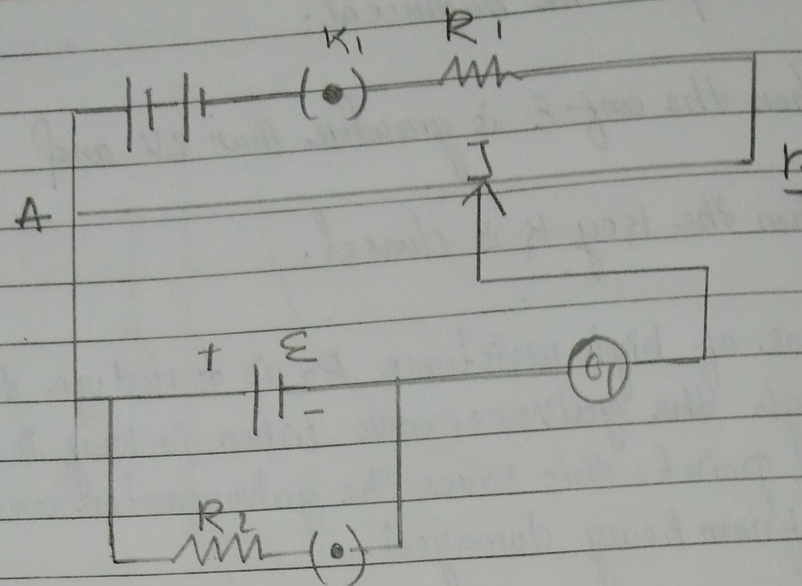


Ans (i) R_1 is increased because the potential gradient would increase.

(ii) R_2 is increased because the terminal p.d across the cell would increase.

NCERT EXERCISE

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 $E = 12V$ $r = 0.4\Omega$

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

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

2. A battery of emf 10V and internal resistance 3Ω is

connected to a resistor. If the current in the circuit is 0.5A what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

Ans $r = 3\Omega$ $I = 0.5A$.

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

$$0.5 = \frac{10}{R+3}$$

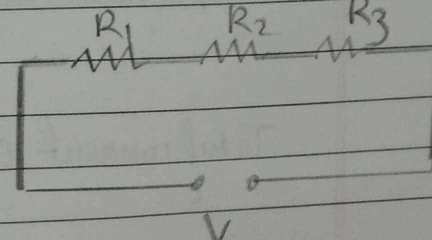
$$R+3 = 20$$

$$R = 17\Omega$$

The circuit is closed the terminal voltage.

$$V = E - Ir = 10 - 0.5 \times 3 = 10 - 15 = 8.5V.$$

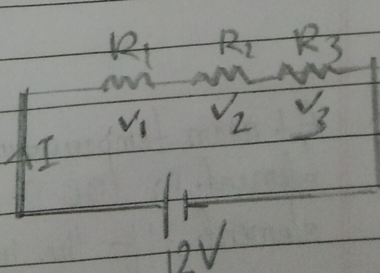
3. (a) Three resistance 1Ω, 2Ω, and 3Ω are combined in series. What is the total resistance of the combination.
(b) If the combination is connected to a battery of emf 12V and negligible internal resistance, obtain the potential drop across each resistor.



Ans a) $R_1 = 1\Omega$ $R_2 = 2\Omega$ $R_3 = \Omega$.

$$R_S = R_1 + R_2 + R_3$$

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



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

R_1 $V_1 = IR_1 = 2 \times 1 = 2V$

R_2 $V_2 = IR_2 = 2 \times 2 = 4V.$

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4. (a) Three region resistor 2Ω, 4Ω and 5Ω are combined in parallel. what is the total resistance of the combination?

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

Ans- $R_1 = 2\Omega$, $R_2 = 4\Omega$ $R_3 = 5\Omega$

(a) $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5}$.

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

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

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

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

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

Total current drawn $I = I_1 + I_2 + I_3$.

