

3.Current Electricity

Answers

Module 1 : Kirchhoff's Laws

A.3.1.1 (D)

- A. Electric current is a scalar quantity, Hence (A) is incorrect.
- B. As the potential changes. Hence energy does not remain conserved. Hence (B) is incorrect.
- C. Charge accelerates in the presence of an electric field, hence linear momentum is not conserved. Therefore, (C) is incorrect.
- D. There is no accumulation or depletion of charge at a junction. Hence, (D) is correct.

A.3.1.2 (B)

Applying Kirchhoff's junction rule

$$4 + 2 + I = + 1$$

$$\text{or } I = -5 \text{ A}$$

A.3.1.3 (A)

The arms of the network having capacitor C have zero current. Capacitor does not allow d.c. to flow through it.

Applying Kirchhoff's junction rule

$$3+1=I_3$$

$$\text{Or } I_3 = 4 \text{ A}$$

A.3.1.4 (B)

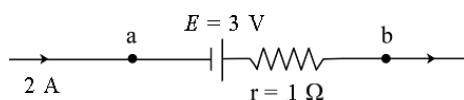


Fig.A.3.1.1

Fig.A.3.1.1 shows the internal resistance of the cell separately. p.d.(V) of the cell is the potential difference between points a and b. Using Kirchhoff's voltage law;

$$V_{ab} = 3 - 1 \times 2$$

$$= 1 \text{ V}$$



A.3.1.5 (C)

$$V_x - 3(2) - 2 - 3 + 2 + V_y = 0$$

$$\text{Therefore, } V_y = +9 \text{ V}$$

A.3.1.6 (B)

Solution: For cells connected in parallel, we know

$$\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2} \text{ and } r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

In given arrangement; $E_2 = +10 \text{ V}$, $E_1 = -2 \text{ V}$;

$$E_{eq} = \frac{10 \times 5 + (-2) \times 10}{10 + 5} = \frac{30}{15} = 2 \text{ V}$$

$$r_{eq} = \frac{5 \times 10}{5 + 10} = 3.33 \Omega$$

A.3.1.7 (C)

(B) Charge moves under the effect of force. So linear momentum does not remain conserved. Hence (B) is incorrect.

(C) As no change in potential, hence energy remains the same. Therefore, (C) is correct.

A.3.1.8 (C)

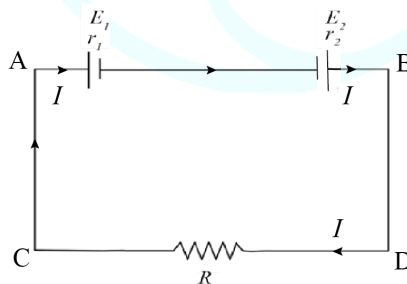


Fig.A.3.1.2

I is current in loop, as shown in Fig.A.3.1.2 Applying Kirchoff's loop law

$$(-E_1 - Ir_1) + (E_2 - Ir_2) - IR = 0$$

$$\text{or } I = \frac{E_2 - E_1}{R + r_1 + r_2}$$

$$V_1 = \text{p.d. of cell } E_1 = -E_1 I r_1$$

$$= E_1 - \frac{(E_2 - E_1)r_1}{R + r_1 + r_2}$$

$$= \frac{E_1 R - (E_2 r_1 - E_1 r_2)}{R + r_1 + r_2}$$

$$V_1 = 0; \text{ if}$$

$$E_1 R = (E_2 r_1 - E_1 r_2)$$

$$\therefore R = \left(\frac{E_2}{E_1}\right)r_1 - r_2$$

A.3.1.9 (B)

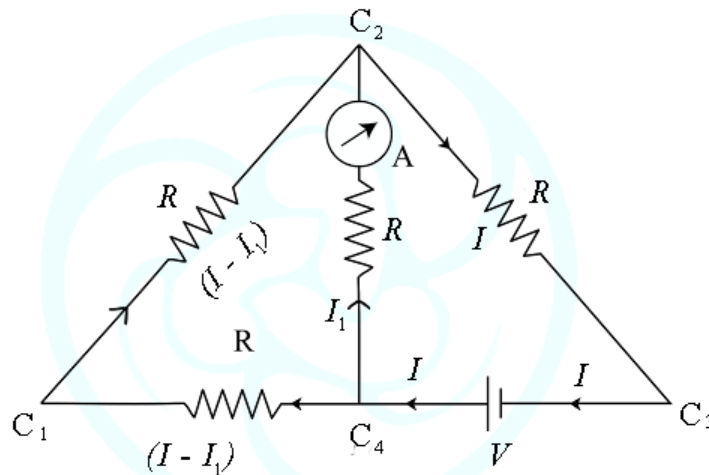


Fig.A.3.1.3

Fig.A.3.1.3 shows current distribution in accordance with Kirchhoff's junction law. Applying Kirchhoff's loop law to

