Date: 20/10/2021

Q1. **What is the significance of direction of electric current?**

Q2. **What is the direction of conventional current?**

Q3. **It is found that 10^{19} electrons, each having a charge of 1.6×10^{-19} C, pass from a point *M* towards another point *N* in 0.01 s. What is the current and its direction?**

Q4. **A Potential difference of 220 V is maintained across a conductor of resistance 90 Ω calculation the number of electron flowing five second ($e = 1.6 \times 10^{-19}$).**

Q5. **The resistance of the platinum wire of a platinum resistance thermometer at the ice point is 5 Ω and at steam point is 5.23 Ω. When the thermometer is inserted in a hot bath, the resistance of the platinum wire is 5.795 Ω. Calculate the temperature of the bath.**

Date: 20/10/2021

S1. The direction of *conventional* electric current is opposite to the direction of flow of electrons and the direction of *electric current* is same as that of the flow of electrons.

S2. In an electric circuit, the direction of conventional electric current is from positive end to negative end of the battery.

S3. Given: $q = ne = 10^{19} \times 1.6 \times 10^{-19} = 1.6\,\text{C}$; $t = 0.01\,\text{s}$

$$\therefore \quad I = \frac{q}{t} = \frac{1.6}{0.01} = 160\ \text{A}.$$

The direction of current is from the point N to M.

S4. Given: $V = 220\,\text{V}$; $R = 90\,\Omega$; $e = 1.6 \times 10^{-19}\,\text{C}$

We know, $V = IR \Rightarrow I = V/R$

$$= \frac{220}{90} = \frac{22}{9}$$

Charge flow in five sec $q = It$

$$= \frac{22}{9} \times 5 = \frac{110}{9}$$

from quantisation of change of charge

$$q = ne \Rightarrow n = q/e$$

$$n = \frac{110}{9 \times 1.6 \times 10^{-19}} = 7.64 \times 10^{19}$$

$$n = 7.64 \times 10^{19}.$$

S5. $R_0 = 5\,\Omega$, $R_{100} = 5.23\,\Omega$ and $R_t = 5.795\,\Omega$

Now, $$t = \frac{R_t - R_0}{R_{100} - R_0} \times 100, \qquad R_t = R_0\,(1 + \alpha t)$$

$$= \frac{5.795 - 5}{5.23 - 5} \times 100$$

$$= \frac{0.795}{0.23} \times 100 = 345.65\ °\text{C}.$$

Date: 20/10/2021

Q1. The potential difference across a given copper wire is increased. What happens to the drift velocity of the charge carriers?

Q2. State Ohm's law.

Q3. Why bends in a wire do not affect its resistance?

Q4. If the electron drift velocity is so small and the charge on electron is small, how can we still obtain large amount of current?

Q5. A steady current flows in a metallic conductor of non-uniform cross-section. Explain which of these quantities is constant along the conductor : current, current density, electric field and drift speed?

Q6. How does the drift velocity of electrons in a metallic conductor vary with increase in temperature?

Q7. Define drift velocity of an electron.

Q8. Alloys usually have much (lower/higher) temperature coefficients of resistance than pure metals.

Q9. Alloys of metals usually have (greater/less) resistivity than that of their constituent metals.

Q10. The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 0.4 Ω, what is the maximum current that can be drawn from the battery?

Q11. The electron drift speed is estimated to be only a few mm s^{-1} for currents in the range of a few amperes? How then is current established almost the instant a circuit is closed?

Q12. What is Ohmic device? Give an example.

Q13. Two wires *A* and *B* of same metal have the same area of cross-section and have their lengths in the ratio 2 : 1. What will be the ratio of currents flowing through them, when the same potential difference is applied across length of each of them?

Q14. Does the value of resistance of a metallic conductor depend upon the potential difference applied across it or the current passed through it?

Q15. What happens to the drift velocity of electron and to the resistance, if length of the conductor is doubled keeping potential difference unchanged?

Q16. The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed?

Q17. What is non-ohmic device? Give an example.

Q18. The three coloured bands on a carbon resistor are red, green and yellow, respectively. Write the value of its resistance.

Q19. What is difference between ohmic and non-ohmic devices.

Q20. Is the motion of a charge across junction momentum conserving? Why or why not?

Q21. When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction?

Q22. Explain how electron mobility changes for a good conductor, when
(a) the temperature of the conductor is decreased at constant potential difference.
(b) Applied potential difference is doubled at constant temperature.

Q23. You are required to selected a carbon resistor of resistance 47 kΩ $\pm$ 10% from a large collection. What should be the sequence of colour bands used to code it?

Q24. Write the mathematical relation between mobility and drift velocity of charge carriers in a conductor. Name the mobile charge carriers responsible for conduction of electric current in (a) an electrolyte (b) an ionized gas.

Q25. The number density of free electrons in a copper conductor is $8.5 \times 10^{28} m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? the area of cross-section of the wire is $2.0 \times 10^{-6} m^2$ and is carrying a current of 3.0 A.

Q26. The sequence of coloured bands in two carbon resistors R_1 and R_2 is
(a) brown, green, blue and
(b) orange, black, green
Find the ratio of their resistances.

Q27. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

Q28. At room temperature (27.0 °C) the resistance of a heating element is 100 Ω. What is the temperature of the element if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the resistor is $1.70 \times 10^{-4}\,°C^{-1}$.

Q29. A silver wire has a resistance of 2.1 Ω at 27.5 °C, and a resistance of 2.7 Ω at 100 °C. Determine the temperature coefficient of resistivity of silver.

Q30. A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27.0 °C? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is $1.70 \times 10^{-4}\,°C^{-1}$.

Q31. A voltage of 30 V is applied across a Carbon resistor with first, second and third rings of blue, black and yellow colours, respectively. Calculate the value current, in mA, through the resistor.

Q32. A wire of 15Ω resistance is gradually stretched to double its original length. It is then cout into two equal parts. These parts are then connected in parallel across a 3.0V battery. Find the the curren drawn from the battery.

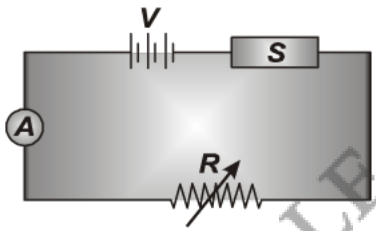
Q33. What conclusion can you draw from the following observations on a resistor made of alloy manganin?

Current A	Voltage V	Current A	Voltage V
0.2	3.94	3.0	59.2
0.4	7.87	4.0	78.8
0.6	11.8	5.0	98.6
0.8	15.7	6.0	118.5
1.0	19.7	7.0	138.2
2.0	39.4	8.0	158.0

Q34. A cylindrical metallic wire is stretched to increase length by 5%. Calculate the percentage change in its resistance.