$10 + 5 + 4 = 19A$.

Total current drawn from the battery $I = I_1 + I_2 + I_3$

$= 10 + 5 + 4$

$= 19A$.

5. At room temperature ($27°C$) the resistance of a heating element in 100Ω. what is the temperature of the element if the resistance is found to be 117Ω given

given that the temperature coefficient of the material of the resistor is $1.70 \times 10^{-4}/°C$.

Ans

$R_{27} = 100\Omega$ $\quad t°C = R_t = 117\Omega$

$\alpha = 1.70 \times 10^{-4}/°C$.

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

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

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

$$t = 1000 + 27$$

$$= 1027°C$$

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

Ans

$A = 6.0 \times 10^{-7} m^2$

$l = 15m$

$R = 5\Omega$

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

$$\rho = \frac{RA}{l} = \frac{5 \times 6.0 \times 10^{-7}}{15}$$

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

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 $R_{27.5} = 2.1\,\Omega$

$R_{100} = 2.7\,\Omega$.

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

$$\alpha = \frac{R_{100} - R_{27.5}}{R_{27.5}(100 - 27.5)}$$

$$\frac{2.7 - 2.1}{2.1 \times 72.5}$$

$$\alpha = 0.0039\,/^\circ C.$$

8. A heating element using nichrome connected to a 230V 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 $1.70 \times 10^{-4}\,°C^{-1}$. Q

Ans potential difference = 230V.

$I_{27°C} = 3.2A$.

$t°C = I_{t°C} = 2.8A$.

Room temperature = 27°C

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

~~$1.7 \times 10^{-4} = \frac{2300}{28}$~~

$$R_{27^\circ C} = \frac{V}{I_{27^\circ C}} = \frac{230}{3.2} = \frac{2300}{32}\ \Omega$$

$$R_{t^\circ C} = \frac{V}{I_{t^\circ C}} = \frac{230}{2.8} = \frac{2300}{28}\ \Omega.$$

$$\alpha = 1.7 \times 10^{-4} = \frac{\frac{2300}{28} - \frac{2300}{32}}{\frac{2300}{32}(t-27)}.$$

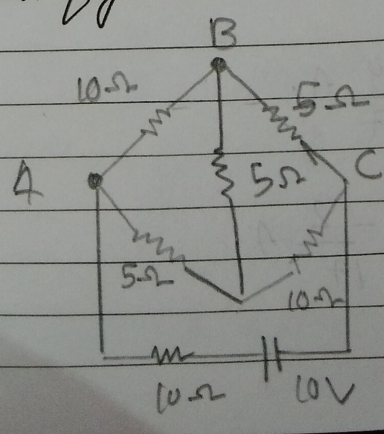
$$t - 27 = \frac{82.143 - 71.875}{71.875 \times 1.7 \times 10^{-4}}$$

$$= 840.347.$$

$$t = 840.3 + 27$$

$$= 867.3^\circ C.$$

Q. Determine the current in each branch of the network shown in figure -



In loop ABDA.

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

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

$$3I_1 + I_2 = I$$

In loop BCDB

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

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

$$3I_1 - 4I_2 = 2I.$$

$$I_1 = \frac{2I}{5} \quad I_2 = -\frac{1}{5}$$

In loop ABCEFA.

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

$$2 = 2I + 3I_1 - I_2$$

$$2 = 2I + 3\left(\frac{2I}{5}\right) - \left(-\frac{1}{5}\right)$$

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

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

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

$$I_2 = -\frac{1}{5} = -\frac{2}{17} A.$$

$$I_1 = \frac{4}{17} A.$$

$$I_1 - I_2 = \frac{4}{17} - \left(-\frac{2}{17}\right) = \frac{6}{17} A.$$

$$1 - I_1 = \frac{10}{17} - \frac{4}{17} = \frac{6}{17} A.$$

$$(1 - I_1) + I_2 = \frac{6}{17} + \left(\frac{-2}{17}\right) = \frac{4}{17} A.$$

Q10. (a) In a meter bridge the balance point is found to be at 39.5 cm from the end A, when the resistor Y is of 12.5 Ω. Determine the resistance of X. Why are the connection between resistor 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 happens, if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

Ans (a) $l = 39.5\,cm$.

