Chapter 9: Current Electricity

EXERCISES [PAGES 228 - 229]

Exercises | Q 1.1 | Page 228

Kirchhoff's first law, i.e., ΣI = 0 at a junction, deals with the conservation of

1. **charge**
2. energy
3. momentum
4. mass

SOLUTION

charge

Explanation: The principle of conservation of electric charge implies that: at any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node. This is known as Kirchhoff's current law.

Exercises | Q 1.2 | Page 228

When the balance point is obtained in the potentiometer, a current is drawn from

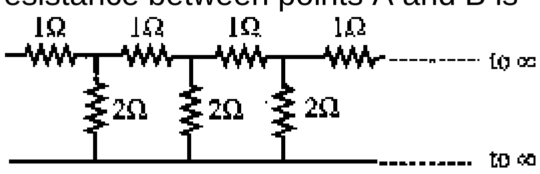
1. both the cells and auxiliary battery
2. cell only
3. auxiliary battery only
4. **neither cell nor auxiliary battery**

SOLUTION

Neither cell nor auxiliary battery

Exercises | Q 1.3 | Page 228

In the following circuit diagram, an infinite series of resistances is shown. Equivalent resistance between points A and B is



1. infinite
2. zero
3. **2 Ω**
4. 30 Ω

SOLUTION

2 Ω

Exercises | Q 1.4 | Page 228

Four resistances 10 Ω, 10 Ω, 10 Ω and 15 Ω form a Wheatstone's network. What shunt is required across 15 Ω resistor to balance the bridge

1. 10 Ω
2. 15 Ω
3. 20 Ω
4. **30 Ω**

SOLUTION

30 Ω

Exercises | Q 1.5 | Page 228

A circular loop has a resistance of 40 Ω. Two points P and Q of the loop, which are one-quarter of the circumference apart are connected to a 24 V battery, having an internal resistance of 0.5 Ω. What is the current flowing through the battery?

1. 0.5 A
2. 1A
3. 2A
4. **3A**

SOLUTION

3A

Explanation:

A circular loop has a resistance of 40 Ω.

Two points P and Q of the loop, which are one quarter of the circumference apart

Resistance of Each part = (1/4) 40 = 10 Ω and (3/4) 40 = 30 Ω

10 Ω ‖ 30 Ω

1/R = 1/10 + 1/30

⇒ 1/R = (3 + 1)/30

⇒ R = 30/4

⇒ R = 7.5 Ω.

internal resistance of 0.5 Ω.

Total Resistance = 7.5 + 0.5 = 8 Ω

Voltage applied = 24V

Current = 24/8 = 3A

3A current flowing through the battery.

Exercises | Q 1.6 | Page 228

To find the resistance of a gold bangle, two diametrically opposite points of the bangle are connected to the two terminals of the left gap of a meter bridge. A resistance of 4 Ω is introduced in the right gap. What is the resistance of the bangle if the null point is at 20 cm from the left end?

1. 2 Ω
2. **4 Ω**
3. 8 Ω
4. 16 Ω

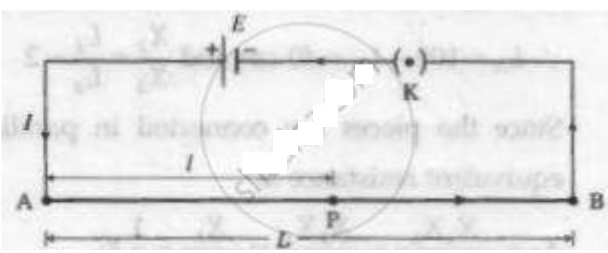
SOLUTION

4 Ω

Exercises | Q 2.01 | Page 228
Define or describe a Potentiometer.

SOLUTION

The potentiometer is a device used for accurate measurement of potential difference as well as the emf of a cell. It does not draw any current from the circuit at the null point. Thus, it acts as an ideal voltmeter and it can be used to determine the internal resistance of a cell. It consists of a long uniform wire AB of length L, stretched on a wooden board. A cell of stable emf (E), with a plug key K in series, is connected across AB as shown in the following figure.



Exercises | Q 2.02 | Page 228
Define Potential Gradient.

SOLUTION

The potential gradient is defined as the potential difference (the fall of potential from the high potential end) per unit length of the wire.

Exercises | Q 2.03 | Page 228
Why should not the jockey be slided along the potentiometer wire?

SOLUTION

Sliding the jockey on the potentiometer wire decreases the cross-sectional area of the wire and thereby affects the fall of potential along the wire. This affects the potentiometer readings. Hence, the jockey should not be slided along the potentiometer wire.

Exercises | Q 2.04 | Page 228

Are Kirchhoff's laws applicable to both AC and DC currents?

SOLUTION

Kirchhoff's laws are applicable to both AC and DC circuits (networks). For AC circuits with different loads, (e.g. a combination of a resistor and a capacitor, the instantaneous values for current and voltage are considered for addition.

Exercises | Q 2.05 | Page 228

In Wheatstone's meter-bridge experiment, the null point is obtained in the middle one-third portion of the wire. Why is it recommended?