Q35. Define the term current density of a metallic conductor. Deduce the relation connecting current density (j) and the conductivity (σ) of the conductor, when an electric field E, is apllied to it.

Q36. Figure shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant, when semiconductor S is heated? Give reason.



Q37. If the current supplied to a variable resistor is constant, draw a graph between voltage and resistance.

Q38. State the conditions under which Ohm's Law is not obeyed in a conductor.

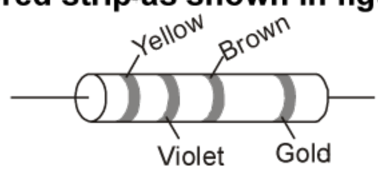
Q39. What are the factors on which resistance of a conductor depends? Give the corresponding relation.

Q40. Obtain Ohm's Law in terms of current density vector and the electric field vector.

Q41. Define the terms (a) drift velocity, (b) relaxation time.

Q42. Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons? Use this relation of deduce the expression for the electrical resistivity of the material.

Q43. A Carbon resistor has colored strip as shown in figure below. What is the resistance?



Q44. How will you represent a resistance of 3700 $\Omega \pm 10\%$.

Q45. What happens to the drift velocity (v_d) of electrons and to the resistance (R), if length of conductor is double (Keeping potential difference uncharged)?

Q46. A current of 1.2 A flows through a copper wire cross-sectional area 2.4 mm^2 find the current density in the wire. If the wire contain 8×10^{28} free electron m^{-3} find the drift velocity of electron.

Q47. A current of 2 A flows through a conducting wire of length 0.48 m area of the cross section 3.6 mm^2 when connected a battery 3 V find the number density of free electrons in the wire if the electrons mobility is 4.8×10^{-6} $m^2 V^{-1} s^{-1}$ ($e = 1.6 \times 10^{-19}$)

Q48. A current of 5 A is passing through a metallic wire of area of cross-section 4×10^{-6} m^2, If the number density of electrons in the wire is 5.0×10^{26} m^{-3}, find the drift velocity of electrons.

Q49. In the atom, electron revolves around the nucleus along a path radius 0.52 Å making 7.5×10^{15} revolutions per second. Determines the equivalent current ($e = 1.6 \times 10^{-19}$ C)

Q50. A carbon resistor marked in coloured bond red, black, orange and silver. What is the resistance and tolerance value of the resistor?

Q51. A potential difference of 12 V is applied across a copper wire of resistance 500 Ω find the number of electrons flowing through the copper wire in 10 minutes.

Q52. The resistance of a tungsten filament at 150°C is 125 Ω what will be its resistance at 520°C the temperature coefficient of resistance of tungsten at 0°C is 0.0045°C^{-1}.

Q53. A conductor of length L is connected to a d.c. source of e.m.f. E. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3 L. How will the drift velocity change?

Q54. A potential difference of 10 V is applied across a conductor having a esistance 1 kΩ. Find the number of electrons flowing through the conductor in 5 minutes.

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S1. When potential difference is increased. Therefore, the drift velocity of electrons will be increase.

We know,

$$v_d = \frac{eE}{m}\tau \qquad \dots (i)$$

If l is length of the copper wire and V, the potential difference across it, then

$$E = \frac{V}{l}$$

put the value E in Eq. (i), we get

$$v_d = \frac{e}{m}\left(\frac{V}{l}\right)\tau$$

$\because \quad \frac{e}{m}$, l, and τ are constant.

Hence, $v_d \propto V$ *i.e.*, if potential difference is increased, drift velocity of the electrons will *increase*.

S2. **According to the Ohm's law:** If all physical condition of the conductor kept constant current flowing through conductor is directly proportional to the potential difference

S3. Resistance of a conductor $R = \rho\frac{l}{A}$

S4. Because, the number of electrons per unit volume is very large ($\approx 10^{28}\,m^{-3}$).

S5. Current.

S6. The drift velocity of electrons in a conductor inversely proportional to the temperature *i.e.*, The drift velocity of the electron decrease with increase the temperature.

S7. The drift velocity is mapping by average velocity with which free electrons in a conductor get drifted under the influence of an external electric field applied across the metal conductor.

S8. Alloys usually have lower temperature coefficients of resistance than pure metals.

S9. Alloys of metals usually have greater resistivity than that of their constituent metals.

S10. Emf of the battery, $E = 12\,V$

Internal resistance of the battery, $r = 0.4\,\Omega$

Maximum current drawn from the battery = I

According to Ohm's law,

$$E = Ir$$

$$I = \frac{V}{r} = \frac{12}{0.4} = \mathbf{30\,A}$$

The maximum current drawn from the given battery is 30 A.

S11. It is the electric field which spreads throughout a circuit with speed of light. At every point a local electron drift is induced by the field. This way, current attains its steady value almost instantaneously.

S12. A device, which has follow Ohm's law that is known as Ohmic device.

Resistor is an Ohmic device.

S13. 1 : 2

Given cross-section area of two wire $A_A = A_B = A$

Potential difference e $V_A = V_B = V$; ratio of length $l_A : l_B = 2 : 1$

We know, $R_A = \rho \frac{l_A}{A}$; ... (i)

Similarly,

$R_B = \rho \frac{l_B}{A}$ ... (ii)

Eqn. (i) ÷ (ii), we get

$$\frac{R_A}{R_B} = \frac{l_A}{l_B}$$

$$\frac{I_A}{I_B} = \frac{R_B}{R_A} = \frac{l_B}{l_A}$$

$$I_A : I_B = 1 : 2$$

S14. No, the resistance of a metallic conductor does not depend upon the potential difference applied across it or the current passed through it.

S15. When the length l is doubled, resistance become twice the initial value and drift velocity become half of the initial value.

We know

$$v_d = \frac{eE\tau}{m} \quad \text{where} \quad E = \frac{V}{l}$$

$$v_d = \frac{eV\tau}{ml}$$

Hence, when l is doubled, resistance become twice the initial value.

S16. The electron does accelerate but lose its drift speed during subsequent collisions which a positive ion of the metal. Hence, it is the average drift speed which is acquired by an electron.

S17. A device, which has not follow Ohm's law is known as a non-ohmic device. The diode is a non-ohmic device.

S18. Value of given resistance is

$$(25 \times 10^4 + 20\%)\Omega$$

S19.

Ohmic device	***Non-ohmic device***
(a) A device which has follow the Ohm's law that is known as Ohmic device	(a) A device which has not follow the not follow Ohm's law that is known as non-ohmic device
(b) Resistor is an Ohmic device	(a) Diode is a non-ohmic device

S20. When an electron approaches a junction, in addition to the uniform E that it normally faces (which keep the drift velocity v_d fixed), there are accumulation of charges on the surfaces of wires at the junction. These produce electric field. These fields alter direction of momentum.