(i) loop $C_1 C_2 C_4 C_1$

$$-(I - I_1)R + I_1 R - (I - I_1)R = 0$$

$$\text{or } I_1 = 2(I - I_1)$$

$$\therefore I_1 = \frac{2I}{3} \quad (\text{A.3.1.1})$$

(ii) loop $C_2 C_3 C_4 C_2$;

$$-IR + V - I_1 R = 0$$

$$(I + I_1)R = V$$

$$\therefore I = \frac{3V}{5R} \quad (\text{A.3.1.2})$$

From Eqns (A.3.1.1) and (A.3.1.2), we have

$$I_1 = \frac{2V}{5R}$$

A.3.1.10 (C)

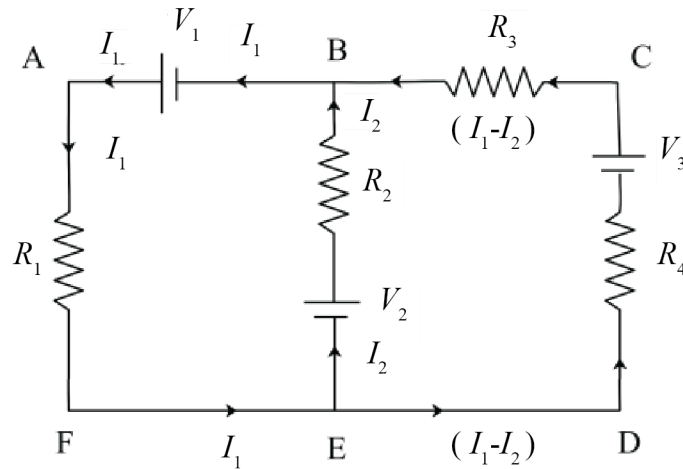


Fig.A.3.1.4

Fig.A.3.1.4 shows current distribution in the circuit arrangement. Applying Kirchhoff's loop law to

(i) loop ABEFA

$$-V_1 + I_2 R_2 - V_2 + I_1 R_1 = 0$$

$$\text{or } I_1 + 2I_2 = 7 \quad (\text{A.3.1.3})$$

(ii) loop BCDEB

$$R_3(I_1 - I_2) - V_3 + (I_1 - I_2)R_4 + V_2 - I_2R_2 = 0$$

$$\text{or, } 3(I_1 - I_2) - 5 + 5(I_1 - I_2) + 3 - 2I_2 = 0$$

$$8I_1 - 10I_2 = 2$$

$$4I_1 - 5I_2 = 1 \quad (\text{A.3.1.4})$$

From Eqns (A.3.1.3) and (A.3.1.4);

$$I_1 = \frac{37}{13} \text{ A}$$



Module 2 : Wheatstone Bridge

A.3.2.1 (B)

Current I_3 ; (assumed to flow from B to D) is proportional to $(R_2R_3 - R_1R_4)$. Using given values of the parameters

$$R_2R_3 = 6 \times 2 = 12; \quad R_1R_4 = 4 \times 4 = 16$$

Since $R_2R_3 < R_1R_4$; actual direction of current in arm BD is from D to B. Therefore the potential of point D; (V_D) is more than the potential of point B (V_B); $V_D > V_B$.

A.3.2.2 (A)

For the pair of points A and C; the arrangement is a balanced Wheatstone bridge. There is no current in arm BD. The arrangement can be redrawn removing 7Ω resistance in arm BD. Therefore

$$R_{AC} = \frac{(4+12) \times (3+9)}{(4+12) + (3+9)} = \frac{48}{7} \Omega$$

For the pair of points B and D; $R' = (4+3) = 7 \Omega$; $R'' = (12+9) = 21 \Omega$ and $R_5 = 7 \Omega$ are in parallel with one another. Therefore,

$$\frac{1}{R_{BD}} = \frac{1}{7} + \frac{1}{21} + \frac{1}{7} = \frac{1}{3} \quad \therefore R_{BD} = 3 \Omega$$

Obviously,

$$\frac{R_{AC}}{R_{BD}} = \frac{48}{7 \times 3} = \frac{16}{7}$$

A.3.2.3 (C)

