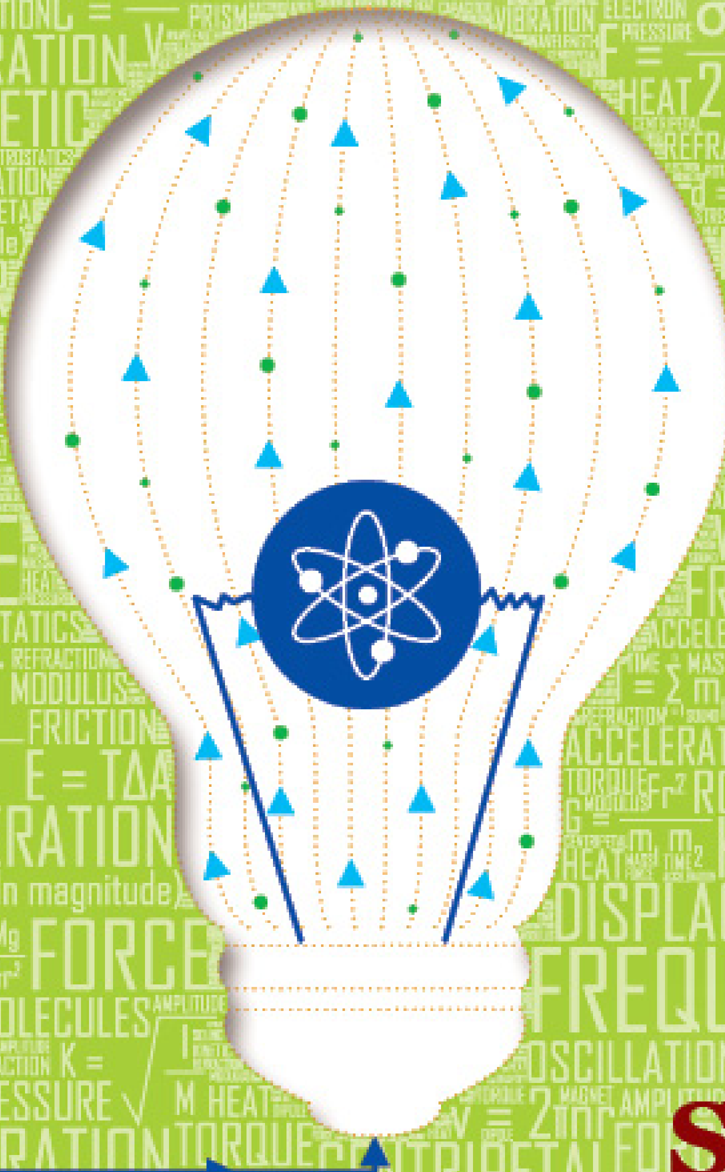
SAMPLE CONTENT

Physics Numericals



Std. XII

Target Publications Pvt. Ltd.

Physics Numericals

STD. XII Sci.

Salient Features

- Subtopic wise numericals with solutions.
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- Practice problems for every subtopic.
- Includes solved board numericals.
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Preface

In the case of good books, the point is not how many you can get through, but rather how many can get through to you.

"STD XII Sci.: PHYSICS NUMERICALS" is a complete and thorough guide to the numerical aspect of the HSC preparation. The book is prepared as per the Maharashtra State Board syllabus .Subtopic wise segregation of **Solved Numericals** in each chapter help the student to gain knowledge of the broad spectrum of problems in each subtopic **Formulae** which form a vital part of problem-solving are provided in every chapter. Solutions and calculations have been broken down to the simplest form possible (with **log calculation** provided wherever needed) so that the student can tackle each and every problem with ease.

Problems for practice are provided to test the vigilance and alertness of the students and build their confidence. **Board Numericals** till the latest year have been provided to help the student get accustomed to the different standards of board numericals. Numerical based **multiple choice questions** are covered sub-topic-wise to prepare the student on a competitive level.

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A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

Yours faithfully

Authors

Edition: Second

Contents

13 Current Electricity

Formulae

Section 1: Kirchhoff's Laws

1. **Resistance of a wire:**

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

where, A = area of cross-section
ρ = resistivity

2. **Kirchhoff's laws:**

i. $\sum I = 0$ (current law)
ii. $\sum RI = \sum E = 0$ (voltage law)

3. **Voltage across an external resistance:**

$$V = \frac{ER}{R + r}$$

where, E = e.m.f. of the cell
r = internal resistance of the cell

Section 2: Wheatstone's Bridge

1. **In balance position of Wheatstone's bridge:**

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

where, R_1, R_2, R_3 and R_4 are resistances in the four branches of Wheatstone's bridge.

Section 3: Metre Bridge

2. **Metre bridge:**

Unknown resistance $X = R \cdot \frac{\ell_1}{\ell_2}$

Section 4: Potentiometer

1. **Potentiometer:**

i. Current through driver cell,

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

ii. Resistance per unit length,

$$\sigma = \frac{R}{\ell}$$

iii. Potential gradient,

$$K = \frac{V}{\ell} = I\sigma \text{ volt/ metre}$$

2. **Comparison between the e.m.f.s of two cells:**

i. $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$ [Individual method]

ii. $\frac{E_1 + E_2}{E_1 - E_2} = \frac{\ell_1 + \ell_2}{\ell_1 - \ell_2}$

[Sum and difference method]

3. **Internal resistance of a cell:**

$$r = R\left(\frac{\ell_1 - \ell_2}{\ell_2}\right) = R\left(\frac{E}{V} - 1\right)$$

Shortcuts

1. Whenever there is more than one loop in the given question, apply Kirchoff's second law.

2. Remember, the potentiometer deals with potential difference & not with emf. Actual formula is: $\frac{V_1}{V_2} = \frac{\ell_1}{\ell_2}$.

We write it as: $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$ because in the experiments of potentiometer, cells are used in open circuit. Therefore V = E.

3. If in the question it is given that length increases by $\frac{1}{5}$th, then in the formula

$\frac{V_1}{V_2} = \frac{\ell_1}{\ell_2}$, replace V_2 by

$V_1 + \frac{1}{5}V_1 = \frac{6}{5}V_1$.

4. Whenever a question on internal resistance is asked, apply the formula,

$$r = \frac{\text{greater length} - \text{smaller length}}{\text{smaller length}}$$

$$r = \frac{(\ell_2 - \ell_1)}{\ell_1} R$$

where, R = the external resistance.

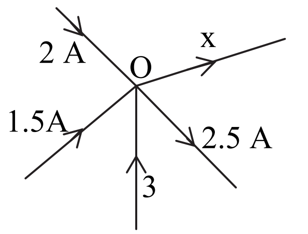
Solved Examples

Section 1: Kirchhoff's Laws

Example 1.1

In an electric circuit, the currents 2 A, 1.5 A and 3 A flow towards the junction while a current of magnitude 2.5 A and an unknown current leave the junction as shown in figure. Find the magnitude of unknown current.

Solution:



Given: $I_1 = 2$ A, $I_2 = 1.5$ A, $I_3 = 3$ A, $I_4 = -2.5$ A (Opposite direction)

To find: Unknown current (x)

Formula: $\sum I = 0$

Calculation: Let the unknown current be x.
From formula (Kirchoff's 1st law),
$I_1 + I_2 + I_3 + I_4 + (-x) = 0$
Negative sign indicates that current leaves the junction

$\therefore$ $2 + 1.5 + 3 + (-2.5) - x = 0$

$\therefore$ $4 - x = 0$

$\therefore$ $\mathbf{x = 4\ A}$

Ans: The magnitude of unknown current is **4 A.**

***Example 1.2**

A voltmeter has a resistance of 100 Ω. What will be its reading when it is connected across a cell of e.m.f. 2 V and internal resistance 20 Ω? [July 16]

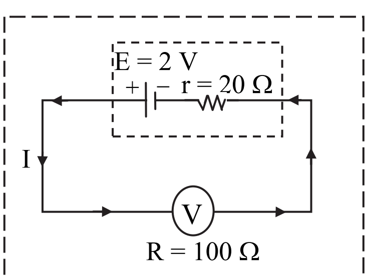
Solution:

Given: R = 100 Ω, r = 20 Ω, E = 2 V

To find: Reading of voltmeter (V)

Formula: V = E – Ir

Calculation: Current through the circuit is given by



$$I = \frac{E}{R+r} = \frac{2}{100+20} = \frac{2}{120}$$

$\therefore$ $I = \frac{1}{60}$ A

From formula,

$$V = 2 - \left(\frac{1}{60} \times 20\right) = 2 - 0.3333$$

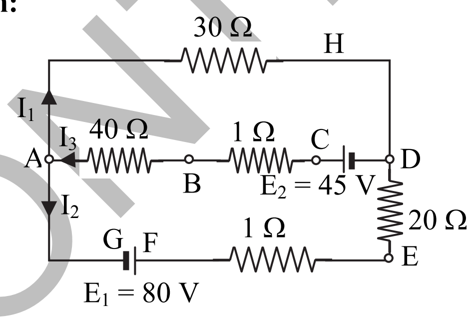
$\therefore$ $V = \mathbf{1.667\ V}$

Ans: The reading on the voltmeter is **1.667 V**.