S21. It is not so. The drift velocity is superposed over the random thermal velocities of the electrons.

S22. The electron mobility (μ)

(a) increase with the decrease of temperature

(b) no change with the increase of potential difference.

S23. Given, resistance = $47\ k\Omega \pm 10\%$

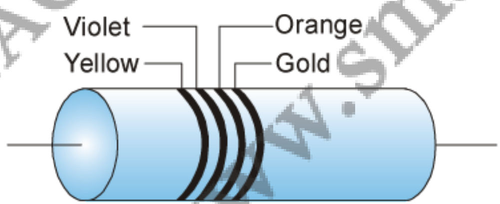
$$= 47 \times 10^3\ \Omega \pm 10\%$$

$\therefore$ I[st] colour band should be yellow as code for it is 4.

II[nd] colour band should be violet as code for it is 7.

III[rd] colour band should be orange as code for it is 3.

IV[th] colour band should be gold because approximation is $\pm 10\%$



S24. The drift speed per unit applied electric field intensity is known as mobility of electron i.e.,

$$\mu = \frac{v_d}{E}$$

where, μ = mobility, v_d = drift velocity,

E = electric field intensity.

(a) Mobile charge carrier in electrolyte : cation and anion.

(b) Mobile charge carrier in ionized gas positively charged ions.

S25. Here, $n = 8.5 \times 10^{28}\ m^{-3}$,

$A = 2.0 \times 10^{-6}\ m^2$, $I = 3.0$ A

and $l = 3.0$ m

As drift speed $v_d = \dfrac{I}{nAel}$

$\therefore$ Time taken to drift through entire length

$$t = \frac{l}{v_d} = \frac{l n Ae}{I}$$

$\Rightarrow$
$$t = \frac{3.0 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$$

or $t = 2.7 \times 10^4$s

S26. According to colour codes, resistance of two wires are

(a) $R_1 = 15 \times 10^6 \Omega \pm 10\%$

(b) $R_2 = 30 \times 10^5 \Omega \pm 20\%$

$\therefore$ Ratio of resistances

$$\frac{R_1}{R_2} = \frac{15 \times 10^6}{30 \times 10^5} = 20$$

$\Rightarrow$
$$\frac{R_1}{R_2} = 20$$

S27. Since, the relationship between electric current density (j) and drift velocity v_d is given by

Current $I = n e v_d A$

$\therefore$ Current $j = n e v_d$ $\left(\because \ J = \dfrac{I}{A}\right)$

$j = nev_d$

where n = number of free electrons per unit volume .

e = charge on each electron

S28. Room temperature, $T = 27°C$

Resistance of the heating element at T, $R = 100\,\Omega$

Let T_1 is the increased temperature of the filament.

Resistance of the heating element at T_1, $R_1 = 117\,\Omega$

Temperature co-efficient of the material of the filament,

$$\alpha = 1.70 \times 10^{-4}\,°C^{-1}$$

α is given by the relation,

$$\alpha = \frac{R_1 - R}{R(T_1 - T)}$$

$$T_1 - T = \frac{R_1 - R}{R\alpha}$$

$$T_1 - 27 = \frac{117 - 100}{100(1.7 \times 10^{-4})}$$

$$T_1 - 27 = 1000$$

$$T_1 = 1027\,°C^{-1}$$

Therefore, at 1027 °C, the resistance of the element is $117\,\Omega$.

S29. Temperature, $T_1 = 27.5°C$

Resistance of the silver wire at T_1, $R_1 = 2.1\,\Omega$

Temperature, $T_2 = 100°C$

Resistance of the silver wire at T_2, $R_2 = 2.7\,\Omega$

Temperature coefficient of silver = α

It is related with temperature and resistance as

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039\,°C^{-1}$$

Therefore, the temperature coefficient of silver is $0.0039\,°C^{-1}$.

S30. Supply voltage, $V = 230\,V$

Initial current drawn, $I_1 = 3.2\,A$

Initial resistance = R_1, which is given by the relation,

$$R_1 = \frac{V}{I} = \frac{230}{3.2} = 71.87\,\Omega$$

Steady state value of the current, $I_2 = 2.8$ A

Resistance at the steady state = R_2, which is given as

$$R_2 = \frac{230}{2.8} = 82.14\,\Omega$$

Temperature co-efficient of nichrome, $\alpha = 1.70 \cdot 10^{-4}\,°C^{-1}$

Initial temperature of nichrome, $T_1 = 27.0\,°C$

Study state temperature reached by nichrome = T_2

T_2 can be obtained by the relation for α,

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

$$T_2 - 27\,°C = \frac{82.14 \times 71.87}{71.87 \times 1.7 \times 10^{-4}}$$

$$T_2 = 840.5 + 27 = 867.5\,°C$$

Therefore, the steady temperature of the heating element is 867.5 °C.

S31. Resistance of carbon resistor

$$R = 60 \times 10^4\,\Omega \pm 20\%$$

First ring is blue (code 6), second ring is black (code 0) and third ring is yellow (code 4)

$\because$ Current through the resistor, $I = \frac{V}{R}$ [Ohm's law]

$$= \frac{30}{60 \times 10^4}$$

$$= \frac{1}{2} \times 10^{-4}$$

$$= \frac{1}{20} \times 10^{-3}\,A$$

$$= 0.05 \times 10^{-3}\,\text{A}$$

$$I = 0.05\text{ mA}$$

S32. Let original cross-sectional area and length of 15 Ω resistance are A and l after stretching they become A' and l', respectively.

Initial resistance, $R = \rho \frac{l}{A}$

$\therefore$ In case of stretching volume of the wire remains same, so

$$Al = A'l' \qquad \ldots(i)$$

$$l' = 2l$$

$\Rightarrow$ $$A' = \frac{A}{2}$$

$\therefore$ Resistance after stretching

$$R' = \rho \frac{l'}{A'} = \rho\left(\frac{2l}{A/2}\right) = 4\left(\rho \frac{A}{l}\right)$$

$$R' = 4 \times 15 \qquad \text{[From Eq. (i)]}$$

Now resistance $R' = 60\Omega$

After dividing into two parts, resistance of each part = 30 Ω

$\therefore$ Effective resistance after connecting them into parallel combination.

$$R_{\text{effective}} = \frac{30}{2} = 15\Omega$$

$\because$ Applied potential difference, $V = 3\text{V}$

$\therefore$ Current drawn from the battery, $I = \frac{V}{R}$ [From Ohm's law]

$\Rightarrow$ $$I = \frac{3}{15}$$

$$I = \frac{1}{5} A$$

S33. It can be inferred from the given table that the ratio of voltage with current is a constant, which is equal to 19.7. Hence, manganin is an ohmic conductor *i.e.*, the alloy obeys Ohm's law. According to Ohm's law, the ratio of voltage with current is the resistance of the conductor. Hence, the resistance of manganin is 19.7 Ω.