The given arrangement is a balanced Wheatstone bridge having AB, BC, AD and CD as the four arms.

$$R_1 = 3 \Omega; R_2 = 6 \Omega;$$

$$R_3 = 1 \Omega; R_4 = 2 \Omega$$

and

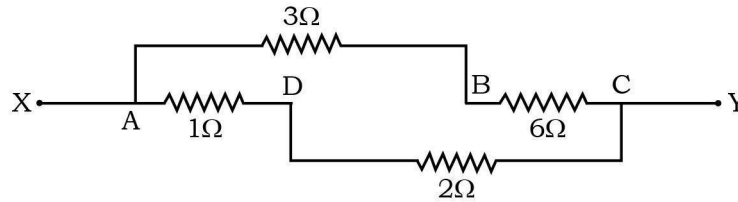


Fig.A.3.2.1

R_5 = Resistance in arm BD = 10Ω .

In a balanced Wheatstone bridge, there is no current in arm BD, so R_5 can be removed. The arrangement is redrawn as

shown in Fig.A.3.2.1. Obviously 3Ω and 6Ω are in series with one another.

$R' = 3 + 6 = 9 \Omega$ is their equivalent resistance. Similarly, 1Ω and 2Ω are in series with one another.

$R'' = 1 + 2 = 3 \Omega$. Now R' and R'' are in parallel with one another.

The equivalent resistance (R_{eq}) between X and Y is

$$\frac{1}{R_{eq}} = \frac{1}{9} + \frac{1}{3}$$

$$\therefore R_{eq} = \frac{9}{4} = 2.25 \Omega$$

A.3.2.4 (A)

Pull out point O from inside the triangle ΔABC and redraw the given arrangement as shown in Fig.A.3.2.2 (a).

This is a balanced Wheatstone bridge. There is no current in arm AB. Removing the resistance of 4Ω in arm AB; the arrangement is shown in Fig.A.3.2.2 (b). Obviously

$$R_{eq} = \frac{(2+4) \times (4+8)}{(2+4) + (4+8)} = 4 \Omega$$

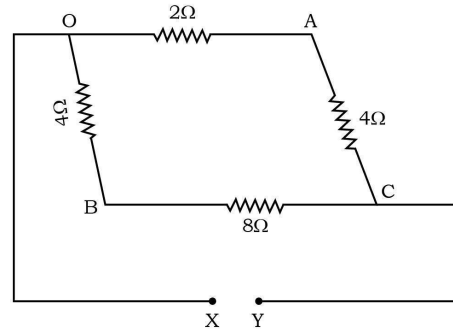
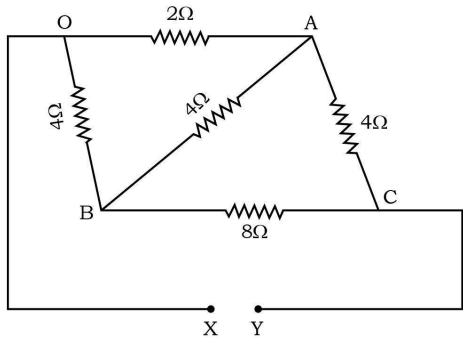


Fig.A.3.2.2 (a) and (b)

A.3.2.5 (D)

Fig.A.3.2.4 shows the redrawn arrangement on pulling point O out of triangle ΔABC . OA; AC; OB; BC; and AB are arms of a balanced Wheatstone bridge. There is no current in arms AB. The equivalent resistance between points O and C is R. Fig.A.3.2.5 shows the equivalent agreement. Obviously; R_{eq} ; the equivalent resistance between X and Y is $(3R + R + 4R = 8R)$

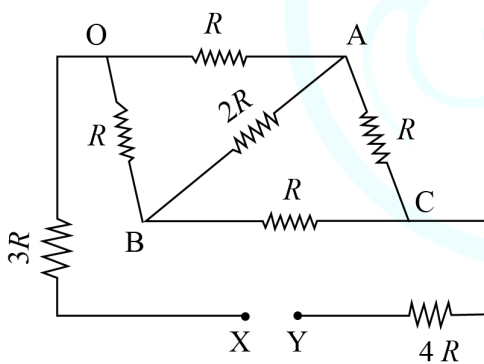


Fig.A.3.2.3 (a)