Example 1.3

Determine the currents I_1, I_2 and I_3 from the network shown in figure.

Solution:



Applying of Kirchhoff's first law at junction 'A' we get,

$I_3 = I_1 + I_2$ ….(1)

Applying Kirchhoff's second law to loop ABCDHA we get,

$-30\,I_1 + (40 + 1)\,I_3 = -45$

$\therefore$ $-30\,I_1 + 41\,I_3 = -45$ ….(2)

$\therefore$ $-30\,I_1 - 41\,(I_1 + I_2) = -45$ [From (1)]

$\therefore$ $-71\,I_1 - 41\,I_2 = -45$

$\therefore$ $71\,I_1 + 41\,I_2 = 45$ ….(3)

Again, for loop AGFEDHA

$-30\,I_1 + (20 + 1)\,I_2 = 80$

$\therefore$ $-30\,I_1 + 21\,I_2 = 80$ ….(4)

On solving equations (3) and (4), we get

$I_1 = \mathbf{-0.86\ A}$

$I_2 = \mathbf{2.59\ A}$

$I_3 = I_1 + I_2 = 1.73$ A.

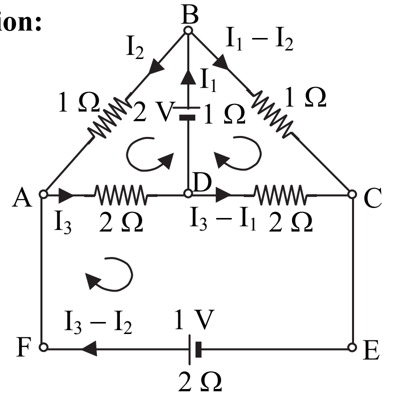
$\therefore$ $I_3 = \mathbf{1.73\ A}$

Ans: The current I_1, I_2 and I_3 are **–0.86 A**, **2.59 A** and **1.73 A** respectively.

Example 1.4

AB, BC, CD and DA are resistors of 1 Ω, 1 Ω, 2 Ω and 2 Ω respectively connected in series. Between A and C is a 1 volt cell of resistance 2 Ω, A being positive. Between B and D is a 2 V cell of 1 Ω resistance, B being positive. Find the current in each branch of the circuit.

Solution:



Applying Kirchhoff's second law to loop BADB, BCDB and ADCEFA, respectively we get,

$1.I_2 + 2.I_3 + 1.I_1 = 2$

$\therefore$ $I_1 + I_2 + 2I_3 = 2$ ….(1)

$\therefore$ $1(I_1 - I_2) - 2(I_3 - I_1) + 1.I_1 = 2$

$\therefore$ $4I_1 - I_2 - 2I_3 = 2$ ....(2)

$\therefore$ $2I_3 + 2(I_3 - I_1) + 2(I_3 - I_2) = 1$

$\therefore$ $-2I_1 - 2I_2 + 6I_3 = 1$ ….(3)

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

$I_1 = 0.8$ A, $I_2 = 0.2$ A and $I_3 = 0.5$ A

Currents in different branches are

$I_{AB} = I_2 =$ **0.2 A**, $I_{BC} = I_1 - I_2 =$ **0.6 A,**

$I_{CD} = I_1 - I_3 = 0.3$ A, $I_{AD} = I_3 =$ **0.5 A,**

$I_{EF} = I_3 - I_2 =$ **0.3 A**

Ans: The currents in branches AB, BC, CD, AD and EF are **0.2 A, 0.6 A, 0.3 A, 0.5 A** and **0.3 A** respectively.

Example 1.5

A current of 1 A flows through an external resistance of 5 Ω when it is connected to the terminals of a cell. The current is reduced to 0.6 A. When the external resistance is 10 Ω. Calculate internal resistance of the cell by using Kirchhoff's law.

Solution:

Given: $R_1 = 5\ \Omega$, $I_1 = 1$ A, $R_2 = 10\ \Omega$, $I_2 = 0.6$ A

To find: Internal resistance (r)

Formula: $I_1R_1 + I_1r - E = 0$

Calculation: From formula,

$1 \times 5 + 1 \times r - E = 0$

$5 + r - E = 0$ ….(1)

$I_2R_2 + I_2r - E = 0$

$0.6 \times 10 + 0.6 \times r - E = 0$

$6 + 0.6 \times r - E = 0$ ….(2)

Subtracting equation (2) from (1) we get,

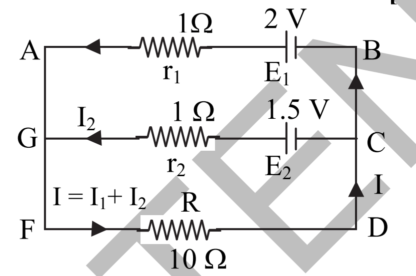
$-1 + 0.4\ r = 0$

$\therefore$ **r = 2.5 Ω**

Ans: The internal resistance of the cell is **2.5 Ω.**

Example 1.6

Two cells of e.m.f. 2 V and 1.5 V with internal resistance 1 ohm each are connected in parallel with similar poles joined together. The combination is connected to an external resistance of 10 ohm. Find the current through the external resistance. [Mar 93]



Solution:

Let I_1 = current through E_1

and I_2 = current through E_2

By Kirchoff's first law,

$I = I_1 + I_2$ ….(1)

Applying Kirchoff's voltage law to the loop AFDBA we get,

$2 = I \times I_1 + 10\ A\ (I_1 + I_2)$

$= I_1 + 10\ I_1 + 10\ I_2$

$\therefore$ $2 = 11\ I_1 + 10\ I_2$ ….(2)

Applying Kirchoff's voltage law to the loop GFDCG we get,

$1.5 = 1 \times I_2 + 10\ x\ (I_1 + I_2)$

$= I_2 + 10\ I_1 + 10\ I_2$

$\therefore$ $1.5 = 10\ I_1 + 11\ I_2$ ….(3)

Multiplying eq. (2) by 11 and eq. (3) by 10 we get,

$22 = 121\ I_1 + 110\ I_2$ ….(4)

and $15 = 100\ I_1 + 110\ I_2$ ….(5)

Now, subtracting eq. (5) from eq. (4) we get,

$21\ I_1 = 7$ or $I_1 = \frac{7}{21} = \frac{1}{3}$ A

$\therefore$ $I_1 = 0.333$ A

Substituting $I_1 = 0.333$ in eq. (2) we get,

$2 = 11 \times 0.333 + 10\ I_2$

$\therefore$ $10\ I_2 + 3.663 = 2$

$\therefore$ $10\ I_2 = 2 - 3.663$

$\therefore$ $10\ I_2 = -1.663$

$\therefore$ $I_2 = \frac{-1.663}{10}$

$\therefore$ $I_2 = -0.166$ A

$\therefore$ $I_1 + I_2 = 0.333 - 0.166$

$=$ **0.167 A**

Ans: Current through the external resistance is **0.167 A.**

Example 1.7

A battery of e.m.f. 4 V and internal resistance 1 Ω is connected in parallel with another battery of emf 1 V and internal resistance 1 Ω (with their like poles connected together). The combination is used to send current through an external resistance of R = 2 Ω. Calculate current through the external resistance. Mention the direction of current.

Solution:

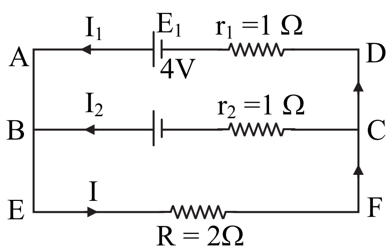
Given: $E_1 = 4$ V, $r_1 = 1\ \Omega$, $E_2 = 1$ V, $r_2 = 1\ \Omega$, $R = 2\ \Omega$

To find: Current (I) and direction of I

Formulae: i. $\Sigma I = 0$ at any junction

ii. $\Sigma IR = \Sigma E$

Calculation:



From formula (i) at junction B we get,

$I = I_1 + I_2$ ….(1)

From formula for the loop ABCDA we get,

$1 \times I_1 - 1 \times I_2 = 4 - 1$

$\therefore$ $I_1 - I_2 = 3$ ….(2)

From formula for the loop AEFDA we get,

$1 \times I_1 - 2 \times I = 4$

$\therefore$ $1 \times I_1 + 2 \times (I_1 + I_2) = 4$

$\therefore$ $I_1 + 2 I_1 + 2 I_2 = 4$

$\therefore$ $3I_1 + 2I_2 = 4$ ….(3)

Adding [2 × eq. (2)] to eq. (3)

$3 I_1 + 2 I_2 + 2(I_1 - I_2) = 4 + 6$

$\therefore$ $5 I_1 = 10$

$\therefore$ $I_1 = 2$

Substituting in eq. (2) we get,

$2 - I_2 = 3$

$\therefore$ $I_2 = -1$

$\therefore$ $I = I_1 + I_2$

$= 2 + (-1)$

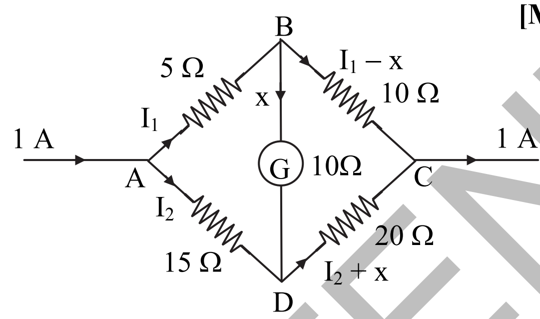
$\therefore$ I **= 1 A from E to F**

Ans: The current through the external resistance is **1 A** and **flows from E to F.**

Example 1.8

Determine the current flowing through the galvanometer shown in the figure.