S34. Volume of the wire $V = Al$

$\Rightarrow$ $$\frac{\Delta V}{V} \times 100 = \frac{\Delta A}{A} \times 100 + \frac{\Delta l}{l} \times 100$$

But $\Delta V = 0$ [$\because$ Volume remains constant]

$$\Rightarrow \quad \frac{\Delta A}{A} \times 100 = \frac{\Delta l}{l} \times 100$$

Negative sign imply that increase in length of conductor would facilitate decrease area.

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

For given resistor, ρ = constant

$$\Rightarrow \quad \frac{\Delta R}{R} \times 100 = \left(\frac{\Delta l}{l} \times 100\right) - \left(\frac{\Delta A}{A} \times 100\right)$$

Here, $\frac{\Delta l}{l} \times 100 = 5\%$

Therefore, $\frac{\Delta A}{A} \times 100 = -5\%$

$$\therefore \quad \frac{\Delta R}{R} \times 100 = (5\%) - (-5\%)$$

$$\frac{\Delta R}{R} \times 100 = 10\%$$

$\therefore$ Percentage rise of resistance = 10%

S35. Current density: The current density at any point inside a conductor is defined as the amount of charge flowing per second per unit cross-sectional area in a direction perpendicular to cross-section. It is a vector quantity whose direction is in the direction of flow of positive charge.

Current density $j = \frac{I}{A}$

$\because$ By Ohm's law

$$V = IR = I\left(\rho \frac{l}{A}\right)$$

$$\frac{1}{\rho}\left(\frac{V}{l}\right) = \left(\frac{I}{A}\right)$$

$$(\sigma)\,(E) = j \qquad \left[\therefore \frac{1}{\rho} = \sigma = \text{conductivity}, \frac{V}{l} = E = \text{electric field,}\right.$$

current density $j = \frac{I}{A}\Big]$

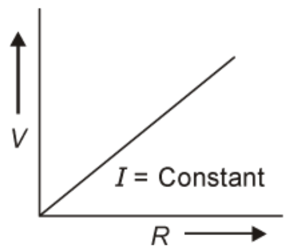
$\Rightarrow \qquad j = \sigma E$

This is the required relation.

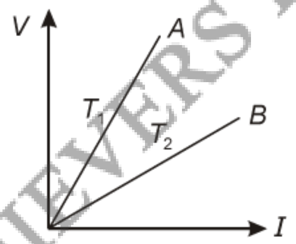
S36. The resistance of a semiconductor decreases on increase of its temperature. To keep the reading of the reading of the ammeter same, the total resistance in the circuit should remain unchanged. Therefore, in order to keep the ammeter reading constant (while the semiconductor is heated), the value of R has to be increased.

S37. According to the Ohm's law, $V = IR$

If a constant current is passed, then the above relation represents a straight line passing through origin. Hence, when a constant current is passed through a variable resistor, the graph will be as shown in figure below.



S38. When current flowing through a conductor is increased, the conductor becomes hotter and it resistance increases. In other words, its V-I graph is no longer linear as in case of an ohmic conductor. That is, it becomes a non-ohmic conductor.



Disordered conductors at very low temperature (of the order of 4 K or less) do not obey Ohm's Law.

As the impurity and homogeneity in a conductor increases, its behaviour begins to deviate from ohmic to non-ohmic.

S39. The resistance R of a conductor of length l and cross-sectional area A is given by

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

where ρ is the resistivity of the conductor.

Thus, the resistance of a conductor depends on the following factors:

(a) The nature of the material of which conductor is made from, which determines the value of ρ.

(b) Its cross-sectional area A. Resistance is inversely proportional to cross-sectional area.

(c) The length l of the conductor. Resistance is directly proportional to the length of a conductor.

S40. Current $I = n e v_d A$

∴ Current $j = n e v_d$ $\left(\because \ j = \frac{I}{A}\right)$

Also, drift velocity $v_d = -\frac{eE}{m}\tau$

$j = (-ne)\left(-\frac{eE}{m}\tau\right)$ (∵ charge on electron is –ve)

$= \frac{ne^2}{m}\tau E$

We know, conductivity $\sigma = \frac{ne^2}{m}\tau$

∴ $\boldsymbol{j} = \sigma \mathbf{E}$.

S41. (a) **Drift velocity:** The drift velocity defined as the average velocity with which free electrons in a conductor get drifted under the influence of an external electric field applied across the conductor.

(b) **Relaxation time:** The short time, for which a free electron accelerates before it undergoes a collision with the positive in the conductor, is called relaxation time.

S42. ***Relaxation time:*** The average time difference between two successive collisions of drifting electrons inside the conductor under the influence of electric field applied across the conductor, is known as relaxation time.

Drift speed and relaxation time

$$v_d = -\frac{eE\tau}{m}$$

Where, E = electric field due to applied potential difference

τ = relaxation time

m = mass of electron

e = electronic charge

$\because$ Electron current $I = -neAv_d$

$$I = \left(-\frac{eE\tau}{m}\right)$$

$$v_d = \frac{ne^2 A\tau}{m}\left(\frac{V}{l}\right) \qquad \left(\because \ E = \frac{V}{l}\right)$$

$$\Rightarrow \qquad \frac{V}{I} = \frac{ml}{ne^2 A\tau} = \rho\frac{l}{A} = R$$

$$\Rightarrow \qquad \rho = \frac{m}{ne^2\tau}$$

This is required expression.

S43. Corresponding to first two colour is yellow and violet colours, the figures are 4 and 7. Corresponding to the third brown colour the multiplier is 10 *i.e.*, the given carbon resistor is of value 47 × 10 *i.e.*, 470. Therefore the band showing the tolerance is golden the value of resistor.

$$\boldsymbol{R = 470\ \Omega \pm 5\%}$$

S44. According to colour code of carbon resistance colour band corresponding figures 3 and 7 are orange and violet respectively and corresponding multiplier 10^2 the colour of band red finally tolerance 10% the colour band is silver.

Therefore the resistance of $3700\,\Omega \pm 10\%$ will be represented by the band of orange violet, red, and silver.

S45. Drift velocity of electrons is given by

$$v_d = \frac{eE}{m}\tau$$

If V is potential difference across the conductor of length l, then

$$\because \qquad E = \frac{V}{l}$$

$$\therefore \qquad v_d = \frac{eV}{ml}\tau \quad \text{or} \quad v_d = \left(\frac{eV\tau}{m}\right)\frac{1}{l}$$

$$v_d \propto \frac{1}{l}.$$

As l is doubled (keeping potential difference unchanged), the drift velocity will become half of the initial value.

As R is directly proportional to length, the resistance will become double of the initial value, when length is doubled.