SOLUTION

1. The value of unknown resistance X, may not be accurate due to the non-uniformity of the bridge wire and development of contact resistance at the ends of the wire.

2. To minimize these errors, the value of R is so adjusted that the null point is obtained in the middle one-third of the wire (between 34 cm and 66 cm) so that the percentage errors in the measurement of l_X and l_R are minimum and nearly the same.

Exercises | Q 2.06 | Page 228

State any two sources of errors in the meter-bridge experiment. Explain how they can be minimized.

SOLUTION

The chief sources of error in the meter bridge experiment are as follows:

1. The bridge wire may not be uniform in cross-section. Then the wire will not have a uniform resistance per unit length and hence its resistance will not be proportional to its length.
2. End resistances at the two ends of the wire may be introduced due to
   (i) the resistance of the metal strips
   (ii) the contact resistance of the bridge wire with the metal strips

(iii) unmeasured lengths of the wire at the ends because the contact points of the wire with the metal strips do not coincide with the two ends of the metre scale attached.

Such errors are almost unavoidable but can be minimized considerably as follows:

1. Readings must be taken by adjusting the standard known resistance such that the null point is obtained close to the centre of the wire. When several readings are to be taken, the null points should lie in the middle one-third of the wire.
2. The measurements must be repeated with the standard resistance (resistance box) and the unknown resistance interchanged in the gaps of the bridge, obtaining the averages of the two results.

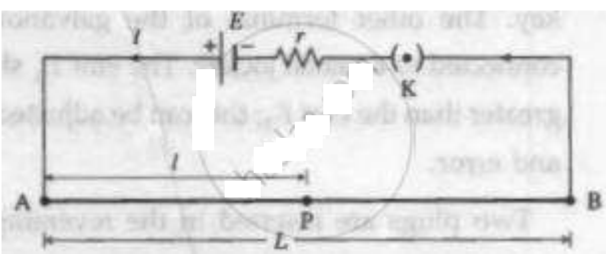
Exercises | Q 2.07 | Page 228

What is a potential gradient? How is it measured? Explain.

SOLUTION

The potential gradient is defined as the fall of potential per unit length of potentiometer wire. The gradient of potential energy is a force (measured in newtons).

Consider a potentiometer consisting of a long uniform wire AB of length L and resistance R, stretched on a wooden board and connected in series with a cell of stable emf E and internal resistance rand a plug key K as shown in the following figure.



Let I be the current flowing through the wire when the circuit is closed.

Current through AB, I = $\frac{\mathrm{E}}{\mathrm{R}+\mathrm{r}}$

Potential difference across AB. V_{AB} = IR

$$\therefore \mathrm{V_{AB}} = \frac{\mathrm{ER}}{\mathrm{R}+\mathrm{r}}$$

The potential difference (the fall of potential from the high potential end) per unit length of the wire,

$$\frac{\mathrm{V_{AB}}}{\mathrm{L}} = \frac{\mathrm{ER}}{(\mathrm{R}+\mathrm{r})\mathrm{L}}$$

As long as E and r remain constant, $\frac{V_{AB}}{L}$ will remain constant. $\frac{V_{AB}}{L}$ is known as a potential gradient along with AB and is denoted by K. Thus the potential gradient is calculated by measuring the potential difference between ends of the potentiometer wire and dividing it by the length of the wire.

Let P be any point on the wire between A and B and AP= l =length of the wire between A and P.

Then $V_{AP} = Kl$

$\therefore V_{AP} \propto l$ as K is constant in a particular case. Thus, the potential difference across any length of the potentiometer wire is directly proportional to that length. This is the principle of the potentiometer.

Exercises | Q 2.08 | Page 228

On what factors does the potential gradient of the wire depend?

SOLUTION

The potential gradient depends upon the potential difference between the ends of the wire and the length of the wire.

Exercises | Q 2.09 | Page 228

Why is a potentiometer preferred over a voltmeter for measuring emf?

SOLUTION

A voltmeter should ideally have an infinite resistance so that it does not draw any current from the circuit. However a voltmeter cannot be designed to have infinite resistance. A potentiometer does not draw any current from the circuit at the null point. Therefore, it gives a more accurate measurement. Thus, it acts as an ideal voltmeter.

Exercises | Q 2.10 | Page 228

State the uses of a potentiometer.

SOLUTION

The applications (uses) of the potentiometer:

1. **Voltage divider:** The potentiometer can be used as a voltage divider to change the output voltage of a voltage supply.

2. **Audio control:** Sliding potentiometers are commonly used in modem low-power audio systems as audio control devices. Both sliding (faders) and rotary potentiometers (knobs) are regularly used for frequency attenuation, loudness control and for controlling different characteristics of audio signals.

3. **Potentiometer as a sensor:** If the slider of the potentiometer is connected to the moving part of a machine, it can work as a motion sensor. A small displacement of the moving part causes a change in potential which is further amplified using an amplifier circuit. The potential difference is calibrated in terms of displacement of the moving part.

4. To measure the emf (for this, the emf of the standard cell and potential gradient must be known).

5. To compare the emfs of two cells.

6. To determine the internal resistance of a cell.

Exercises | Q 2.11 | Page 228

What are the disadvantages of a potentiometer?