[Mar 03]



Solution:

Let current I = 1A split as shown in the figure. Then the currents in the four branches of the bridge and galvanometer will be as follows:

Current through AB = I_1

Current through BC = $I_1 - x$

Cureent through AD = I_2

Current through DC = $I_2 + x$

Current through G = x

$\therefore$ At junction C,

$I_1 - x + I_2 + x = I_1 + I_2 = I = 1$ A

Applying Kirchoff's voltage law to circuit ABDA we get,

$5I_1 + 10\ x - 15\ I_2 = 0$ ….(1)

Now, applying the same to circuit BCD we get,

$10(I_1 - x) - 20\ (I_2 + x) - 10x = 0$

$10\ I_1 - 10x - 20\ I_2 - 20x - 10x = 0$

$10\ I_1 - 20\ I_2 - 40\ x = 0$ ….(2)

Now we multiply eq. (1) by 2 and subtract it from eq. (2):

Eq. (1) × 2 gives,

$10\ I_1 + 20x - 30\ I_2 = 0$ ….(3)

Eq. (2) – Eq. (3) gives,

$10\ I_1 - 20\ I_2 - 40\ x - 10\ I_1 - 20x + 30\ I_2 = 0$

$\therefore$ $10\ I_2 - 60x = 0$ or $I_2 - 6x = 0$

$\therefore$ $I_2 = 6x$

Substituting this value in eq. (2) we get,

$10\ I_1 - 20(6x) - 40x = 0$

$\therefore$ $10\ I_1 - 120\ x - 40x = 0$

$\therefore$ $10\ I_1 - 160\ x = 0$ or $I_1 - 16\ x = 0$

$\therefore$ $I_1 = 16\ x$

$\therefore$ $I_1 + I_2 = 16\ x + 6\ x = 22\ x.$

$\therefore$ $22\ x = 1$ or $x = \dfrac{1}{22}$ A

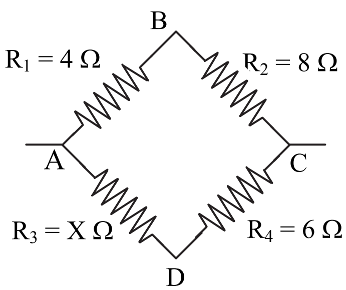
Ans: Current through the galvanometer is $\mathbf{\dfrac{1}{22}}$ **A.**

Section 2: Wheatstone's Bridge

Example 2.1

Four resistances 4 Ω, 8 Ω, X Ω and 6 Ω are connected in a series so as to form Wheatstone's network. If the network is balanced, find the value of 'X'. [Oct 13]

Solution:



Given: $R_1 = 4\ \Omega$, $R_2 = 8\ \Omega$, $R_4 = 6\ \Omega$

To find: Unknown resistance (X).

Formula: $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

Calculation: From formula,

$$R_3 = \frac{R_1}{R_2} \times R_4$$

$$= \frac{4}{8} \times 6 = 3\ \Omega$$

$\therefore$ X = **3 Ω**

Ans: The unknown resistance is **3 Ω.**

Example 2.2

Resistances in the branches of Wheatstone's bridge are 30 Ω, 60 Ω, 15 Ω and a series combination of X and 5 Ω resistances. If the bridge is balanced, calculate the unknown resistance X.

Solution:

Given: $R_1 = 30\ \Omega$, $R_2 = 60\ \Omega$, $R_3 = 15\ \Omega$ and $R_4 = (X + 5)\ \Omega$

To find: Unknown resistance (X)

Formula: For balance condition of bridge,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Calculation: From formula,

$$\frac{30}{60} = \frac{15}{X+5}$$

$$\therefore\ X + 5 = \frac{15 \times 60}{30} = 30\Omega$$

$\therefore$ X = **25 Ω**

Ans: The unknown resistance is **25 Ω.**

Example 2.3

In a Wheatstone's bridge arrangement PQRS, the ratio arms P and Q are nearly equal. The bridge is balanced when R = 500 Ω. On interchanging P and Q, the value of R for balancing is 510 Ω. Find the value of S and the ratio P/Q.

Solution:

For balanced Wheatstone's bridge,

$$\frac{P}{Q} = \frac{R}{S}$$

In the first case, R = 500 Ω.

$$\therefore\ \frac{P}{Q} = \frac{500}{S} \quad \text{....(1)}$$

In the second case when P and Q are interchanged, R = 510 Ω

$$\therefore\ \frac{Q}{P} = \frac{510}{S} \quad \text{....(2)}$$

Multiplying equations (1) and (2), we get

$$1 = \frac{500 \times 510}{S^2}$$

$$\text{or}\ S = \sqrt{500 \times 510}$$

$$\therefore\ S = \mathbf{504.97\ \Omega}$$

Substituting the value of S in (1), we get

$$\frac{P}{Q} = \frac{500}{504.97} = 0.9901 \approx 1$$

$$\therefore\ \frac{P}{Q} \approx \mathbf{1 : 1}$$

Ans: The value of S is **504.97 Ω** and the ratio $\dfrac{P}{Q}$ is **1.1.**

Section 3: Metre Bridge

Example 3.1

An unknown resistance 'X' is placed in the left gap and a known resistance of 60 Ω is placed in the right gap of a metre bridge. The null point is obtained at 70 cm from the left end of the bridge. Find the unknown resistance.

Solution:

Given: R = 60 Ω, $\ell_1 = 70$ cm, $\ell_2 = 100 - 70 = 30$ cm

To find: Unknown resistance (X)

Formula: $\dfrac{X}{R} = \dfrac{\ell_1}{\ell_2}$

Calculation: From formula,

$$\frac{X}{60} = \frac{70}{30}$$

$\therefore$ X = **140 Ω**

Ans: The unknown resistance is **140 Ω.**

Example 3.2

In a metre bridge, the length of the wire is 100 cm. At what position will the balance point be obtained if the two resistances are in the ratio 2 : 3?

Solution:

Given: $\ell = 100$ cm, $\frac{X}{R} = \frac{2}{3}$

To find: Position of balance point (ℓ)

Formula: $\frac{X}{R} = \frac{\ell}{100-\ell}$

Calculation: From formula,

$$\frac{2}{3} = \frac{\ell}{100-\ell}$$

$\therefore \quad 200 - 2\ell = 3\ell$

$\therefore \quad 5\ell = 200$

$\therefore \quad \ell = \frac{200}{5}$

$\therefore \quad \ell = \mathbf{40\ cm.}$

Ans: The balance point will be obtained at **40 cm** from the left end of the metre bridge.

Example 3.3

With resistances P and Q in the left and right gaps respectively of a metre bridge, the null point divides the wire in the ratio 1 : 2. If P and Q are increased by 20 Ω each, the null point divides the wire in the ratio 3 : 4. Find value of P and Q.

Solution:

Given: $\frac{P}{Q} = \frac{1}{2}, \frac{P+20}{Q+20} = \frac{3}{4}$

To find: Values of P and Q

Formula: $\frac{P}{Q} = \frac{\ell_1}{\ell_2}$

Calculation: From formula,

$$\frac{P+20}{Q+20} = \frac{3}{4}$$

$\therefore \quad \frac{P+20}{2P+20} = \frac{3}{4} \quad ....(\because Q = 2P)$

$\therefore \quad 6P + 60 = 4P + 80$ or $2P = 20$

$\therefore \quad P = \mathbf{10\ \Omega}, Q = \mathbf{20\ \Omega}$

Ans: The values of resistances P and Q are **10 Ω** and **20 Ω** respectively.

Example 3.4

In comparing the resistances of two coils P and Q with the help of a metre bridge arrangement, a balance point is obtained when the sliding contact is 30 cm from the zero end of the wire. The resistances P and Q are then interchanged and the balance point is obtained at 120 cm from the zero end. Find the ratio of the resistances P and Q and the length of the bridge wire.

Solution:

Let ℓ be the length of the bridge wire.

In the first case, the balance point is at 30 cm from the zero end.

$\therefore \quad \frac{P}{Q} = \frac{30}{\ell-30} \quad ….(1)$

When the coils P and Q are interchanged, the balance point is at 120 cm from the zero end.

$\therefore \quad \frac{Q}{P} = \frac{120}{\ell-120} \quad ….(2)$

Multiplying eq. (1) and (2) we get,

$$1 = \frac{30}{\ell-30} \times \frac{120}{\ell-120}$$

$\therefore \quad (\ell - 30)(\ell - 120) = 30 \times 120$

$\ell^2 - 150\ell = 0$

$\therefore \quad \ell(\ell - 150) = 0$

As $\ell \neq 0$, so $\ell = \mathbf{150\ cm.}$

From (1), $\frac{P}{Q} = \frac{30}{150-30} = \frac{1}{4}$

$\therefore \quad \frac{P}{Q} = \mathbf{1 : 4}$

Ans: The ratio of resistances $\frac{P}{Q}$ is **1 : 4** and the length of the bridge wire is **150 cm.**

Example 3.5

In the metre bridge experiment with unknown resistance X in the left gap and a known resistance of 60 Ω in the right gap, null point is obtained at ℓ cm from left. If the unknown resistance X is shunted by an equal resistance, what should be the value of the known resistance in the right gap in order to get the null point at the same position?

