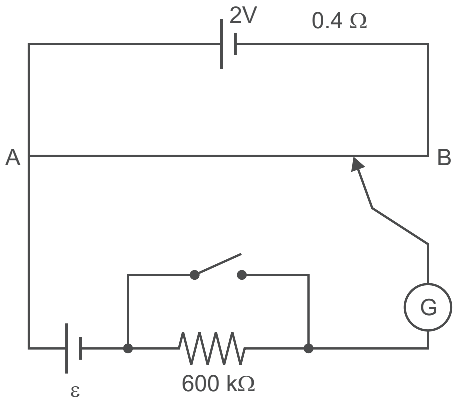
(Ignore $1-\sqrt{3}$ as resistance cannot be negative)

Hence $\quad R_{net} = 1+\sqrt{3} = 2.732\ \Omega$

Current drawn from 12 V, 0.5 Ω source is given by

$$I = \frac{E}{R+r} = \frac{12}{2.732+.5} = \frac{12}{3.232} = 3.71 \text{ A.}$$

22. The figure below shows a potentiometer with a cell of 2.0 V and internal resistance 0.40 Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents up a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf ε and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



(*a*) What is the value ε?

(*b*) What purpose does the high resistance of 600 kΩ have?

(*c*) Is the balance point affected by this high resistance?

(*d*) Is the balance point affected by the internal resistance of the driver cell?

(e) Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0V instead of 2.0V?

(*f*) Would the circuit work well for determining an extremely small emf, say of the order of a few mV (such as the typical emf of a thermo-couple)? If not, how will you modify the circuit?

Ans. (*a*) Solve as Q. 12 on page 83

(*b*) The high resistance reduces the current through the galvanometer when it is far from the balance point and hence protects the galvanometer from damage.

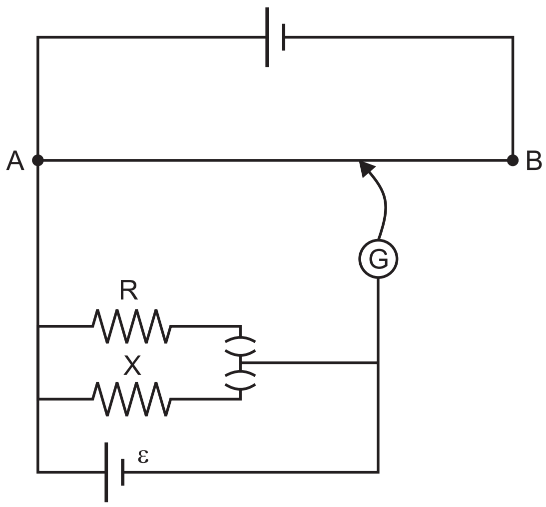
(*c*) It does not affect the balance point.

(*d*) Higher the internal resistance, smaller the current. This reduces case, the potential gradient. So the balancing length increases.

(e) With 1V driver cell; no balance point will be obtained.

(*f*) A high resistance in series with the driver cell (2V) reduces the current and hence the potential gradient. This increases the balancing length for smaller emf reducing the error.

23. The figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistor R = 10.0 Ω is found to be 58.3 cm, while that with the unknown resistance X is 68.5 cm. Determine the value of X. What might you do if you failed to find a balance point with the given cell of emf ε?



Ans. Let k be the potential gradient of the wire.

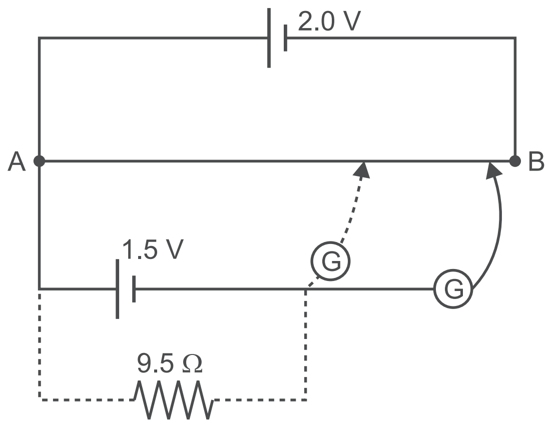
Then $$\frac{V_X}{V_R} = \frac{X}{R} = \frac{k\,l_2}{k\,l_1} = \frac{l_2}{l_1}$$

$\therefore$ $$X = \frac{R\,l_2}{l_1} = 10 \times \frac{68.5}{58.3} = 11.8\ \Omega.$$

Balance point is not obtained if V_R or V_X exceed the potential difference across AB.

In such case, balance point can be obtained by reducing V_R and V_X by means of a series resistance with E.

24. The figure below shows a 2.0 V potentiometer used for the determination fo internal resistance of a 1.5 V cell. The balance point of the cell in open circuit is 76.3 cm. When a resistor of 9.5 Ω is used in the external circuit of the cell, the balance point shifts to 64.8 cm length of the potentiometer wire. Determine the internal resistance of the cell.



Ans. In open circuit; $E = k\,l_1 = 76.3$ k

In closed circuit $V = k\,l_2 = 64.8$ k with $R = 9.5\ \Omega$.

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

$$= \mathbf{1.7\ \Omega.}$$