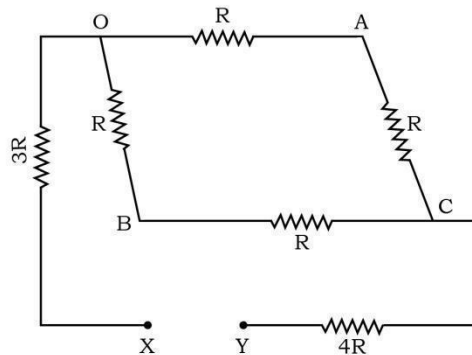


Fig.A.3.2.3 (b)

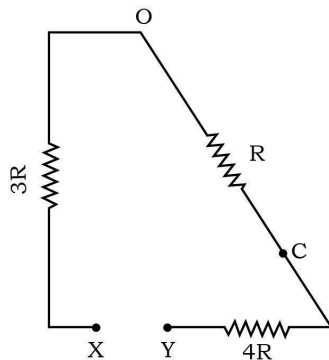


Fig.A.3.2.3 (c)

A.3.2.6 (C)

For observer P, all the four arms of the Wheatstone bridge have resistances of the same order of magnitude. This is not so for observer Q. Measurement of P is more accurate because the bridge is more sensitive for the values used by P.

A.3.2.7 (A)

Let l be the balancing length. Given

$$\frac{l}{100-l} = \frac{9}{11}$$

$$\therefore l = 45 \text{ cm}$$

Using the condition of balance;

$$\frac{R}{2.2} = \frac{9}{11}$$

$$\therefore R = 1.8 \Omega$$

A.3.2.8 (A)

Connecting 4Ω in parallel with S the equivalent resistance in the arm equals 2Ω . At balance

$$\frac{2}{2} = \frac{l_1}{100-l_1}$$

$$\therefore l_1 = 50 \text{ cm}$$

Disconnecting 4Ω from S and connecting it in series with R changes the effective resistance of that arm to 6Ω . At balance

$$\frac{6}{4} = \frac{l_2}{100-l_2}$$

$$\therefore l_2 = 60 \text{ cm}$$

$$\text{Obviously } \frac{l_1}{l_2} = \frac{5}{6}$$

A.3.2.9 (A)

Given

$$\frac{R}{S} = \frac{1}{2}$$

$$\therefore S = 2R$$

When resistors each of value X are connected in series with R and S respectively. At balance

$$\frac{R+X}{S+X} = \frac{2}{3}$$

$$\frac{R+X}{2R+X} = \frac{2}{3}$$

$$\therefore X = R$$

A.3.2.10 (C)

Increasing S at balance length $CD = CJ$ increases. The balance point moves away from the end C of meter bridge wire.



Module 3 : Potentiometer

A.3.3.1 (D)

Let ρ be the initial potential gradient across potentiometer wire. Given

$$\varepsilon = \rho l \quad (\text{A.3.3.1})$$

Let ρ' and l' denote the new value of potential gradient and balancing length respectively. Given ,

$$l' = l + \frac{l}{2} = \frac{3l}{2} . \text{ Also}$$

$$\varepsilon = \rho' l' \quad (\text{A.3.3.2})$$

From Eqns (A.3.3.1) and (A.3.3.2), we have

$$\rho' = \rho (l/l') = \frac{2}{3}\rho$$

$$\begin{aligned} \% \text{ change in } \rho &= \frac{\rho' - \rho}{\rho} \times 100\% \\ &= -33.3\% \end{aligned}$$

A.3.3.2 (A)

Given

$$V=5 \text{ V}; R_{AB}=0.1 \times 100 = 10 \Omega; R = 490 \Omega$$

The potential gradient ρ is

$$\rho = \frac{VR_{AB}}{(R+R_{AB})L}$$

$$\begin{aligned}
 &= \frac{5 \times 10}{(490 + 10) \times 1} \text{ Vm}^{-1} \\
 &= 10^{-1} \text{ Vm}^{-1} \\
 &= 10^{-3} \text{ Vcm}^{-1}
 \end{aligned}$$

A.3.3.3 (C)

R_{AB} = Total resistance of potentiometer wire

$$= 2 \times 10 = 20 \Omega$$

Let ρ be the potential gradient across potentiometer wire.