Solution:

When the unknown resistance X is in the left gap and 60 Ω in the right gap we have,

$\frac{X}{60} = \frac{\ell}{100-\ell} \quad ….(1)$

When the known resistance X is shunted by an equal resistance X, total resistance in the left gap is,

$$X' = \frac{X \times X}{X + X} = \frac{X}{2}$$

To obtain null point at the same position, suppose the resistance R is changed to R′. Then,

$$\frac{X'}{R'} = \frac{\ell}{100-\ell} \quad \text{or} \quad \frac{X/2}{R'} = \frac{\ell}{100-\ell} \quad ....(2)$$

From equations (1) and (2) we get,

$$\frac{X}{60} = \frac{X/2}{R'} \quad \text{or} \quad R' = \frac{60}{2}$$

∴ $R' = \mathbf{30\ \Omega}$

Ans: The value of the known resistance in the right gap is **30 Ω.**

Example 3.6

An unknown resistance X is placed in the left hand gap of the metre bridge. A known resistance of 20 ohm in the other gap gives a balance point at 60 cm from the left end of the bridge wire. Determine the value of X. How will you connect a resistance Y with X so as to obtain the balance point at the midpoint of the wire? Also find the value of Y.

Solution:

The unknown resistance X is placed in the left gap and known resistance of 20 Ω in right gap and null point is at 60 cm from left.

According to the balance condition,

∴ $\frac{X}{20} = \frac{60}{100-60} = \frac{60}{40}$

∴ $X = \frac{20 \times 60}{40}$

∴ $X = \mathbf{30\ \Omega}$

Now, a resistance Y is connected with X to obtain the balance point at the midpoint of the wire.

∴ $\frac{X+Y}{20} = \frac{50}{50} = \frac{1}{1}$

∴ $X + Y = 20$

As X = 30 Ω, Y cannot to be connected in series with X as $30 + Y \neq 20$

Hence, Y has to be connected in parallel to X to have an equivalent resistance of 20 Ω.

∴ $20 = \frac{X \times Y}{X+Y} = \frac{30Y}{30+Y}$

∴ $600 + 20\ Y = 30\ Y$

∴ $10\ Y = 600$

∴ $Y = \mathbf{60\ \Omega}$

Ans: The value of Y is **60 Ω.**

Example 3.7

Two diametrically opposite points of a metal ring are connected to two terminals of the left gap of metre bridge. The resistance of 11 Ω is connected in right gap. If null point is obtained at a distance of 45 cm from the left end, find the resistance of metal ring. [Mar 14]

Solution:

Given: $R_2 = 11\Omega$, $l_1 = 45\ \text{cm} = 45 \times 10^{-2}\ \text{m}$,
$l_2 = 100 - l_1 = 100 - 45 = 55 \times 10^{-2}\ \text{m}$

To find: Resistance of metal ring (R_1)

Formula: $\frac{R_1}{R_2} = \frac{l_1}{l_2}$

Calculation: Resistance of each half segment of the metal ring = $\frac{R_2}{2}$ and these half segments are connected in parallel in the left gap.

∴ $R_{eff.} = \frac{\frac{R_1}{2} \times \frac{R_1}{2}}{\frac{R_1}{2} + \frac{R_1}{2}} = \frac{\frac{R_1}{2} \times \frac{R_1}{2}}{R_1}$

∴ $R_{eff.} = \frac{R_1}{4}\Omega$

From the formula,

$\frac{R_{eff.}}{R_2} = \frac{l_1}{l_2}$

∴ $\frac{\frac{R_1}{4}}{11} = \frac{45}{55}$

∴ $\frac{R_1}{44} = \frac{9}{11}$

∴ $R_1 = \frac{9}{11} \times 44$

∴ $R_1 = \mathbf{36\ \Omega}$

Ans: The Resistance of the metal ring is **36 Ω**.

Section 4: Potentiometer

Example 4.1

A potentiometer wire has a resistance per unit length 0.1 Ω/m. A cell of e.m.f. 1.5 V balances against 300 cm length of the wire. Find the current through potentiometer wire.

[Mar 09, Oct 15]

Solution:

Given: $\sigma = 0.1\ \Omega/\text{m}$, $E = 1.5\ \text{V}$,
$L = 300\ \text{cm} = 3\ \text{m}$.

To find: Current through potentiometer (I).

Formulae: i. $\sigma = R/L$
ii. $I = E/R$

Calculation: From formula (i),
$R = \sigma L$
$= 0.1 \times 3 = 0.3\ \Omega$
From formula (ii),
$I = \frac{1.5}{0.3} = \mathbf{5\ A}$

Ans: Current through the potentiometer wire is **5 A.**

Example 4.2

A potentiometer wire is 10 m long and a potential difference of 5 V is maintained between its ends. Find the e.m.f. of a cell which balances against a length of 180 cm of the potentiometer wire.

Solution:

Given: $K = \frac{5}{1000}$ V/cm
$= \frac{1}{200}$ V/cm, $\ell = 180$ cm

To find: e.m.f. of the cell (E)

Formula: $E = K\ell$

Calculation: From formula,
$E = \frac{1}{200} \times 180$
$\therefore$ $E = \mathbf{0.9\ V}$

Ans: The e.m.f. of the cell is **0.9 V.**

Example 4.3

A potentiometer wire is supplied a constant voltage of 3 V. A cell of e.m.f. 1.08 V is balanced by the voltage drop across 216 cm of the wire. Find the total length of the potentiometer wire.

Solution:

Given: $E_1 = 3V$, $E_2 = 1.08$ V,
$\ell_2 = 216$ cm

To find: Total length of wire (ℓ_1)

Formula: $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

Calculation: From formula,
$\ell_1 = \frac{E_1}{E_2} \times \ell_2$
$= \frac{3 \times 216}{1.08}$
$= 600$ cm
$\therefore$ $\ell_1 = \mathbf{6\ m}$

Ans: The total length of the potentiometer wire is **6 m.**

Example 4.4

Resistance of a potentiometer wire is 0.1 Ω/cm. A cell of e.m.f. 1.5 V is balanced at 300 cm on this potentiometer wire. Calculate the current and balancing length for another cell of e.m.f. 1.4 V on the same potentiometer wire. [Mar 15]

Solution:

Given: $\sigma = 0.1\ \Omega$/cm
$= 0.1 \times 100\ \Omega/m = 10\ \Omega/m$,
$l_1 = 300$ cm $= 3$ m
$E_1 = 1.5$ V, $E_2 = 1.4$ V

To find: Current (I), balancing length (l_2)

Formulae: i. $I = \frac{E_1}{\sigma l_1}$ ii. $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

Calculation: Using formula (i),
$I = \frac{1.5}{10 \times 3} = \mathbf{0.05\ A}$
Using formula (ii),
$l_2 = \frac{E_2 l_1}{E_1} = \frac{1.4 \times 3}{1.5} = \mathbf{2.8\ m}$

Ans: The flow of current is **0.05 A**. The balancing length for second cell is **2.8 m**.

Example 4.5

A potentiometer wire is 100 cm long and a constant potential difference is maintained across it. Two cells of emfs E_1 and E_2 are connected in series first to assist one another and then in opposition. The balance points were obtained at 60 cm and 12 cm respectively from the same end of the wire in the two cases. Find the ratio of the e.m.f.s of the two cells.

Solution:

When the two cells are connected to assist each other,
$E_1 + E_2 = k \times 60$ ….(1)
When the two cells are connected in opposition,
$E_1 - E_2 = k \times 12$ ….(2)
Dividing equation (1) by (2), we get
$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{60}{12} = \frac{5}{1}$$
Applying componendo and dividendo, we get
$$\frac{(E_1 + E_2) + (E_1 - E_2)}{(E_2 + E_2) - (E_1 - E_2)} = \frac{5+1}{5-1}$$
$$\therefore \quad \frac{2E_1}{2E_2} = \frac{6}{4} \quad \text{or} \quad \frac{E_1}{E_2} = \frac{3}{2}$$
$= 3 : 2$

Ans: Ratio of e.m.fs of the two cells is **3 : 2.**

***Example 4.6**

A potentiometer wire has a length of 2 m and resistance of 10 Ω. It is connected in series with resistance 990 Ω and a cell of e.m.f 2 V. Calculate the potential gradient along the wire. [July 16]

Solution:

Given: $L = 2$ m, $R = 10\ \Omega$, $R_E = 990\ \Omega$, $E = 2$ V

To find: Potential gradient of wire (K)

Formula: $K = \dfrac{V}{L}$

Calculation: Since, $I = \dfrac{E}{R + R_E}$

Also, $V = IR = \dfrac{ER}{R + R_E}$

$= \dfrac{2 \times 10}{10 + 990} = \dfrac{20}{1000}$

$V = 2 \times 10^{-2}$ volt

From formula,

$K = \dfrac{2 \times 10^{-2}}{2}$

$\therefore$ $K = \mathbf{10^{-2}\ V/m}$

Ans: The potential gradient of wire is $\mathbf{10^{-2}\ V/m}$.