$Y = 12.5\,\Omega$.

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

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

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

The resistance of resistor X is 8.16 Ω.

In meter bridge, the resistance at the connection is not taken in the consideration that's why the connections between resistors in a Wheatstone bridge or meter bridge made of thick copper strips because more is the thickness lesser the resistance (as $R \propto \frac{1}{A}$) So due to thick copper strips, the resistance at the connection becomes minimum.

(b) If X and Y are interchanged then the balance length will also interchanged. Thus the balance length becomes

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

(c) If the galvanometer and cell are interchanged at the balance point of the bridge, the balance point is not obtained. The galvanometer shows no 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 series resistor in the charging circuit?

$e = 8\text{ V}$ $V = 120\text{ V}$.

$$E = V - e = 120 - 8 = 112\text{ V}.$$

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

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

$V = E + Ir = 8 + 7(0.5) = 11.5 V.$

12. The number density of free electron in a copper conductor estimated at $8.5 \times 10^{28} m^{-3}$. 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 $2.0 \times 10^{-6} m^2$ and it is carrying a current of 3.0 A.

$n = 8.5 \times 10^{28} / m^3$

$l = 3 m$

$A = 2 \times 10^{-6} m^2$

$I = 3 A \quad e = 1.6 \times 10^{-19}$

$$t = \frac{\text{length of the wire}}{\text{Drift velocity}} = \frac{l}{V_d}$$

$I = neAV_d$

$$V_d = \frac{I}{neA}$$

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

$t = 2.72 \times 10^4 s$

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13. (a) Six lead acid type of secondary cell 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 are the current draw from the supply and its terminal voltage?

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

Ans

Ans $E = 2V$.

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

$n = 6$.

$r = 0.015 \Omega$.

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

$R = 8.5 \Omega$.

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

$= 1.4A$.

$V = IR = 1.4 \times 8.5 = 11.9V$.

(b) Emf of cell $E = 1.9V$.

$r = 380 \Omega$.

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

14. Two wire of equal length one of aluminum and the other of copper have the same resistance. Which of the two wires is lighter? Hence explain why aluminium wire are preferred for

over head power cables?
($\rho_{Al} = 2.63 \times 10^{-8}\ \Omega m$, $\rho_{Cu} = 1.72 \times 10^{-8}\ \Omega \cdot m$ Relative density of Al = 2.7 of Cu = 8.9).

Ans

$$R_{Al} = \rho_{Al} \cdot \frac{l_{Al}}{A_{Al}} = \frac{2.63 \times 10^{-8} \times L}{A}.$$

$$m_{Al} = A_{Al} \times L_{Al} \times d_{Al} = A_1 \times L \times 2.7.$$

$$R_{Cu} = \rho_{Cu} \times \frac{l_{Cu}}{A_{Cu}} = \frac{1.72 \times 10^{-8} \times L}{A_2}.$$

$$m_{Cu} = A_{Cu} \times l_{Cu} \times d_{Cu} = A_2 \times L \times 8.9.$$

$$R_{Al} = R_{Cu}.$$

$$\frac{2.63 \times 10^{-8} \times L}{A_1} = \frac{1.72 \times 10^{-8} \times L}{A_2}$$

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

$$\frac{m_{Al}}{m_{Cu}} = \frac{A_1 \times L \times 2.7}{A_2 \times L \times 8.9}.$$