For $V = 20 \times 10^{-3} \text{ V}$; balancing length $l = 4 \text{ m}$. Therefore

$$\rho = \frac{V}{l} = \frac{20 \times 10^{-3}}{4} = 5 \times 10^{-3} \text{ Vm}^{-1}$$

We know

$$\rho = \frac{V \times R_{AB}}{(R + R_{AB})L}$$

$$5 \times 10^{-3} = \frac{4 \times 20}{(R + 20) \times 10}$$

$$\therefore R + 20 = \frac{8}{5} \times 10^3$$

$$= 1600$$

$$\text{or } R = 1580 \Omega$$

A.3.3.4 (D)

Let ρ be the potential gradient across the potentiometer. E' is equivalent e.m.f of the series, a combination of E_1 and E_2 . Then

$$E' = E_1 + E_2 = \rho l \quad (\text{A.3.3.3})$$

Let E'' be the equivalent e.m.f of E_1 and E_2 in opposition. $E'' = E_1 - E_2$. The balancing length (l') for E'' is

$$l' = 1 - 0.4l = 0.6l$$

$$\text{and } E'' = E_1 - E_2 = \rho \times 0.6l \quad (\text{A.3.3.4})$$

From Eqns (A.3.3.3) and (A.3.3.4)

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{L}{0.6L} = \frac{10}{6}$$

$$\therefore \frac{E_1}{E_2} = 4$$

A.3.3.5 (A)

P.d. of 1 V is connected appropriately i.e. in opposition to p.d across potentiometer. The total p.d. across the potentiometer = $0.2 \times 4 = 0.8$ V, This is LESS than the p.d. to be measured (1 V). Hence a balance cannot be obtained. Since 0.8 V and 1 V are in opposition; deflection in the galvanometer decreases in the same direction, but cannot be zero as the jockey moves from one end to the other end of the potentiometer. To balance 1 V across potentiometer; the minimum potential gradient, $\rho_{min} = \frac{1}{4} = 0.25 \text{ Vm}^{-1}$

A.3.3.6 (D)

The p.d. across the potentiometer wire(= V_{AB}) is Not connected in opposition to unknown emf(= E). The two are connected in series with one another.

To have p.d. across potentiometer wire AB in opposition to E ; the polarity of E has to be reversed.

A.3.3.7 (D)

Let V_1 and V_2 be p.d. across R_1 and $(R_1 + R_2)$ respectively in the circuit shown. R_1 and R_2 are connected in series with one another, therefore,

$$\frac{V_1}{V_2} = \frac{R_1}{(R_1 + R_2)} \quad (\text{A.3.3.5})$$

Also

$$\frac{V_1}{V_2} = \frac{5}{7.5} = \frac{2}{3} \quad (\text{A.3.3.6})$$

From Eqns (A.3.3.5) and (A.3.3.6) we have

$$\frac{R_1}{R_2} = 2$$

A.3.3.8 (C)

Let I' be the true value of current in resistance R .

The p.d. across R is $V = I'R = \rho l$

where ρ and l and denote the potential gradient and the balancing length respectively, for the potentiometer given.

Given $\rho = 10^{-2} \text{ V}(\text{cm})^{-1} = 1 \text{ Vm}^{-1}$, $l = 4.5 \text{ m}$

$$I' = \frac{1 \times 4.5}{5} = 0.9 \text{ A}$$

The ammeter reads current as 1 A. The error in the ammeter is + 0.1 A. Therefore

$$\begin{aligned} \% \text{ Error in reading of ammeter} &= \frac{0.1}{0.9} \times 100 \% \\ &\simeq 11.1\% \end{aligned}$$

A.3.3.9 (B)

Let V and V' be p.d of cell when it is shunted by resistance R and R' ($>R$) respectively

$$V = E - Ir$$

$$V' = E - I'r$$

From ohm's law

$$I = \frac{E}{R+r} \text{ and } I' = \frac{E}{R'+r}$$

Given $R' > R$; therefore

$$I' < I \text{ and } V' > V$$

$$\text{or } \rho l_2 > \rho l_1$$

$$\therefore l_2 > l_1$$

where ρ is the potential gradient across potentiometer

A.3.3.10 (B)

ρ = potential gradient across potentiometer

$$= \frac{5 \times 10^{-3} \text{ V}}{10^{-2} \text{ m}} = 0.5 \text{ Vm}^{-1}$$

$$l = \text{balancing length} = 4\text{m}$$

The actual p.d. across resistance $R = \rho \times l = 0.5 \times 4 = 2 \text{ V}$

The voltmeter read p.d as 1.9 V. There is an error of 0.1 V in voltmeter. Therefore

$$\begin{aligned} \% \text{ Error in voltmeter} &= \left(\frac{-0.1}{2} \times 100 \right) \% \\ &= -5 \% \end{aligned}$$



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