Example 4.7

A potentiometer wire is 10 m long and has a resistance of 18 Ω. It is connected to a battery of emf 5 V and internal resistance 2 Ω. Calculate the potential gradient along the wire.

Solution:

Given: $\ell = 10$ m, $R = 18\ \Omega$, $E = 5$ V, $r = 2\ \Omega$

To find: Potential gradient (K)

Formula: i. $I = \dfrac{E}{R + r}$

ii. Potential gradient $K = \dfrac{V}{\ell} = \dfrac{IR}{\ell}$

Calculation: From formula (i),

Current through the potentiometer wire,

$I = \dfrac{E}{R + r} = \dfrac{5}{18 + 2} = \dfrac{5}{20} = \dfrac{1}{4}$ A

From formula (ii),

$K = \dfrac{1}{4} \times \dfrac{18}{10}$

$\therefore$ $K = \mathbf{0.45\ Vm^{-1}}$

Ans: The potential gradient along the wire is $\mathbf{0.45\ Vm^{-1}}$.

Example 4.8

A potentiometer wire has a length of 4 m and a resistance of 5 Ω. What resistance should be connected in series with a potentiometer wire and a cell of e.m.f. 2 V having internal resistance 1 Ω to get a potential gradient of 10^{-3} V/cm? [Oct 14]

Solution:

Given: $L = 4$ m, $R_1 = 5\ \Omega$, $E = 2$ V, $r = 1\ \Omega$, $K = 10^{-3}$ V/cm $= 10^{-1}$ V/m

To find: Series resistance (X)

Formula: $K = \dfrac{V}{L} = \dfrac{IR}{L}$

$= \left(\dfrac{E}{R + r + X}\right)\dfrac{R}{L}$

Calculation: From fomula,

$10^{-1} = \dfrac{2}{5 + 1 + X}\left(\dfrac{5}{4}\right)$

$\therefore$ $6 + X = 20 \times \dfrac{5}{4}$

$\therefore$ $6 + X = 25$

$\therefore$ $X = 25 - 6 = \mathbf{19\ \Omega}$

Ans: A resistance of **19 Ω** should be connected in series.

Example 4.9

A 10 metre long wire of uniform cross-section and having a resistance of 20 Ω is fitted in a potentiometer. This wire is connected in series with a battery of 5 V along with an external resistance of 480 Ω. If an unknown e.m.f. E is balanced at 600 cm of this wire, calculate

i. the potential gradient of the potentiometer wire and

ii. the value of the unknown e.m.f. E.

Solution:

Given: $\ell = 10$ m $= 1000$ cm,

$R = 20\ \Omega$, $E = 5$ V,

$r = 480\ \Omega$,

Balancing length, $\ell' = 600$ cm

To find: i. Potential gradient (K)

ii. Unknown emf (E)

Formulae: i. $I = \dfrac{E}{R + r}$ ii. $K = \dfrac{V}{\ell}$

iii. $E = K\ell'$

Calculation:

From formula (i),

Current through the potentiometer wire,

$I = \dfrac{5}{(20 + 480)} = \dfrac{5}{500} = 0.01$ A

From formula (ii),

$V = IR = 0.01 \times 20 = 0.2$ V

$\therefore \quad K = \frac{V}{\ell} = \frac{0.2}{1000}$

$= 0.0002$ V cm^{-1}

$\therefore \quad$ **K = 2×10^{-4} V cm^{-1}**

From formula (iii),

$E = 2 \times 10^{-4} \times 600$

$\therefore \quad$ E = **0.12 V**

Ans: i. The potential gradient of the potentiometer wire is **2×10^{-4} V cm^{-1}.**

ii. The unknown e.m.f. is **0.12 V.**

Example 4.10

The length of a potentiometer wire is 10 m. An accumulator of steady e.m.f. is connected across the wire. A Leclanche cell gives a null point at 750 cm. If the length of the potentiometer wire is increased by 100 cm, find the position of the balance point.

Solution:

Given: $\ell_1 = 10$ m, $E = E_1$,

$\ell_2 = 7.5$ m, $E = E_2$

Case 2: $\ell'_1 = 11$ m, $E = E_1$

$E = E_2$ (Balance condition)

To find: Position of balance point (ℓ'_2)

Formula: $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$

Calculation: From formula,

$$\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2} = \frac{10}{7.5} \quad \ldots(1)$$

In case (2), for balance condition,

$$\frac{E_1}{E_2} = \frac{\ell'_1}{\ell'_2} = \frac{11}{\ell'_2} \quad \ldots(2)$$

From equation (1) and (2) we get,

$$\frac{10}{7.5} = \frac{11}{\ell'_2}$$

$\therefore \quad \ell'_2$ = **8.25 m**

Ans: The position of the balance point will be **8.25 m** from the zero end.

Example 4.11

An accumulator of e.m.f. 2 V and internal resistance 1 Ω is connected to a potentiometer wire of length 4 m and resistance 24 Ω. What resistance must be connected in series with potentiometer wire so that the potential gradient along the wire is 0.24 V/m ?

Solution:

Given: $E = 2$ V, $r = 1\ \Omega$, $\ell = 4$ m,

$R = 24\ \Omega$, $\frac{V}{\ell} = 0.24$ V/m.

To find: External resistance (R_{ext})

Formula: $I = \left(\frac{E}{R + r_i + R_{ext}}\right) \times \frac{R}{\ell}$

Calculation: From formula,

$$0.24 = \left(\frac{2}{24 + 1 + R_{ext}}\right) \times \frac{24}{4}$$

$$\therefore \quad 0.24 = \left(\frac{2}{25 + R_{ext}}\right) \times 6$$

$$\therefore \quad 0.24 = \frac{12}{25 + R_{ext}}$$

$$\therefore \quad \frac{24}{100} = \frac{12}{25 + R_{ext}} \text{ or } \frac{2}{100} = \frac{1}{25 + R_{ext}}$$

$\therefore \quad 50 + 2\ R_{ext} = 100$

$\therefore \quad R_{ext} = \frac{50}{2}$

$\therefore \quad R_{ext}$ = **25 Ω.**

Ans: A resistance of **25 Ω** must be connected in series with the potentiometer wire.

Example 4.12

A potentiometer of length 10 m and resistance of 20 Ω are connected to a cell of e.m.f. 4 V and resistance of 5 Ω in series. What is the distance of the null point, when two cells E_1 and E_2 are connected

i. so as to assist each other?

ii. so as to oppose each other?

[Given: E_1 = 1.5 V, E_2 = 1.1 V]

Solution:

Given: $\ell = 10$ m, $R = 20\Omega$, $E = 4$V,

$r = 5\Omega$, $E_1 = 1.5$V, $E_2 = 1.1$ V.

To find: Distance of null point when E_1 and E_2 assist/oppose each other ($\ell_1 + \ell_2$, $\ell_1 - \ell_2$)

Formulae: i. $I = \frac{E}{R + r}$

ii. $K = \frac{V}{\ell}$

iii. $E_1 + E_2 = K(\ell_1 + \ell_2)$

iv. $E_1 - E_2 = K(\ell_1 - \ell_2)$

Calculation: From formula (i),

$$I = \frac{4}{20 + 5} = \frac{4}{25}$$

$\therefore$ $I = 0.16$ A

From formula (ii),

$$K = \frac{V}{\ell} = \frac{IR}{\ell} = \frac{0.16 \times 20}{10}$$

$\therefore$ $K = 0.32$ V/m

From formula (iii),

$E_1 + E_2 = K(\ell_1 + \ell_2)$

$$\therefore \quad \ell_1 + \ell_2 = \frac{E_1 + E_2}{K}$$

$$= \frac{1.5 + 1.1}{0.32}$$

$= 8.125$ m

$\therefore$ $\ell_1 + \ell_2$ **= 812.5 cm**

From formula (iv),

$E_1 - E_2 = K(\ell_1 - \ell_2)$

$$\therefore \quad \ell_1 - \ell_2 = \frac{E_1 - E_2}{K}$$

$$= \frac{1.5 - 1.1}{0.32}$$

$= 1.25$ m

$\therefore$ $\ell_1 - \ell_2$ **= 125 cm**

Ans: The distance of null point when the two cells are connected

i. so as to assist each other is **812.5 cm.**

ii. so as to oppose each other is **125 cm.**

Example 4.13

In a potentiometer experiment, the length of the wire is 5 m. When two cells of e.m.f.s E_1 and E_2 are connected in series so as to assist each other, the balancing length is found to be 375 cm. When the cells are connected in series so as to oppose each other, the balancing length is found to be 75 cm. Compare the e.m.f.s of the two cells.

Solution:

Given: $\ell = 5$ m, $\ell_1 + \ell_2 = 375$ cm,

$\ell_1 - \ell_2 = 75$ cm.