SOLUTION

Disadvantages of a potentiometer over a voltmeter:

1. The use of a potentiometer is an indirect measurement method while a voltmeter is a direct reading instrument.

2. A potentiometer is unwieldy while a voltmeter is portable.

3. Unlike a voltmeter, the use of a potentiometer in measuring an unknown emf requires a standard source of emf and calibration.

Exercises | Q 2.12 | Page 228

Distinguish between a potentiometer and a voltmeter.

SOLUTION

	Potentiometer	**Voltmeter**
1.	A potentiometer is used to determine the emf of a cell, potential difference, and internal resistance.	A voltmeter can be used to measure the potential difference and terminal voltage of a cell. But it cannot be used to measure the emf of a cell.
2.	Its accuracy and sensitivity are very high.	Its accuracy and sensitivity are less as compared to a potentiometer.
3.	It is not a portable instrument.	It is a portable instrument.
4.	It does not give a direct reading.	It gives a direct reading.

Exercises | Q 2.13 | Page 228

What will be the effect on the position of zero deflection if only the current flowing through the potentiometer wire is increased?

SOLUTION

On increasing the current through the potentiometer wire, the potential gradient along the wire will increase. Hence, the position of zero deflection will occur at a shorter length.

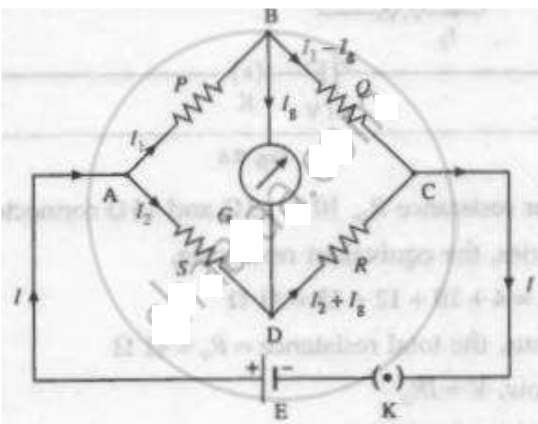
Exercises | Q 3 | Page 228

With the help of a labelled diagram, show that the balancing condition of a Wheatstone bridge is

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$ where the terms have their usual meaning.

SOLUTION

Wheatstone's network or bridge is a circuit for indirect measurement of resistance by the null comparison method by comparing it with a standard known resistance. It consists of four resistors with resistances P, Q, R and S arranged in the form of a quadrilateral ABCD. A cell (E) with a plug key (K) in series is connected across one diagonal AC and a galvanometer (G) across the other diagonal BD as shown in the following figure.



With the key K closed, currents pass through the resistors and the galvanometer. One or more of the resistances is adjusted until no deflection in the galvanometer can be detected. The bridge is then said to be balanced.

Let I be the current drawn from the cell. At junction A, it divides into a current I_1 through P and a current I_2 through S.

$I = I_1 + I_2$ (by Kirchhoffs first law).

At junction B, current I_g flows through the galvanometer and current $I_1 - I_g$ flows through Q. At junction D, I_2 and I_g combine. Hence, the current $I_2 + I_g$ flows through R from D to C. At junction C, $I_1 - I_g$ and $I_2 + I_g$ combine. Hence, current $I_1 + I_2$ (= I) leaves junction C.

Applying Kirchhoff's voltage law to loop ABDA in a clockwise sense, we get,

$- I_1P - I_gG + I_2S = 0$ ...(1)

where G is the resistance of the galvanometer.

Applying Kirchhoff's voltage law to loop BCDB in a clockwise sense, we get,

$- (I_1 - I_g)Q + (I_2 + I_g)R + I_gG = 0$ .....(2)

When $I_g = 0$, the bridge (network) is said to be balanced. In that case, from Eqs. (1) and (2), we get,

$I_1P = I_2S$ .....(3)

and $I_1Q = I_2R$ .....(4)

From Eqs. (3) and (4), we get,

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

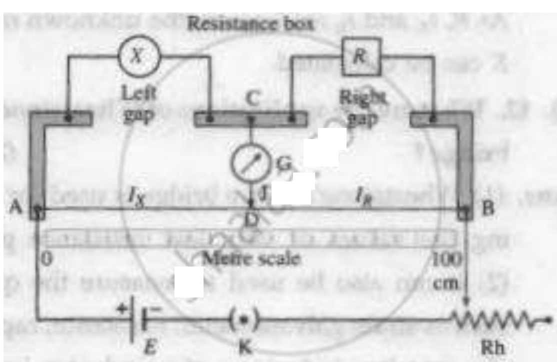
This is the condition of balance.

Exercises | Q 4 | Page 228

Explain with a neat circuit diagram how will you determine unknown resistance ‘X' by using meter bridge

SOLUTION

A meter bridge consists of a rectangular wooden board with two L-shaped thick metallic strips fixed along its three edges. A single thick metallic strip separates two L-shaped strips. A wire of length one meter and uniform cross-section is stretched on a meter scale fixed on the wooden board. The ends of the wire are fixed to the L-shaped metallic strips.