S46. Given: $I = 1.2\text{ A}$; $A = 2.4 \times 10^{-6}\text{ m}^2$; $n = 8 \times 10^{28}\text{ m}^{-3}$

We know,

Current density $j = I/A$

$$= \frac{1.2}{2.4 \times 10^{-6}} = 0.5 \times 10^6\text{ Am}^{-2}$$

Drift velocity $v_d = \frac{j}{ne} = \frac{0.5 \times 10^6}{8 \times 10^{28} \times 1.6 \times 10^{-19}}$

$\mathbf{v_d = 391 \times 10^{-5}\,ms^{-1}}$

S47. Given: $V = 3$ volt ; $A = 3.6\text{ mm}^2 = 3.6 \times 10^{-6}\text{ m}^2$

$\mu = 4.8 \times 10^{-6}\text{ m}^2\text{ V}^{-1}\text{s}^{-1}$; $l = 0.48$ m

$I = 2$ A

We know $E = \frac{V}{l} = \frac{3}{0.48} = 6.25\text{ Vm}^{-1}$

$v_d = \mu E = 4.8 \times 10^{-6} \times 6.25 = 3 \times 10^{-5}\text{ ms}^{-1}$

$$v_d = \frac{I}{nAe} \Rightarrow n = \frac{I}{v_d Ae}$$

$$= \frac{2}{3 \times 10^{-5} \times 3.6 \times 10^{-6} \times 1.6 \times 10^{-19}}$$

$n = 1.157 \times 10^{29}\text{ m}^{-3}$

S48. Given: $I = 5$ A; $n = 5 \times 10^{26}$; $A = 4 \times 10^{-6}\text{ m}^2$; $e = 1.6 \times 10^{-19}$ C

$$v_d = \frac{I}{neA} = \frac{5}{5 \times 10^{26} \times 4 \times 10^{-6} \times 1.6 \times 10^{-19}}$$

$v_d = 1.563 \times 10^{-2}\text{ ms}^{-1}$.

S49. Given $e = 1.6 \times 10^{-19}$ C $\nu = 7.2 \times 10^{15}$ rev s^{-1}

$r = 0.52\text{ Å} = 0.52 \times 10^{-10}$ m

let T is time period of electron, then it crosses a point on its circular path after T. Sec. Therefore equivalent current.

$$I = \frac{e}{T} = e\nu = 1.6 \times 10^{-19} \times 7.2 \times 10^{15}$$

$I = 1.152 \times 10^{-3}$ A

S50. The first two colour bonds of red and black colours the figures are 2 and 0 corresponding to the given carbon resistor is of value 20×10^3 since the band showing the tolerance is silver the value of resistor.

$$R = 20 \times 10^3 \Omega \pm 10\%.$$

S51. Given: $V = 12\,V$; $R = 500\,\Omega$; $t = 10$ min $= 10 \times 60 = 600$ sec.

We know, $V = IR$ or $I = \frac{V}{R} = \frac{12}{500} = 0.024$ A

$$I = \frac{q}{t} = \frac{ne}{t} \qquad (q = ne)$$

or $n = \frac{It}{e} = \frac{0.024 \times 600}{1.6 \times 10^{-19}} = 9 \times 10^{19}$

$\boldsymbol{n = 9 \times 10^{19}}$.

S52. We know,

$$R_t = R_O (1 + \alpha t)$$

$$R_{150} = R_O (1 + 0.0045 \times 150) \qquad \text{... (i)}$$

$$R_{520} = R_O (1 + 0.0045 \times 520) \qquad \text{... (ii)}$$

From Eqns. (i) and (ii), we get

$$R_{520} = R_{150} \times \frac{1 + 0.0045 \times 520}{1 + 0.0045 \times 150} = 125 \times 1.994$$

$$\boldsymbol{R_{520} = 249.25\Omega}.$$

S53. We know,

$$v_d = \frac{V}{ne\rho L}$$

Now, change the length $L' = 3L$ therefore drift velocity is change v_d'

$$v_d' = \frac{V}{ne\rho L'} = \frac{V}{ne\rho 3L}$$

$$= \frac{1}{3}\left(\frac{V}{ne\rho L}\right)$$

Change the drift velocity

$$v_d' = \frac{\mathbf{1}}{\mathbf{3}} \mathbf{v_d}.$$

S54. Here,

$$R = 1\ k\Omega = 10^3\ \Omega,$$

$$t = 5 \text{ minute} = 60 \times 5 \text{ second} = 300 \text{ seconds}$$

$$V = 10\ V$$

$$I = \frac{V}{R} = \frac{10V}{10^3\Omega} = 10^{-2}\ A$$

Also, $$I = \frac{q}{t} = \frac{ne}{t}$$

$\therefore$ $$n = \frac{It}{e} = \frac{10^{-2} A \times 300s}{1.6 \times 10^{-19}\ C} = 1.875 \times 10^{19} \text{ electrons.}$$

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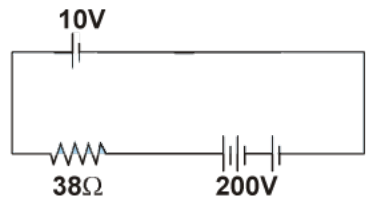
Q1. A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 Ω. What is the resistivity of the material at the temperature of the experiment?

Q2. The resistivity of the alloy manganin is nearly independent of/increases rapidly with increase of temperature.

Q3. The resistivity of a typical insulator (*e.g.*, amber) is greater than that of of a metal by a factor the order of (10^{22}/10^3).

Q4. Resistivity's of copper, silver and manganin are 1.7×10^{-8} Ωm, 1.0×10^{-8} Ωm and 44×10^{-8} Ωm respectively. Which of these is the best conductor?

Q5. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current in circuit.



Q6. What happens to the resistance of a metal wire, when its temperature is reduced to Kelvin zero?

Q7. A wire of resistivity ρ is stretched to double its length. What will be its new resistivity?

Q8. What is the order of resistivity of an insulator?

Q9. How does the conductance of a semiconducting material changes with rise in temperature?

Q10. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker?

Q11. Name the materials used for making standard resistance. Give reasons for this choice.

Q12. Two wires *A* and *B* are of the same metal and of the same length have their areas of cross-section in the ratio of 2 : 1. If the same potential difference is applied across each wire in turn, what will be the ratio of the currents flowing in *A* and *B*?

Q13. What is the effect of rise in temperature on the conductivity of copper and silicon?

Q14. Sketch a graph showing variation of resistivity of carbon with temperature.

Q15. Define superconductor.

Q16. Give two parameters determining the resistivity of a material.

O17. Define thermistor.

Q18. What do you mean by temperature coefficient of resistance?

Q19. Draw a graph to show the variation of resistance of a metal wire as a function of its diameter, keeping length and temperature constant.