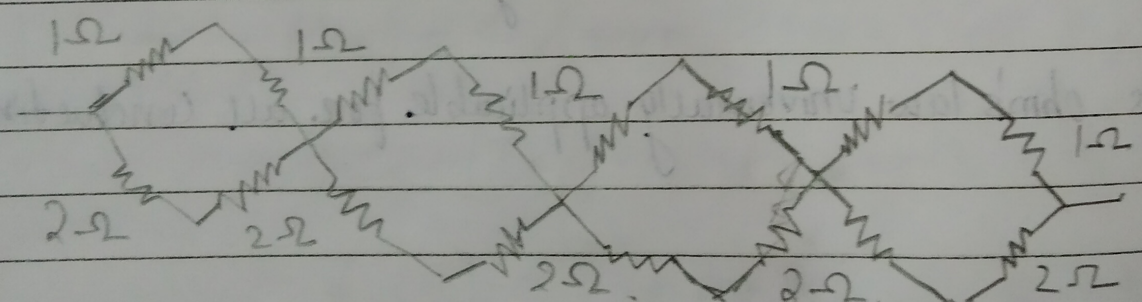
$$\frac{m_{Al}}{m_{Cu}} = \frac{2.63 \times 2.7}{1.72 \times 8.9}.$$

$$\frac{m_{Cu}}{m_{Al}} = 2.16.$$

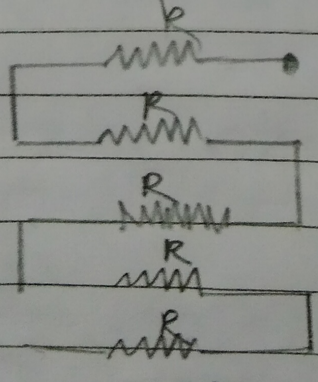
14. (a) Given n resistor each of resistance R how will you combine them to get the (i) maximum (ii) minimum effective resistance? What is the ratio of the maximum to minimum resistance?

(b) Given the resistance of 1Ω, 2Ω and 3Ω how will we combine them to get an equivalent resistance of
(i) $\frac{11}{3}\Omega$ (ii) $\frac{11}{5}\Omega$ (iii) 6Ω (iv) $\frac{6}{11}\Omega$.

(c) Determine the equivalent resistance of networks shown in given figure.



(a)



(b)

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

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

$$R_{min} = \frac{R}{n}.$$

$$\frac{R_{max}}{R_{min}} = \frac{nR \cdot n}{R}$$

$$= n^2$$

(b) (i) $R_1 = 1\Omega$ $R_2 = 2\Omega$ $R_3 = 3\Omega$.

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

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

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

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

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

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

(iii) $R_s = R_1 + R_2 + R_3 = 1 + 2 + 3 = 6\Omega$.

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

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(c) $R_S = 1+1 = 2\Omega$.

$R'_S = 2+2 = 4\Omega$.