An unknown resistance X is connected in the left gap and a resistance box R is connected in the right gap as shown above figure. One end of a center-zero galvanometer (G) is connected to terminal C and the other end is connected to a pencil jockey (J). A cell (E) of emf E, plug key (K) and rheostat (Rh) are connected in series between points A and B.

Working: Keeping a suitable resistance (R) in the resistance box, key K is closed to pass a current through the circuit. The jockey is tapped along the wire to locate the equipotential point D when the galvanometer shows zero deflection. The bridge is then balanced and point D is called the null point and the method is called a null deflection method. The distances l_X and l_R of the null point from the two ends of the wire are measured.

According to the principle of Wheatstone's network,

$$\frac{X}{R} = \frac{\text{resistance of the wire of length } l_X\ (R_{AD})}{\text{resistance of the wire of length } l_R\ (R_{DB})}$$

$$\therefore \frac{X}{R} = \frac{R_{AD}}{R_{DB}} \qquad .....(1)$$

Now, R = $\rho\frac{1}{A}$ where l is the length of the wire, ρ is the resistivity of the material of the wire and A is the area of cross-section of the wire.

$$\therefore R_{AD} = \rho\frac{l_x}{A} \text{ and } R_{DB} = \rho\frac{l_g}{A}$$

$$\therefore \frac{X}{R} = \frac{R_{AD}}{R_{DC}} = \frac{\rho l_x/A}{\rho l_g/A}$$

$$\therefore \frac{X}{R} = \frac{l_x}{l_g}$$

$$\therefore X = \frac{l_x}{l_R} \times R$$

As R, l_x and l_g are known, the unknown resistance X can be calculated.

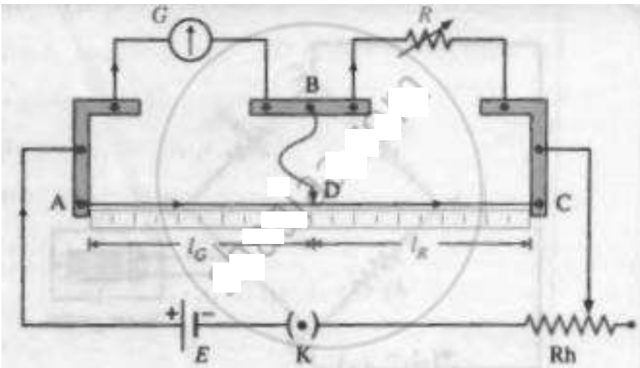
Exercises | Q 5 | Page 228

Describe Kelvin's method to determine the resistance of the galvanometer by using a meter bridge.

SOLUTION

Kelvin's method:

Circuit: The meter bridge circuit for Kelvin's method of determination of the resistance of a galvanometer is shown in the following figure. The galvanometer whose resistance G is to be determined is connected in one gap of the meter bridge. A resistance box providing a variable known resistance R is connected to the other gap.



Kelvin's meter bridge circuit for the measurement of galvanometer resistance

where, G: Galvanometer, R: Resistance box, AC: Uniform resistance wire, D: Balance point, E: Cell, K: Plug key, Rh: Rheostat

The junction B of the galvanometer and the resistance box is connected directly to a pencil jockey. A cell of emf E, a key (K) and a rheostat (Rh) are connected across AC.

Working: Keeping a suitable resistance R in the resistance box and maximum resistance in the rheostat, key K is closed to pass the current. The rheostat resistance is slowly reduced such that the galvanometer shows about 2/3rd of the full-scale deflection.

On tapping the jockey at end-points A and C, the galvanometer deflection should change to opposite sides of the initial deflection. Only then will there be a point D on the wire which is equipotential with point B. The jockey is tapped along the wire to locate the equipotential point D when the galvanometer shows no change in deflection. Point D is now called the balance point and Kelvin's method is thus an equal deflection method. At this balanced condition,

$$\frac{G}{R} = \frac{\text{resistance of the wire of length } l_G}{\text{- resistance of the wire of length } l_g}$$

where l_G ≡ the length of the wire opposite to the galvanometer, l_R ≡ the length of the wire opposite to the resistance box.

If λ ≡ the resistance per unit length of the wire,

$$\frac{G}{R} = \frac{\lambda l_G}{\lambda l_R} = \frac{l_G}{l_R}$$

$$\therefore G = R\frac{l_G}{l_R}$$

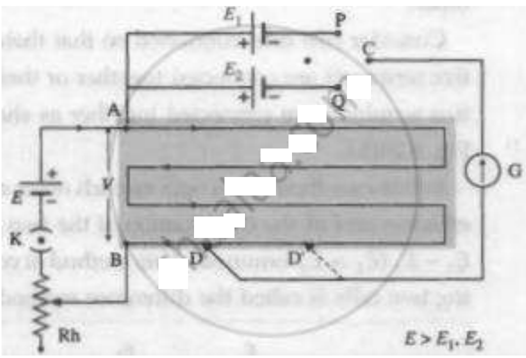
The quantities on the right hand side are known, so that G can be calculated.