To find: Ratio of e.m.f.s of two cells $\left(\frac{E_1}{E_2}\right)$

Formula: $$\frac{E_1 + E_2}{E_1 - E_2} = \frac{\ell_1 + \ell_2}{\ell_1 - \ell_2}$$

Calculation: From formula,

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{375}{75}$$

Using componendo – dividendo,

$$\frac{2E_1}{2E_2} = \frac{375 + 75}{375 - 75}$$

$$\therefore \quad \frac{E_1}{E_2} = \frac{450}{300}$$

$$\therefore \quad \frac{E_1}{E_2} = \mathbf{3 : 2}$$

Ans: The e.m.f.s of the two cells are in the ratio **3 : 2.**

Example 4.14

A cell balances against a length of 250 cm on a potentiometer wire, when it is shunted by a resistance of 10 Ω. The balancing length becomes 200 cm, when it is shunted by a resistance of 5 Ω. Calculate the balancing length when the cell is in open circuit and also find internal resistance of the cell. [Oct 11]

Solution:

Given: $R = 10\ \Omega$, $l_2 = 250$ cm,

$R' = 5\ \Omega$, $l_2' = 200$ cm.

To find: Balancing length (l_1), internal resistance (r)

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

Calculation: From first condition,

$$r = 10\left(\frac{l_1 - 250}{250}\right) \quad \text{….(1)}$$

From second condition,

$$r = 5\left(\frac{l_1 - 200}{200}\right) \quad \text{….(2)}$$

Equating (1) and (2),

$$10\left(\frac{l_1 - 250}{250}\right) = 5\left(\frac{l_1 - 200}{200}\right)$$

$200 \times 10\,(l_2 - 250) = 250 \times 5(l_1 - 200)$

$8\,(l_1 - 250) = 5\,(l_1 - 200)$

$8l_1 - 5l_1 = 8(250) - 5(200)$

$3l_1 = 1000$

$$\therefore \quad l_1 = \frac{1000}{3}$$

$\simeq$ **333.33 cm**

Substituting value of l_1 in equation (2),

$$r = 5\left(\frac{333.33 - 200}{200}\right)$$

$\simeq$ **3.33 Ω**

Ans: i. The balancing length is nearly **333 cm.**

ii. The internal resistance of the cell is approximately **3.33 Ω.**

Example 4.15

An accumulator of e.m.f. 6 V and negligible internal resistance is connected to a 10 m potentiometer wire of 25 Ω. What is the series resistance required so that the potential gradient along the wire is 2 m V/cm? What is the balancing length for a Leclanche cell of e.m.f. 1.51 V?

Solution:

Given: $E = 6$ V, $\ell = 10$ m, $R = 25\ \Omega$, $r = 0$,

$$K = \frac{2\text{ mV}}{\text{cm}} = \frac{2\times10^{-3}}{10^{-2}} = 0.2\text{ V/m},$$

$E_1 = 1.51$ V

To find: i. Series resistance (R_s)
ii. Balancing length (ℓ_1)

Formulae: i. $I = \dfrac{E}{R + r + R_s}$

ii. $K = \dfrac{V}{\ell} = \dfrac{IR}{\ell}$

Calculation: From formula (i),

$$I = \frac{6}{25 + 0 + R_s} = \frac{6}{25 + R_s}$$

From formula (ii),

$$0.2 = \frac{6\times25}{25 + R_s}\times\frac{1}{10}$$

$\therefore$ $2\ (25 + R_s) = 6 \times 25$

$\therefore$ $R_s + 25 = 75$

$\therefore$ $R_s =$ **50 Ω**

From formula (ii),

$$E_1 = K\ \ell_1 \text{ or } \ell_1 = \frac{E_1}{K}$$

$\therefore$ $\ell_1 = \dfrac{1.51}{0.2}$

$\therefore$ $\ell_1 = 7.55$ m

$\therefore$ $\ell_1 =$ **755 cm**

Ans: i. The series resistance required is **50 Ω.**
ii. The balancing length for Leclanche cell is **755 cm.**

Example 4.16

A cell balances against a length of 200 cm on a potentiometer wire when it is shunted by a resistance of 8 Ω. The balancing length reduces by 40 cm when it is shunted by a resistance of 4 Ω. Calculate the balancing length when the cell is in open circuit. Also calculate the internal resistance of the cell. **[Feb 13]**

Solution:

Given: $R_1 = 8\ \Omega$, $l_2 = 200$ cm,
$R_2 = 4\ \Omega$, $l'_2 = 160$ cm

To find: i. Balancing length when the cell is in open circuit (l_1)
ii. Internal resistance of the cell (r)

Formula: $r = R\left(\dfrac{l_1 - l_2}{l_2}\right)$

Calculation: From first condition,

$$r = 8\left(\frac{l_1 - 200}{200}\right) \quad \ldots(1)$$

From second condition,

$$r = 4\left(\frac{l_1 - 160}{160}\right) \quad \ldots(2)$$

From equation (1) and (2),
we get,

$$8\left(\frac{l_1 - 200}{200}\right) = 4\left(\frac{l_1 - 160}{160}\right)$$

$\therefore$ $\dfrac{l_1 - 200}{25} = \dfrac{l_1 - 160}{40}$

$\therefore$ $25l_1 - 4000 = 40\ l_1 - 8000$

$\therefore$ $15l_1 = 4000$

$\therefore$ $l_1 =$ **266.67 cm**

From equation (1) we get,
internal resistance,

$$r = 8\left(\frac{l_1 - 200}{200}\right) = \frac{266.67 - 200}{25}$$

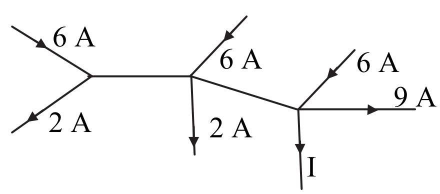
$\therefore$ $r =$ **2.667 Ω**

Ans: i. The balancing length when the cell is in open circuit is **266.67 cm.**
ii. The internal resistance of the cell is **2.667 Ω.**

Problems for Practice

Section 1: Kirchhoff's Laws

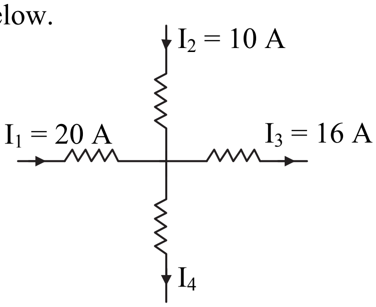
1. In the circuit shown below, calculate the value of the current I.



2. When a certain P.D. was maintained across a conductor, the current flowing through it was found to be 0.5 A. When the P.D. was increased by 10 volt, the current increased by 1 ampere. Find the resistance of the conductor and the original P.D.

3. A 10 volt battery of internal resistance 1 ohm is connected to a 20 volt battery of internal resistance 2 ohm with similar poles together. They send current through a 30 ohm resistance. Calculate current in each battery arm.

4. Find the value of current I_4 in the circuit given below.



5. Two cells of e.m.f. 3 volt and 4 volt having internal resistances 2 ohm and 1 ohm respectively have their negative terminals joined by a resistor of 6 ohm and positive terminals joined by another resistor of 4 ohm. A third resistor of resistance 8 ohm connects the midpoints of these resistors. Find the P.D. at the ends of the third resistor.

6. A current of 3 A flows through certain resistance when a cell is connected across it. The potential difference across the resistance was found to be 4.8 volt. The e.m.f. of cell is 5 volt. Calculate the internal resistance of the cell.

Section 2: Wheatstone's Bridge

7. Four resistances 10 Ω, 10 Ω, 10 Ω and 20 Ω form a Wheatstone's network. Calculate the value of shunt needed across 20 Ω resistor to balance the network.

8. Four resistances P, Q, R, S are connected in cyclic order to form a balanced Wheatstone's network. If P = 20 Ω, Q = 50 Ω, S = 30 Ω, find R. What will be the value of R if another resistance of 50 Ω is connected across Q ?

9. Two wires of same material but of lengths 30 cm and 40 cm and of radii 0.5 mm and 0.6 mm respectively, are introduced in the two gaps of Wheatstone's metre bridge. Find the position of the null point.

10. Four coils of resistances 3 Ω, 6 Ω, 9 Ω and 30 Ω respectively are arranged to form a Wheatstone's bridge. Determine the value of the resistance with which the coil of 30 Ω should be shunted so as to balance the bridge.

11. Two resistance coils P and Q are connected in series across one gap of Wheatstone's metre bridge. A resistance of 27 ohm is connected across the other gap. The null point is obtained at 40 cm from the end corresponding to series combination of P and Q. P and Q are now connected in parallel. The known resistance has now to be decreased by 21 ohm to have the same balance point as before. Determine P and Q.

Section 3: Metre Bridge

12. An unknown resistance is placed in left gap and resistance of 50 Ω in right gap of a metre bridge. The null point is obtained at 40 cm from left end. Determine unknown resistance.

13. Two diametrically opposite points of a metal ring are connected to two terminals of left gap of a metre bridge. In the right gap, resistance of 15 Ω is introduced. If the null point is obtained at a distance of 40 cm from left end, find the resistance of the wire forming the ring.

14. Two unknown resistances are connected in series in one gap of a metre bridge and a known resistance 9 Ω is connected in the other gap of metre bridge. The null point is obtained at midpoint of wire. If the two unknown resistances are connected in parallel in the same gap, the same null point is obtained when the known resistance in other gap is 2 Ω. Calculate values of unknown resistance.