Q20. Explain, how does the resistivity of a conductor depend upon (i) under density (n) of free electrons and (ii) relaxation time (τ).

Q21. Is the value of temperature coefficient of resistance always positive?

Q22. Name the units of conductance and conductivity.

Q23. Why connecting wires are made of copper?

Q24. Why is constantan or Manganin used for making standard resistors?

Q25. Name any one material having a small value of temperature coefficient of resistance. Write one use of this material.

Q26. Explain with the help of graph, the variation of conductivity with temperature for a metallic conductor.

Q27. Out of metals and alloys, which has greater value of temperature coefficient?

Q28. Show on a graph, the variation of resistivity with temperature for a typical semiconductor.

Q29. Write an expression for the resistivity of a metallic conductor showing its variation over a limited range to temperatures.

Q30. The Earth's surface has a negative surface charge density of 10^{-9} C m^{-2}. The potential difference of 400 kV between the top of the atmosphere and the surface results (due to the low conductivity of the lower atmosphere) in a current of only 1800 A over the entire globe. If there were no mechanism of sustaining atmospheric electric field, how much time (roughly) would be required to neutralise the earth's surface? (This never happens in practice because there is a mechanism to replenish electric charges, namely the continual thunderstorms and lightning in different parts of the globe). (Radius of Earth = 6.37×10^6 m.)

Q31. An electric toaster uses nichrome for its heating element. When a negligibly small current passes through it, its resistance at room temperature (27.0 °C) is found to be 75.3 Ω. When the toaster is connected to a 230 V supply, the current settles, after a few seconds, to a steady value of 2.68 A. What is the steady temperature of the nichrome element? The temperature coefficient of resistance of nichrome averaged over the temperature range involved, is 1.70×10^{-4} °C^{-1}.

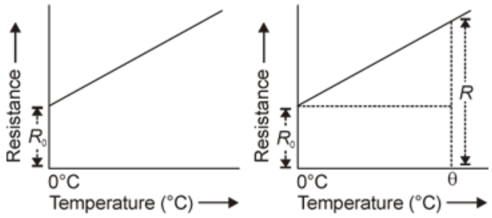
Q32. Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained?

Q33. Derive an expression for the current density of a conductor in terms of the drift speed of electrons.

Q34. Estimate the average drift speed of conduction electrons in a copper wire a cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}].

Q35. Define resistivity of a material and write its SI unit. Does it depend on temperature?

Q36. The variation of resistance of a metallic conductor with temperature is given in figure below. (a) Calculate the temperature coefficient of resistance from the graph. (b) State why the resistance of the conductor increases with rise in temperature.



Q37. A wire of uniform cross section has a resistance of 9 Ω it is cut into three equal pieces. each piece stretched uniformly to three its length and all the three stretched pieces are connected in parallel assuming that stretching of wire does not cause any change in density of their material. Calculate total resistance of the combination described.

Q38. Calculate the conductance and conductivity of a wire of resistance 0.01Ω area of cross-section 10^{-4} m^2 and length 0.1 m

Q39. Two wire is same material having the length ratio 1 : 2 and diameter in the ratio 2 : 3 are connected in series with an accumulator. Find the ratio of potential differential across two wires.

Q40. Find out the resistivity of a conductor in which a current density 2.5×10^6 A m^{-2} is found to exist, when an electric field of 15 V m^{-1} is applied on it.

Q41. Two wires of equal lengths, one of copper and the other of manganin the same resistance. Which wire is thicker?

Q42. A given wire having resistance *R* is stretched so as to reduce its diameter to half of its previous value, what will be its new resistance?

Q43. A copper wire of resistivity ρ is stretched to make it 15% longer find the % change in resistance.

Q44. A wire has a resistance of 32 Ω. It is melted and drawn into a wire of half of its original length calculate the resistance of new wire

Q45. Calculate the resistivity of the material of wire 2 m long 1.0 mm in diameter and having resistances 4 Ω.

Q46. Find the electron conductivity of the copper conductor of length 1.5 m area of cross section 0.6 mm^2 having resistances 2.4 Ω.

Q47. Two wires of equal length, one of aluminium and the other of copper have the same resistance. Which of the two wires is lighter? Hence explain why aluminium wires are preferred for overhead power cables. ($\rho_{Al} = 2.63 \times 10^{-8}\,\Omega$ m, $\rho_{Cu} = 1.72 \times 10^{-8}\,\Omega$ m, Relative density of Al = 2.7, of Cu = 8.9.)

Q48. Write the mathematical relation for the resistivity of material in terms of relaxation time, number density, mass and charge on the charge carries in it. Explain, using this relation, why the resistivity of a metal increases and that of a semiconductor decreases with rise in temperature.

Q49. Derive a mathematical expression for resistivity of a conductor in terms of number density of charge carries in the conductor and relaxation time.

Q50. **Derive the relation connecting drift velocity of electrons and the electric current. Hence prove that current density is directly proportional to the relaxation time.**

Q51. **When a potential difference of 1.5 V is applied across a wire of length 0.2 m and area of cross-section 0.3 mm^2, a current of 2.4 A flows through the wire. If the number density of free electrons in the wire is 8.4×10^{28} m^{-3}, calculate the average relaxations time. Given that mass of electron = 9.1×10^{-31} kg and charge on electron = 1.6×10^{-19} C.**

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S1. Length of the wire, $l = 15\,\text{m}$

Area of cross-section of the wire, $a = 6.0 \times 10^{-7}\,\text{m}^2$

Resistance of the material of the wire, $R = 5.0\,\Omega$

Resistivity of the material of the wire = ρ

Resistance is related with the resistivity as

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

$$\rho = \frac{RA}{l} = \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}\,\Omega\text{m}$$

Therefore, the resistivity of the material is $2 \times 10^{-7}\,\Omega\text{m}$.

S2. The resistivity of the alloy, manganin, is nearly independent of increase of temperature.

S3. The resistivity of a typical insulator is greater than that of a metal by a factor of the order of 10^{22}.

S4. Silver.

Given: $\rho_{Cu} = 1.7 \times 10^{-8}\,\Omega\text{m}$

$$\rho_{Ag} = 1.0 \times 10^{-8}\,\Omega\text{m}$$

$$\rho_{Mn} = 44 \times 10^{-8}\,\Omega\text{m}$$

$$\sigma_{Cu} = \frac{1}{\rho_{Cu}} = \frac{1}{1.7 \times 10^{-8}} = 5.88 \times 10^{7}$$

$$\sigma_{Ag} = \frac{1}{\rho_{Ag}} = \frac{1}{1.0 \times 10^{-8}} = 10 \times 10^{7}$$

$$\sigma_{Mn} = \frac{1}{\rho_{Mn}} = \frac{1}{44 \times 10^{-8}} = 0.227 \times 10^{7}$$

Hence, the silver is best conductor.