Exercises | Q 6 | Page 228

Describe how a potentiometer is used to compare the EMFs of two cells by connecting the cells individually.

SOLUTION

A battery of stable emf E is used to set up a potential gradient V/L along a potentiometer wire, where V ≡ potential difference across the length L of the wire. The positive terminals of the cells, whose em.f's (E_1 and E_2) are to be compared, are connected to the high potential terminal A. The negative terminals of the cells are connected to a galvanometer G through a two-way key. The other terminal of the galvanometer is connected to a pencil jockey. The emf E should be greater than both the emf's E_1 and E_2.



Comparison of two emf's using a potentiometer by the direct method

Connecting point P to C, the cell with emf E_1 is brought into the circuit. The jockey is tapped along the wire to locate the null point D at a distance l_1 from A. Then,

$E_1 = l_1(V/L)$

w, without changing the potential gradient (i.e., without changing the rheostat setting) point Q (instead of P) is connected to C, bringing the cell with emf E_2 into the circuit. Let its null point D' be at a distance l_2 from A, so that

$E_2 = l_2(V/L)$

Hence, by measuring the corresponding null lengths l_1 and l_2, E_1/E_2 can be calculated. The experiment is repeated for different potential gradients using the rheostat.

Exercises | Q 7 | Page 229

Describe how a potentiometer is used to compare the emf's of two cells by the combination method.

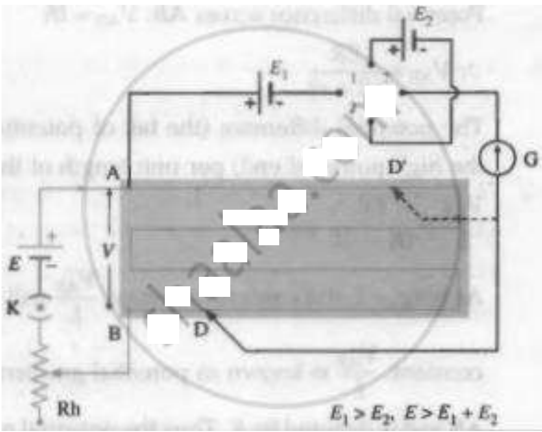
SOLUTION

A battery of stable emf E is used to set up a potential gradient V/L, along the potentiometer wire, where V = potential difference across length L of the wire. The positive terminal of the cell 1 is connected to the higher potential terminal A of the potentiometer; the negative terminal is connected to the galvanometer G through the reversing key. The other terminal of the galvanometer is connected to a pencil jockey.

The cell 2 is connected across the remaining two opposite terminals of the reversing key. The other terminal of the galvanometer is connected to a pencil jockey. The emf E_1 should be greater than the emf E_2; this can be adjusted by trial and error.

Two plugs are inserted in the reversing key in positions 1-1. Here, the two cells assist each other so that the net emf is $E_1 + E_2$. The jockey is tapped along the wire to locate the null point D. If the null point is a distance l_1 from A,

$E_1 + E_2 = l_1 (V/L)$



Comparison of two emf's using a potentiometer by the combination method (the sum and difference method)

For the same potential gradient (without changing the rheostat setting), the plugs are now inserted into position 2-2. (instead of 1-1). The emf E_2 then opposes E_1 and the net emf is $E_1 - E_2$. The new null point D' is, say, a distance l_2 from A and

$$E_1 - E_2 = l_2 (V/L)$$

$$\therefore \frac{E_1 + E_2}{E_1 - E_2} = \frac{l_1}{l_2}$$

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

Here, the emf E should be greater than $E_1 + E_2$. The experiment is repeated for different potential gradients using the rheostat.

Exercises | Q 8 | Page 229

Describe with the help of a neat circuit diagram how you will determine the internal resistance of a cell by using a potentiometer. Derive the necessary formula.

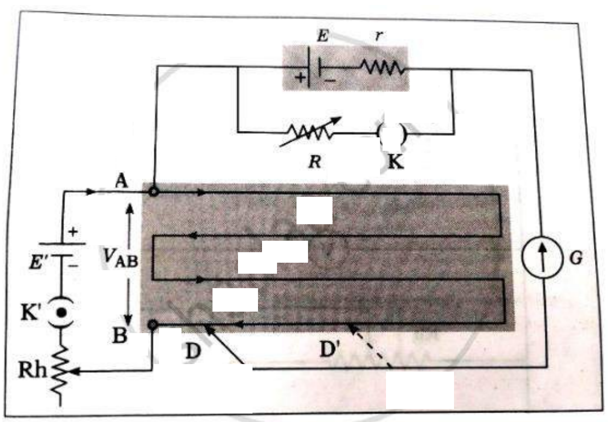
SOLUTION

Principle: A cell of emf E and internal resistance r, which is connected to an external resistance R, has its terminal potential difference V less than its emf E, and

$$\frac{E}{V} = \frac{R + r}{R} = 1 + \frac{r}{R} \text{ ....(where R} \to \infty\text{, V} \to \text{E)}$$

$$\therefore r = \frac{E - V}{V} R$$

Working: A battery of stable emf E' is used to set up a potential gradient V_{AB}/L along the potentiometer wire, where V_{AB} = p.d. across total length L of the wire AB. The positive terminal of the cell of emf E and internal resistance r is connected to the higher potential terminal A of the potentiometer, the negative terminal is connected through a center-zero galvanometer to a pencil jockey. A resistance box R with a plug key K in series is counted across the cell.