15. Two resistances X Ω and Y Ω are connected in the left and right gaps respectively of a metre bridge. A null point was found on the bridge wire such that the ratio of lengths of two segments of wire is 2 : 3. The distance of the null point was measured from the left end of the wire. When the value of X is changed by 20 Ω, the position of the null point divides the wire into segments of lengths in the ratio 1 : 4. Determine X and Y.

16. Two resistances X and Y in the two gaps of a metre bridge give a null point dividing the wire in the ratio 2 : 3. If each resistance is increased by 30 Ω, the null point divides the wire in the ratio 5 : 6. Calculate each resistance.

17. Two equal resistances are introduced in the two gaps of a metre bridge. Find the shift in the null point if the resistance in the left gap is shunted by an equal resistance. What will happen to the null point if an equal resistance is connected in series with the resistance in the left gap?

18. When two resistances P and Q are introduced in the two gaps of a metre bridge, a balance point is found in the bridge wire such that the ratio of the two parts of the wire is 1 : 3. If P and Q are increased by 25 Ω each, balance point divides the wire in the ratio 3 : 7, lengths being measured in the same way as before. Find P and Q.

Section 4: Potentiometer

19. A cell of e.m.f. 1.02 volt is balanced by 150 cm of potentiometer wire. When the cell is shunted by a resistance of 4 Ω, the balancing length reduces to 120 cm. Find the internal resistance of the cell.

20. A potentiometer wire of length 4 m and resistance 8 Ω is connected in series with a battery of e.m.f. 2 V and negligible internal resistance. The e.m.f. of the cell balances against length of 217 cm of wire. When a cell is shunted by a resistance of 15 Ω, the balancing length is reduced to 200 cm. Find the internal resistance of the cell.

21. The resistance of potentiometer wire is 1 Ω/m. A cell of e.m.f. 1.4 V is balanced against 280 cm of wire. Find the current in the wire.

22. In a potentiometer experiment, the balancing length is found to be 1.80 m for a cell of e.m.f. 1.5 V. Find the balancing length for a cell of e.m.f. 1 V.

23. A potentiometer wire has a length of 4 m and resistance of 4 Ω. What resistance must be connected in series with the potentiometer wire and a cell of e.m.f. 2 V and internal resistance 2 Ω to get a p.d. of 10^{-3} V/cm along the wire?

24. Potential drop per unit length of a wire is 5×10^{-3} V/cm. If the e.m.f. of cell balances against a length of 216 cm of potentiometer wire, find the e.m.f. of the cell.

25. Length of potentiometer wire is 10 m and is connected in series with an accumulator. The e.m.f. of a cell balances against 250 cm of the wire. If the length of wire is increased by 1 m, calculate the new balancing length of the wire. (Accumulator has negligible internal resistance)

26. A potentiometer wire of length 2 m and resistance 5 Ω is connected in series with resistance of 998 Ω and cell of e.m.f. 2 V and internal resistance 2 Ω. Find potential drop along the wire and the length required to balance an e.m.f. of 4 mV.

27. A cell of e.m.f. 2 V and negligible internal resistance is connected to a potentiometer wire of length 4 m and resistance 25 Ω to form a closed circuit. Find the potential gradient along the wire.

28. A potentiometer wire of length 10 m and resistance 9 ohm is connected to a battery of e.m.f. 2.1 volt having internal resistance 1.5 Ω. Find the potential gradient along the wire and the balancing length for a cell of e.m.f. 1.08 volt.

29. The resistance of a potentiometer wire is 0.1 Ω per cm. A cell of e.m.f. 1.5 V balances at 300 cm on this potentiometer wire. Find the balancing length for another cell of e.m.f. 1.4 volt on the same potentiometer wire.

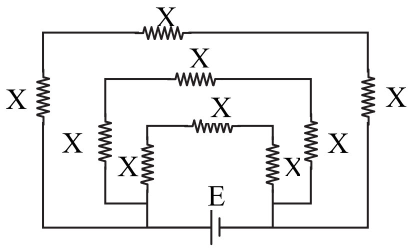
Multiple Choice Questions

Section 1: Kirchhoff's Laws

1. A cell supplies a current of 2 A through two resistors of 4 Ω each when in series and a current of 5 A through the same resistors but in parallel. What is the internal resistance of the cell ?
   (A) 1.0 Ω (B) 2.0 Ω
   (C) 2.2 Ω (D) 2.5 Ω

2. A battery of 4 V and internal resistance 1 Ω sends a current of 1 A through a load. If two such batteries are connected in series across the same load, the current through the load will be
   (A) 1.20 A (B) 1.40 A
   (C) 1.60 A (D) 1.80 A

3. In the circuit given below, if X = 1 Ω and E = 3 V, what is the current drawn from the cell?

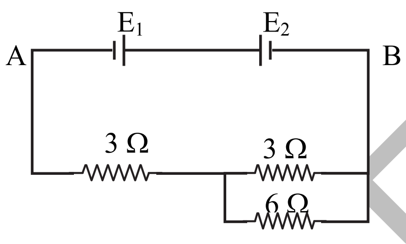


(A) 0.3 A (B) 4 A
(C) 3 A (D) 6 A

4. If the resistance across a 12 V source is increased by 4 Ω, the current drops by 0.5 A. The original resistance was

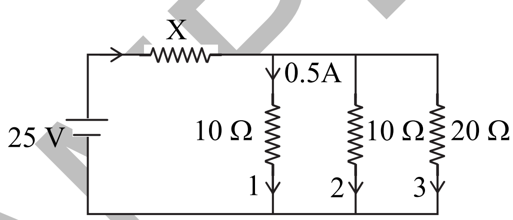
(A) 8 Ω (B) 4 Ω
(C) 16 Ω (D) 24 Ω

5. In circuit given below, the cells E_1 and E_2 have e.m.f.s of 1.5 V and 6 V and internal resistances of 0.4 Ω and 0.8 Ω respectively. Then the p. d. across E_1 and E_2 will be



(A) 3.75 V, 2.5 V (B) 2.5V, 3.75V
(C) 1.8 V, 5.4 V (D) 5.4 V, 1.8 V

6. In circuit shown below, the only correct option is



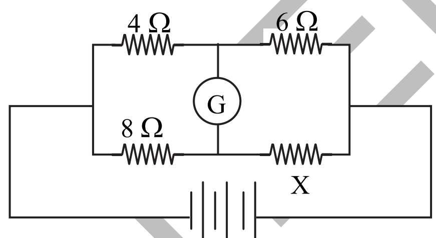
(A) X = 16 Ω
(B) current through 20 Ω is 1 A
(C) p. d. across 10 Ω is 15 V
(D) p. d. across X is 10 V

Section 2: Wheatstone's Bridge

7. In a typical Wheatstone's network, the resistances in cyclic order are A = 10 ohm, B = 5 ohm, D = 4 ohm and C = 4 ohm. For the bridge to balance,

(A) 10 Ω should be connected in series with A.
(B) 10 Ω should be connected in parallel with A.
(C) 10 Ω should be connected in series with B.
(D) 5 Ω should be connected in parallel with B.

8. Four resistors are connected as shown in the figure. It is found that the current flowing through the galvanometer G is zero. The resistance of X is

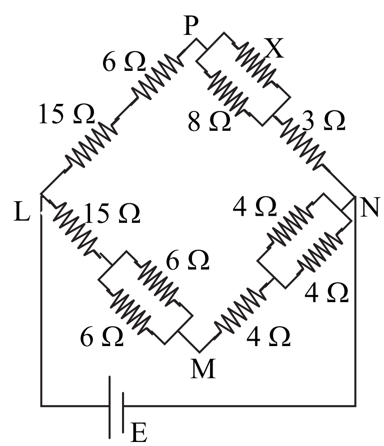


(A) 3 Ω
(B) 6 Ω
(C) 12 Ω
(D) impossible to determine without knowing the e.m.f. of the battery.

9. A Wheatstone's bridge PQRS has resistances PQ = 2 Ω, QR = 3 Ω, PS = 2 Ω and RS = 3 Ω. The points P and R are joined by a resistance of 5 Ω. What is the total resistance of the loop?