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

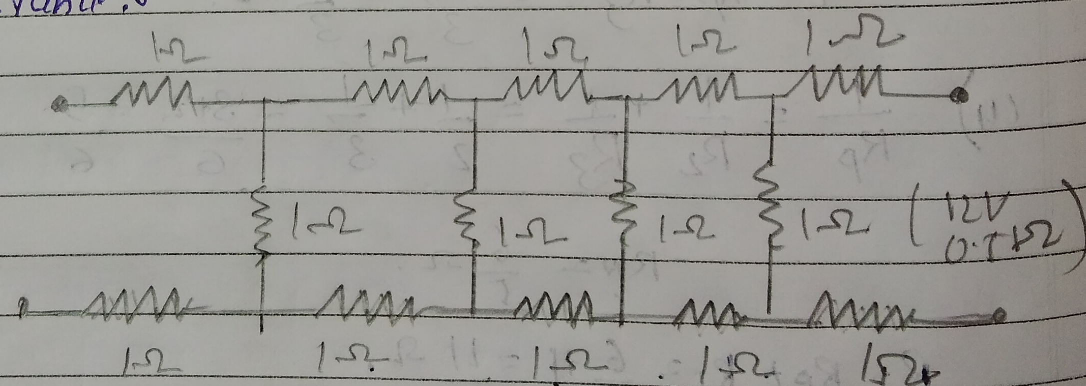
$$R' = \frac{4}{3}\Omega.$$

$$R = 4R' = 4 \times \frac{4}{3} = \frac{16}{3}\Omega$$

$$R = 5.33\Omega.$$

$$R' = R+R+R+R+R = 5R.$$

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



Ans

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

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

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$$R = R_p + 1 + 1 = \frac{x}{1+x} + 1 + 1 = \frac{x}{1+x} + 2.$$

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

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

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

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

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

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

$$x = 2.732\ \Omega.$$

Total resistance of the circuit $= 2.732 + 0.5 = 3.232$

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

3.22 Figure 3.33 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 upto 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.

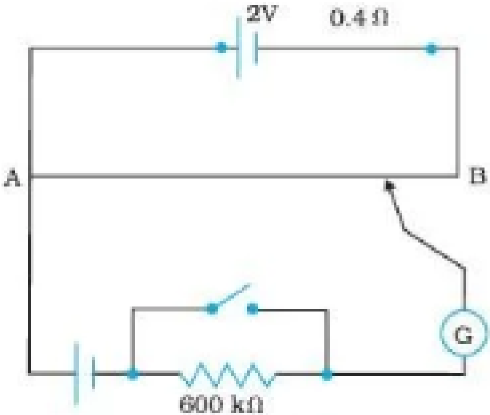

FIGURE 3.33

(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) 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?

(e) 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?

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$F_2 = E = ?$ Ans

Q18 (a) $E_1 = 1.02V$ $l_1 = 67.3 cm$

$l_2 = 82.3 cm$.

$E \propto l$.

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

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

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

$$= 1.247 V.$$

$E = 1.242V$.

(b) The use of very high resistance of 600 kΩ 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.

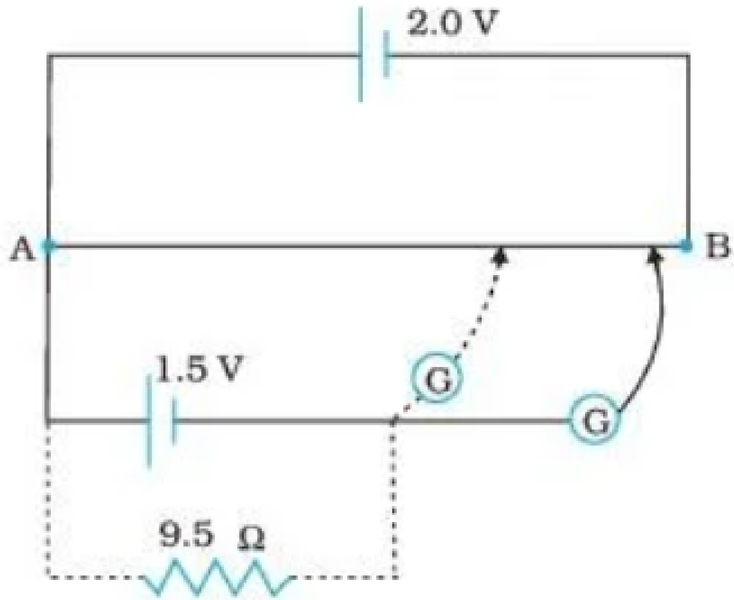
(d) No, the balance point is not affected by the internal resistance of can't work.

(e) ~~If the emf of driver cell is less than the driver cell, the method can't work.~~

(e) No, the circuit does not work well for determining an external small emf of milivolt.

thermo-couple)? If not, how will you modify the circuit?

3.23 Figure 3.34 shows a 2.0 V potentiometer used for the determination of 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.



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Ans

$l_1 = 76.3\,cm$

$l_2 = 64.8$

$R = 9.5\,\Omega.$

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

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