Internal resistance of a cell using a potentiometer

Firstly, key K is kept open, then, effectively, R = ∞. The jockey is tapped on the potentiometer wire to locate the null point D. Let the null length AD = l, so that
$E = (V_{AB} / L)l$

With the same potential gradient and a small resistance R in the resistance box, key K is closed. The new null length AD′ = l_1 for the terminal p.d. V is found: $V = (V_{AB}/L)l_2$

$$\therefore \frac{E}{V} = \frac{l_1}{l_2}$$

$$\therefore \frac{E - V}{V} = \frac{l_1 - l_2}{l_2} = \frac{l_1}{l_2} - 1$$

$$\text{Now, } r = \frac{E - V}{V} R$$

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

R, l and l_1 being known, e can be calculated. The experiment is repeated either with different potential gradients or with different values of R.

Exercises | Q 9 | Page 229

On what factors does the internal resistance of a cell depend?

SOLUTION

The internal resistance of a cell depends on:

1. Nature of the electrolyte:
   The greater the conductivity of the electrolyte, the lower is the internal resistance of the cell.

2. Separation between the electrodes:
   The larger the seperation between the electrodes of the cell, the higher is the internal resistance of the cell. This is because the ions have to cover a greater distance before reaching an electrode.

3. Nature of the electrodes.

4. The internal resistance is inversly proportional to the common area of the electrodes dipping in the electrolyte.

Exercises | Q 10 | Page 229

A battery of emf 4 volt 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 2 Ω. Calculate the current through the external resistance.

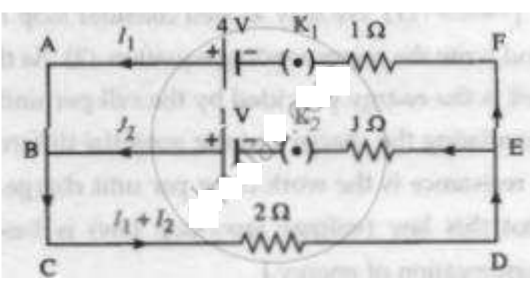
SOLUTION

Let I_1 and I_2 be the currents through the two branches as shown in the following figure. The current through the 2Ω resistance will be $(I_1 + I_2)$ [Kirchhoffs current law].

Applying Kirchhoff's voltage law to loop ABCDEFA, we get,

$-2(I_1 + I_2) - 1(I_1) + 4 = 0$

$\therefore 3I_1 + 2I_2 = 4$ .....(1)



Applying Kirchhoffs voltage law to loop BCDEB, we get,

$-2(I_1 + I_2) - 1(I_2) + 1 = 0$

$2I_1 + 3I_2 = 1$ ....(2)

Multiplying Eq. (1) by 2 and Eq. (2) by 3, we get,

$6I_1 + 4I_2 = 8$ .....(3)

and $6I_1 + 9I_2 = 3$ ....(4)

Subtracting Eq. (4) from Eq. (3), we get,

$- 5I_2 = 5$

$\therefore I_2 = - 1A$

The minus sign shows that the direction of current I_2 is opposite to that assumption. Substituting this value of I_2 in Eq. (1), we get,

$3I_1 + 2(-1) = 4$

$\therefore 3I_1 - 4 + 2 = 6$

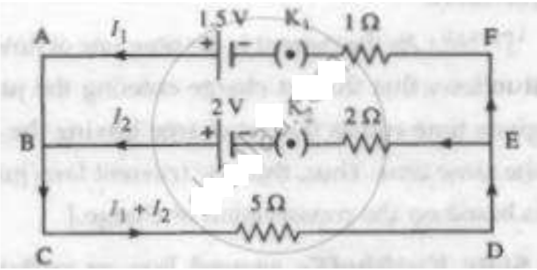
$\therefore I_1 = 2A$

Current through the 2Ω resistance = $I_1 + I_2 = 2 - 1 = 1$ A.

Exercises | Q 11 | Page 229
Answer in Brief.
Two cells of emf 1.5 Volt and 2 Volt having respective internal resistances of 1 Ω and 2 Ω are connected in parallel so as to send current in the same direction through an external resistance of 5 Ω. Find the current through the external resistance.

SOLUTION

Let I_1 and I_2, be the currents flowing through the two branches as shown in the following figure. The current through the 5 Ω resistor will be $I_1 + I_2$ [Kirchhoff's current law].