(A) $\frac{2}{3}$ Ω (B) 1 Ω
(C) $\frac{4}{3}$ Ω (D) $\frac{5}{3}$ Ω

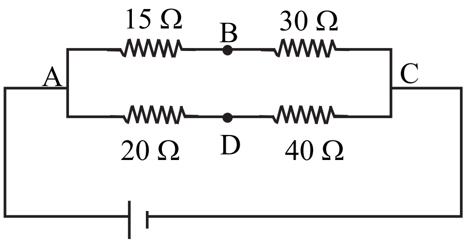
10. In the figure given below, the value of resistance X, when the potential difference between P and M is zero is



(A) 4 ohm (B) 6 ohm
(C) 8 ohm (D) 9 ohm

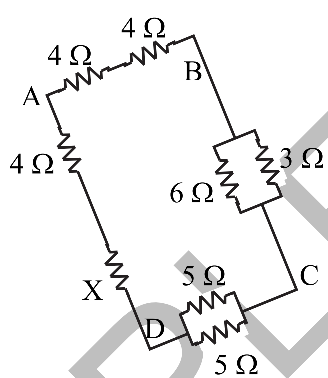
11. Four resistors A, B, C and D having resistances 3 Ω, 3 Ω, 3 Ω and 4 Ω respectively, are arranged to form a Wheatstone's bridge. The value of the resistance with which D must be shunted in order to balance the bridge is
(A) 3 Ω (B) 6 Ω
(C) 9 Ω (D) 12 Ω

12. In the circuit shown below, the potential difference between the points B and D is



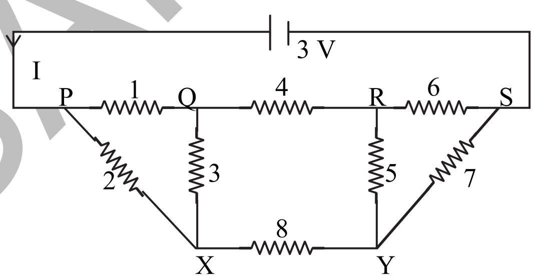
(A) 1 V (B) 0 V
(C) –2 V (D) 4 V

13. In the adjoining figure, the potential drop between B and D is zero. The value of X is



(A) 3 Ω (B) 4 Ω (C) 5 Ω (D) 6 Ω

14. Figure shows a network of eight resistors numbered 1 to 8, each equal to 2 Ω and connected to a 3 V battery of negligible internal resistance. The current I in the circuit is

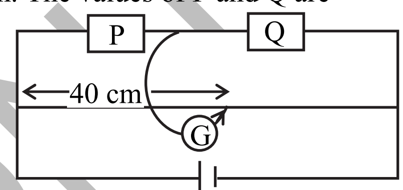


(A) 0.5 A (B) 1.0 A
(C) 2.0 A (D) 4.0 A

Section 3: Metre Bridge

15. With resistances A and B in the left and right gaps of a metre bridge, the balance point divides the wire in the ratio 1/2. When A and B are increased by 10 Ω, the balance point divides the wire in the ratio 3/4. The ratio of A and B will be
(A) 1 : 2 (B) 2 : 1
(C) 3 : 4 (D) 2 : 3

16. In a metre bridge, the gaps are closed by two resistances P and Q and the balance point is obtained at 40 cm. When Q is shunted by a resistance of 10 Ω, the balance point shifts to 50 cm. The values of P and Q are



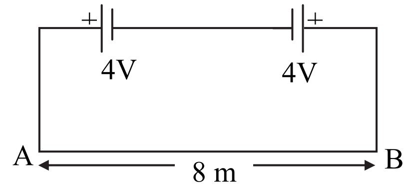
(A) 10/3 Ω, 5 Ω (B) 20 Ω, 30 Ω
(C) 10 Ω, 15 Ω (D) 5 Ω, 15/2 Ω

17. Two resistances are connected in the two gaps of a metre bridge. The balance point is 60 cm from the zero end. When a resistance of 10 Ω is connected in series with a smaller of the two resistances, the null point shifts to 80 cm. The smaller of the two resistance has the value
(A) 8 Ω (B) 6 Ω (C) 4 Ω (D) 2 Ω

18. Unknown resistance is placed in left gap of a metre bridge and known resistance of 30 Ω in the right gap and null point is obtained. If unknown resistance is shunted by $\left(\frac{1}{4}\right)^{\text{th}}$ of its value, then the resistance in the right gap to obtain the null point at the same point will be
(A) 6 Ω (B) 9 Ω
(C) 15 Ω (D) 45 Ω

Section 4: Potentiometer

19. The value of potential gradient in the given circuit will be



(A) 0.5 V/m (B) 0 V/m
(C) 5 V/m (D) 0.05 V/m

20. A voltmeter has a resistance of 40 Ω. When it is connected to a battery of e.m.f 5 V and of internal resistance 5 Ω, the reading of the voltmeter is
(A) 1.1 volt (B) 2.2 volt
(C) 3.3 volt (D) 4.4 volt

21. A standard cell of 1.08 V is connected in the secondary circuit in a potentiometer experiment. The balancing length, in order to obtain a potential gradient of 3×10^{-3} volt/cm, will be
(A) 10.8 m (B) 5.4 m
(C) 3.6 m (D) 1 m

22. The e.m.f. E of the battery is balanced by p. d. across 60 cm of a potentiometer wire. For a standard cell of e.m.f. 1.08 V, the balancing length is 40 cm. The value of E is
(A) 0. 54 V (B) 1.08 V
(C) 1.62 V (D) 1.02 V

23. E.m.f. and internal resistance of a cell are 1.1 V and 0.5 Ω respectively. The e.m.f. balances against 200 cm of a potentiometer wire. On drawing current 'x' from the cell, the balancing length reduces to 150 cm. Then,
(A) x = 0.55 A (B) x = 0.45 A
(C) x = 0.35 A (D) x = 0.25 A

24. The e.m.f. of Daniel cell gets balanced on 600 cm length of potentiometer wire. When a 3 Ω resistance is connected at the terminals of the cell, then the balancing length becomes 200 cm. The internal resistance of the cell will be
(A) 2 Ω (B) 4 Ω
(C) 6 Ω (D) 1 Ω

25. A cell of e.m.f. 2 V and negligible internal resistance is connected in series with a potentiometer wire of length 100 cm. The e.m.f. of the Leclanche cell is found to balance on 60 cm of the potentiometer wire. The e.m.f. of the cell is (in volt)
(A) 3.2 (B) 2.2
(C) 1.2 (D) 0.2

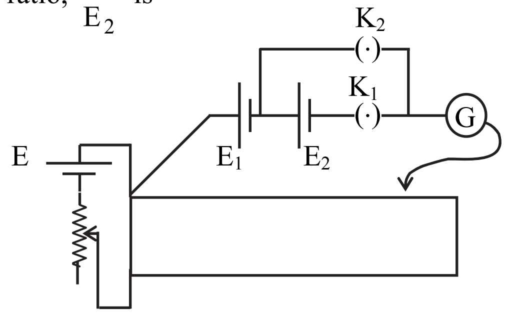
26. When two cells of e.m.f. 1.5 V and 1.1 V connected in series are balanced on a potentiometer, the balancing length is 240 cm. The balancing length, when they are connected in opposition is (in cm)
(A) 37 (B) 74
(C) 111 (D) 148

27. The length of a potentiometer wire is 8 metre. An accumulator of steady e.m.f. is connected to it. A cell connected in usual way gives null point at 6 m. If the length of the potentiometer wire is increased by 2 m, the balance point for the same cell will be
(A) 2.5 m (B) 5.0 m
(C) 7.5 m (D) 1.0 m

28. A potentiometer wire AB is 10 m long and has a resistance of 4 Ω/m. It is connected in series with a battery of e.m.f. 4 V and a resistance of 20 Ω. The potential gradient along the wire in V/m is
(A) 0.01 (B) 0.02
(C) 0.2 (D) 0.3

29. In a potentiometer circuit, there is a cell of e.m.f. 2 volts and internal resistance of 5 Ω, a wire of uniform thickness of length 1000 cm and resistance 20 Ω. The potential gradient of the wire is
(A) 0.6×10^{-3} V/cm (B) 1.6×10^{-3} V/cm
(C) 2.6×10^{-3} V/cm (D) 3.6×10^{-3} V/cm

30. In the potentiometer circuit shown below, when key K_1 is closed and K_2 is open, balancing length is found to be 200 cm. When key K_1 is open and key K_2 is closed, the balancing length is found to be 150 cm. The ratio, $\frac{E_1}{E_2}$ is



(A) 3 : 2 (B) 4 : 1
(C) 5 : 3 (D) 3 : 1

Answers to Problems for Practice

1. 5 A, away from the point
2. 10 Ω, 5 V
3. $I_1 = -3.04$ A, $I_2 = 3.48$ A
4. 14 A
5. 2.52 volt
6. 0.0667 Ω
7. 20 Ω
8. 75 Ω, 37.5 Ω

9. 51.9 cm from one end
10. 45 Ω
11. 6 Ω, 12 Ω
12. 33.33 Ω
13. 40 Ω
14. 3 Ω, 6 Ω
15. 32 Ω, 48 Ω
16. 20 Ω, 30 Ω
17. 16.7 cm to left, 16.7 cm to right
18. 50 Ω, 150 Ω
19. 1 Ω
20. 1.3 Ω
21. 0.5 A
22. 1.2 m
23. 14 Ω
24. 1.08 V
25. 275 cm
26. 9.95×10^{-3} V, 0.804 m
27. 0.5 V/m
28. 0.18 V/m, 6 m
29. 280 cm

Answers to Multiple Choice Questions

1.	(B)	2.	(C)	3.	(C)	4.	(A)
5.	(C)	6.	(A)	7.	(B)	8.	(C)
9.	(D)	10.	(C)	11.	(D)	12.	(B)
13.	(D)	14.	(B)	15.	(A)	16.	(A)
17.	(D)	18.	(A)	19.	(B)	20.	(D)
21.	(C)	22.	(C)	23.	(A)	24.	(C)
25.	(C)	26.	(A)	27.	(C)	28.	(D)
29.	(B)	30.	(D)				