S5. Since, the positive terminal of the batteries are connected together, so the equivalent e.m.f. of the batteries is given by $E = 200 - 10 = 190\,\text{V}$. Hence the current in the circuit is given by

$$I = \frac{E}{R} = \frac{190}{38} = 5\text{A}.$$

S6. It will lose all signs of its resistance.

S7. The resistivity of a wire depends of the nature of its material. The increase in length of the wire will not affect its resistivity.

S8. The resistivity order of an insulator is $10^8 - 10^{15}\,\Omega$m.

S9. The semiconductor material increase the conductivity when we increase the temperature because the temperature coefficient is negative of the semiconductor material.

S10. Manganin wire

Given: $l = l_{Cu} = l_{Mn}$

$R = R_{Cu} = R_{Mn}$

$$R_{Cu} = \rho_{Cu}\frac{l}{A_{Cu}} \quad \text{... (i)}$$

$$R_{Mn} = \rho_{Mn}\frac{l}{A_{Mn}} \quad \text{... (ii)}$$

Eqn. (*i*) ÷ Eqn. (ii)

$$\frac{A_{Cu}}{A_{Mn}} = \frac{\rho_{Cu}}{\rho_{Mn}}$$

$\because \quad \rho_{Mn} > \rho_{Cu}$

Hence manganin wire is more thicker compare to copper wire.

S11. The alloy, such as manganin, constantan or nichrome are used for making standard resistance. The alloys are used for this purpose for the reason that they possess high resistivity and low temperature coefficient of resistance.

S12. Remains same 2 : 1

Given cross-section area of two wire $A_A : A_B = 2 : 1$

Length of the wire $l_A = l_B = l$

Potential difference $V_A = V_B = V$

$$\because \quad R_A = \rho \frac{l}{A_A}$$

$$R_B = \rho \frac{l}{A_B}$$

$$\frac{R_A}{R_B} = \frac{A_B}{A_A}$$

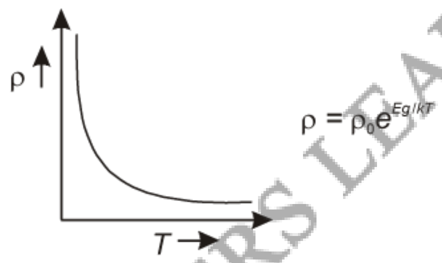
$$\frac{I_A}{I_B} = \frac{R_B}{R_A} = \frac{A_A}{A_B}$$

$$I_A : I_B = 2 : 1$$

S13. The conductivity of copper (a metallic conductor) decreases with increase of its temperature.

The conductivity of silicon (a semi-conductor) increases with increase of its temperature.

S14. The variation of resistivity of carbon with temperature graph as shown below:



S15. A conductor, which loses all signs of resistance on being cooled to its critical temperature, is called a superconductor.

S16. (a) Number density of free electron (n).

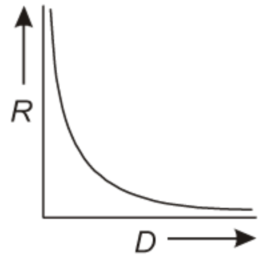
(b) The relaxation time (τ).

S17. A heat sensitive resistor, whose resistance varies appreciably with temperature, that is known as thermistor.

S18. The change in resistance per unit resistance per degree rise or fall in temperature of a material is called the temperature coefficient of the resistance.

$$\alpha = \frac{R_t - R_0}{R_0 \times \theta}$$

S19.



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

$$= \rho \frac{l}{\pi D^2/4} \quad \text{(where } \rho, \frac{\pi}{4} \text{ and } l \text{ are constant)}$$

$$R \propto \frac{1}{D^2}$$

The graph between R an D will be as shown in figure above.

S20. We know,

$$\rho = \frac{m}{ne^2\tau}$$

Hence, the resistivity of the conductor is inversely proportional both (i) number of density of free electron and (ii) relaxation time.

S21. No, it is positive only for metals and alloys. For semiconductors and insulators, it is negative.

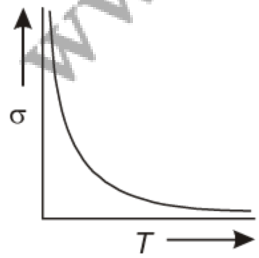
S22. The unit of conductance is ***simen*** and that of conductivity is ***simen metre***$^{-1}$.

S23. Copper has very low resistivity (*i.e.*, very high conductivity). Thus, current in the circuit is not affected practically.

S24. The alloy, its resistivity is very high and temperature coefficient of resistance is very low.

S25. An alloy, such as Nichrome, has a very small value of temperature coefficient of resistance ($= 1.7 \times 10^{-4}\,°C^{-1}$). Because of this, it is used to make standard resistance.

S26. For the metallic conductor the conductivity of the conductor decrease with increase the temperature

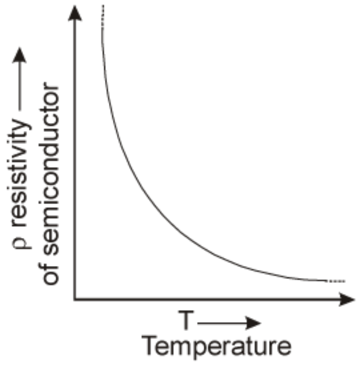


$$\sigma = \frac{1}{\rho} \quad \text{where} \quad \rho = R\frac{A}{l}$$

S27. The value of α is more for metals than that for alloys. For example, for copper, $\alpha = 4 \times 10^{-3}\,°C^{-1}$ and for Manganin, $\alpha = 15 \times 10^{-6}\,°C^{-1}$.

S28. The resistivity of a semiconductor decreases exponentially with temperature.

The variation of resistivity with temperature for semiconductor is shown below.



S29. Required expression $\rho = \rho_0\,[1 + \alpha(T_2 - T_1)]$

where, ρ = resistivity of conductor at lower reference temperature,

α = temperature coefficient of resistivity,

ρ = resistivity of material of conductor.

S30. Surface charge density of the Earth, $\sigma = 10^{-9}\,C\,m^{-2}$

Current over the entire globe, $I = 1800\,A$

Radius of the Earth, $r = 6.37 \times 10^6\,m$

Surface area of the Earth,

$$A = 4\pi r^2 = 4\pi \times (6.37 \times 10^6)^2 = 5.09 \times 10^{14}\,m^2$$

Charge on the Earth surface,

$$q = \sigma \times A = 10^{-9} \times 5.09 \times 10^{14} = 5.09 \times 10^5\,C$$

Time taken to neutralize the Earth's surface = t

Current,

$$I = \frac{q}{t}$$

$$t = \frac{q}{I} = 282.77\,s$$

Therefore, the time taken to neutralize the Earth's surface is 282.77 s.