Applying Kirchhoff's voltage law to loop ABCDEFA, we get,

$-5 (I_1 + I_2) - I_1 + 1.5 = 0$

$\therefore 6I_1 + 5I_2 = 1.5$ ....(1)

Applying Kirchhoff's voltage law to loop BCDEB, we get,

$-5 (I_1 + I_2) - 2I_2 + 2 = 0$

$\therefore 5I_1 + 7I_2 = 2$ ....(2)

Multiplying Eq. (1) by 5 and Eq. (2) by 6, we get,

$30I_1 + 25I_2 = 7.5$ ....(3)

and $30I_1 + 42I_2 = 12$ ....(4)

Subtracting Eq. (3) from Eq. (4), we get,

$17I_2 = 4.5$

$\therefore I_2 = \frac{4.5}{17}$ A

Substituting this value of I_2 in Eq. (1), we get,

$$6I_1 + 5\left(\frac{4.5}{17}\right) = 1.5$$

$$\therefore 6I_1 + \frac{22.5}{17} = 1.5$$

$$\therefore 6I_1 = 1.5 - \frac{22.5}{17} = \frac{28.5 - 22.5}{17} = \frac{3}{17}$$

$$\therefore I_2 = \frac{3}{17 \times 6} = \frac{0.5}{17} \text{ A}$$

Current through the 5 Ω resistance (external resistance) = $I_1 + I_2 = \frac{0.5}{17} + \frac{4.5}{17} = \frac{5}{17}$ A.

Exercises | Q 12 | Page 229

A voltmeter has a resistance of 30 Ω. What will be its reading, when it is connected across a cell of emf 2 V having internal resistance 10 Ω?

SOLUTION

Data: E = 2V, r = 10 Ω, R = 30Ω

The voltmeter reading, V = IR

$$= \left(\frac{E}{R + r}\right)R$$

$$= \left(\frac{2}{30 + 10}\right)30$$

$$= \left(\frac{2}{40}\right)30$$

Data: E = 2V, r = 10 Ω, R = 30Ω

The voltmeter reading, V = IR

$$= \left(\frac{\mathrm{E}}{\mathrm{R}+\mathrm{r}}\right)\mathrm{R}$$

$$= \left(\frac{2}{30+10}\right)30$$

$$= \left(\frac{2}{40}\right)30$$

= 1.5 V

Exercises | Q 13 | Page 229

Answer in brief.

A set of three coils having resistances 10 Ω, 12 Ω, and 15 Ω are connected in parallel. This combination is connected in series with a series combination of three coils of the same resistances. Calculate the total resistance and current through the circuit, if a battery of emf 4.1 Volt is used for drawing current.

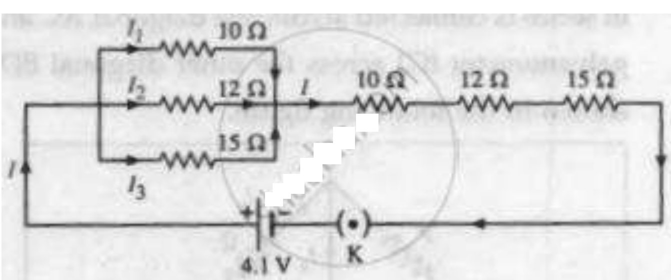
SOLUTION

In the following figure shows the electrical network. For resistances, 10 Ω, 12 Ω and 15 Ω connected in parallel the equivalent resistance (RP) is given by,

$$\frac{1}{\mathrm{R_p}} = \frac{1}{10} + \frac{1}{12} + \frac{1}{15}$$

$$= \frac{6+5+4}{60} = \frac{15}{60} = \frac{1}{4}$$

$\therefore \mathrm{R_p} = 4\Omega$



For resistance R_p , 10 Ω, 12 Ω and 15 Ω connected in series, the equivalent resistance,

R_s = 4 + 10 + 12 + 15 = 41 Ω

Thus, the total resistance = R_S = 41 Ω

Now, $V = IR_S$

∴ 4.1 = I × 41

∴ I = 0.1 A

The total resistance and current through the circuit are 41 Ω and 0.1 A respectively.

Exercises | Q 14 | Page 229

A potentiometer wire has a length of 1.5 m and a resistance of 10 Ω. It is connected in series with the cell of emf 4 Volt and internal resistance 5 Ω. Calculate the potential drop per centimeter of the wire.

SOLUTION

Data: L = 1.5 m, R = 10 Ω, E = 4 V, r = 5 Ω.

$$K = \frac{ER}{(R + r)L}$$

$$\therefore K = \frac{4 \times 10}{(10 + 5)1.5}$$

$$= \frac{40}{15 \times \frac{15}{10}}$$

$$= \frac{400}{225}\frac{V}{m} = \frac{400}{22500}\frac{V}{cm} = 0.0178\frac{V}{cm}$$

The potential drop per centimeter of the wire is $0.0178\frac{V}{cm}$

Exercises | Q 15 | Page 229

When two cells of emf's E_1 and E_2 are connected in series so as to assist each other, their balancing length on a potentiometer wire is found to be 2.7 m. When the cells are connected in series so as to oppose each other, the balancing length is found to be 0.3 m. Compare the emf's of the two cells.

SOLUTION

Data: l_1 = 2.7 m (cells assisting),

l_2 = 0.3 m (cells opposing)

$E_1 + E_2 = Kl_1$ and $E_1 - E_2 = Kl_2$

$$\therefore \frac{E_1 + E_2}{E_1 - E_2} = \frac{Kl_1}{Kl_2}$$

$$\therefore \frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2} = \frac{2.7 + 0.3}{2.7 - 0.3} = \frac{3}{2.4} = \frac{30}{24} = 1.25$$

The ratio of the emf's of the two cells is 1.25.

Exercises | Q 16 | Page 229

The emf of a cell is balanced by a length of 120 cm of a potentiometer wire. When the cell is shunted by a resistance of 10 Ω, the balancing length is reduced by 20 cm. Find the internal resistance of the cell.

SOLUTION

Data: R = 10 Ω, l_1 =120 cm,l_2 = 120 - 20 = 100 cm

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

$$= 10\left(\frac{120 - 100}{100}\right)$$

= 2 Ω

The internal resistance of the cell is 2 Ω.

Exercises | Q 17 | Page 229

A potential drop per unit length along a wire is 5×10^{-3} V/m. If the emf of a cell balances against length 216 cm of this potentiometer wire, find the emf of the cell.

SOLUTION

Data: K = 5 × 10^{-3} $\frac{V}{m}$, L = 216 cm = 216 × 10^{-2} m

E = KL

∴ E = 5 × 10^{-3} × 216 ×10^{-2}

= 1080 × 10^{-5}

= 0.01080 V

The emf of the cell is 0.01080 volL

Exercises | Q 18 | Page 229

The resistance of a potentiometer wire is 8 n and its length is 8 m. A resistance box and a 2 V battery are connected in series with iL What should be the resistance in the box if it is desired to have a potential drop of 1 μV /mm?

SOLUTION

Data: R = 8 Ω, L = 8 m, E = 2 V, K = 1 μV/ mm

$$= 1 \times \frac{10^{-6}\mathrm{V}}{10^{-3}\mathrm{m}} = 10^{-3}\frac{\mathrm{V}}{\mathrm{m}}$$

K = $\frac{V}{L} = \frac{ER}{(R + R_B)L}$, where R_B is the resistance in the box.

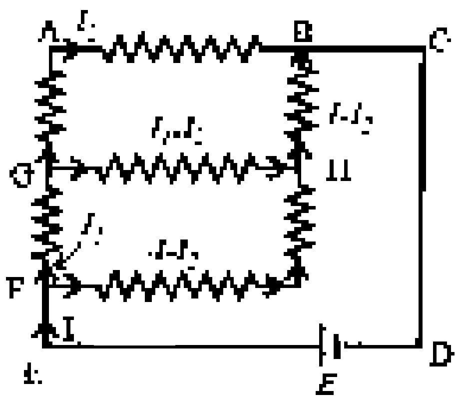
$$\therefore 10^{-3} = \frac{2 \times 8}{(8 + R_B)8}$$

$$\therefore 8 + R_B = \frac{2}{10^{-3}} = 2 \times 10^3$$

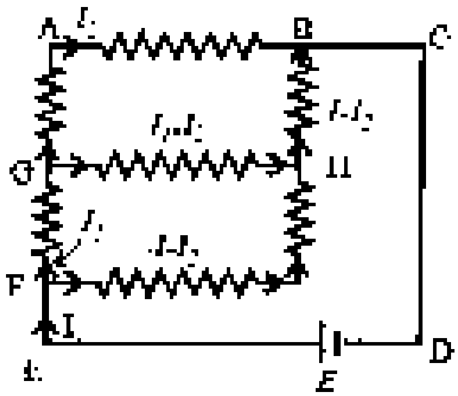
∴ $R_B = 200 - 8$ = 1992 Ω

Exercises | Q 19 | Page 229

Answer in Brief.
Find the equivalent resistance between the terminals of A and B in the network shown in the figure below given that the resistance of each resistor is 10 ohm.



SOLUTION



Applying KVL in loop KLOPK
$-I_1R = (I_1 - I_2)R + (I - I_1)R + R(I - I_1) = 0$
$-I_1R - I_1R + I_2R + 2IR - 2I_1R = 0$
$-4I_1R + I_2R + 2IR = 0$
$\Rightarrow 4I_1 - I_2 = 2I$ ....(i)

Applying KVL in loop LMNOL
$-I^2R - I_2R + (I - I_2)R + R(I_1 - I_2) = 0$
$-2I_2R + IR - I_2R + I_1R - I_1R = 0$
$-4I_2R + IR + I_1R = 0$
$\Rightarrow 4I_2 - I - I1 = 0$
$4I_2 - I_1 = I$ ....(ii)

Applying LVL in loop AKPONBA
$-(I - I_1)R - (I - I_1)R - (I - I_2)R + E = 0$
$2(I - I_1)R + (I - I_2)R = E$ ....(iii)

$$I_1 = \frac{3}{5}I$$
$$I_2 = \frac{2}{5}I$$

$\frac{7}{5}$IR = E

$\frac{7}{5}$IR = IR^1

R^1 = $\frac{7}{5}$R

= $\frac{7}{5}$R

= $\frac{7}{5} \times 10$

= 14 Ω

Exercises | Q 20 | Page 229

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

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

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

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

From formula,

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

∴ V = 1.667 V

The reading on the voltmeter is 1.667 V