S31. When the current through the element is very small, heating effects can be ignored and the temperature T_1 of the element is the same as room temperature. When the toaster is connected to the supply, its initial current will be slightly higher than its steady value of 2.68 A. But due to heating effect of the current, the temperature will rise. This will cause an increase in resistance and a slight decrease in current. In a few seconds, a steady state will be reached when temperature will rise no further, and both the resistance of the element and the current drawn will achieve steady values. The resistance R_2 at the steady temperature T_2 is

$$R_2 = \frac{230\text{ V}}{2.68\text{ A}} = 85.8\,\Omega$$

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

with $\alpha = 1.70 \times 10^{-4}\,°\text{C}^{-1}$, we get

$$T_2 - T_1 = \frac{(85.8 - 75.3)}{(75.3) \times 1.70 \times 10^{-4}} = 820\ °\text{C}$$

that is, $T_2 = (820 + 27.0)\ °\text{C} = 847\ °\text{C}$

Thus, the steady temperature of the heating element (when heating effect due to the current equals heat loss to the surroundings) is 847 °C.

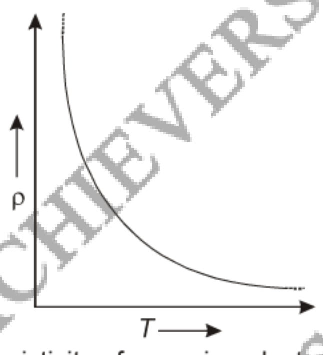
S32. To plot the graph between the two quantities, first of all identify the relation between them.

Since, resistivity of material of conductor (ρ) is given by

$$\rho = \frac{m}{ne^2\tau}$$

where, n = number density of electrons,

τ = relaxation time.



Resistivity of a semiconductor decreases repidly with temperature

With the rise of temperature of semiconductor, number density of free electrons increases whereas τ remains constant and hence resistivity decreases.

S33. Ohm's law states that physical conditions remaining unchanged, the current flowing through a conductor is always directly proportional to the potential difference across its two ends.

Mathematically: $V \propto I$ or $V = RI$

Here, R is called resistance of the conductor.

Consider a conductor of length l and area of cross-section A having n electrons per unit length, as shown in figure.

Volume of the conductor = Al

$\therefore$ Total number of electron, then total charge contained in the conductor,

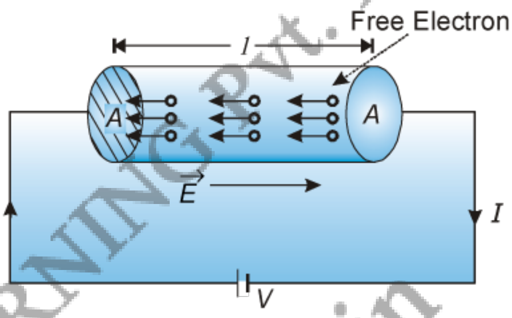
$$Q = enAl$$

Let a potential difference V is applied across the conductor. The resulting electric field in the conductor is given by

$$E = \frac{V}{l}$$

Under the influence of this field E, free electrons begin to drift in a direction opposite to that of the field. Time taken by electrons to cross-over the conductor is

$$t = \frac{l}{v_d}$$



Where, v_d is the drift velocity of electrons.

Therefore, current through the conductor is given by

$$I = \frac{Q}{t} = \frac{enAl}{l/v_d}$$

or $$I = enAv_d$$

$$j = \frac{I}{A} = nev_d$$

S34. Given, $l = 1.5\ A$, $n = 9 \times 10^{28}\ m^{-3}$,

$$A = 1.0 \times 10^{-7}\ \text{m}^2$$

$\therefore$ $$v_d = \frac{l}{neA}$$

$$= \frac{1.5}{9 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.0 \times 10^{-7}}$$

$\Rightarrow$ $$v_d = 1.04 \text{ x } 10^{-3} \text{ m/s.}$$

S35. **Resistivity:** The resistivity of a material may be defined as the specific resistance of the material of a conductor is the resistance offered by wire of this material of unit length and unit area of cross-section.

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

The SI unit of resistivity is Ωm.

Yes, resistivity of a material depends on temperature.

S36. Consider a point A on the resistance-temperature graph as shown in the above figure. Let R be resistance of the conductor and θ be its temperature corresponding to point A on the graph.

(a) Temperature coefficient of the conductor,

$$\alpha = \frac{R - R_0}{R_0 \times \theta}$$

(b) The resistance of a wire is given by

$$R = \rho \frac{l}{A} = \frac{m}{n e^2 \tau} \cdot \frac{1}{A}$$

When temperature of conductor is increased, its average relaxation time decreases due to increase in frequency of collision of electrons with atoms and ions. Since $R \propto 1/\tau$, the resistance of the conductor increases with rise in temperature.

S37. Resistance of each piece of the wire

$$R = 9/3 = 3\Omega$$

let l be the length and A, the area of cross-section of each of the wire

$$\rho\, l/A = 3$$

When each piece of the wire is stretched to three times its length i.e. $3l$, Its area will decrease to A/3 therefore new resistance of piece of wire

$$R' = \rho \frac{3l}{A/3} = R' = \rho \frac{3l}{A/3} = 9\frac{\rho l}{A}$$

$$= 9 \times 3$$

$$= 27\ \Omega$$

Let R_{eq} be the equivalent resistance, when all three pieces are connected in parallel of then

$$\frac{1}{R_{eq}} = \frac{1}{27} + \frac{1}{27} + \frac{1}{27}$$

$$= \frac{3}{27} = \frac{1}{9}$$

$$\boldsymbol{R_{eq} = 9\Omega}$$

S38. Given; $R = 0.01\,\Omega$; $A = 10^{-4}\ m^2$ & $l = 0.1$ m

Conductance's $G = \frac{1}{R} = \frac{1}{0.01} = 100$ S

We know, $R = \rho l/A$

or $\rho = \frac{RA}{l}$

$$\rho = \frac{1}{\sigma} = \frac{l}{RA} \Rightarrow \frac{0.1}{10^{-4} \times 0.01} = 10^5\ Sm^{-1}$$

$$\boldsymbol{\rho = 10^5 Sm^{-1}}$$

S39. Let common factor of length is l. Then length of wire l and $2l$ and common factor of diameter is D then the diameter 2D and 3D. If ρ is resistivity of their material then Resistances of the wires.

$$R_1 = \rho \frac{l}{\pi\left(\frac{2D}{2}\right)^2} = \rho \frac{l}{\pi D^2}$$

$$R_2 = \rho \frac{2l}{\pi\left(\frac{3D}{2}\right)^2} = \frac{8}{9}\left(\frac{\rho l}{\pi D^2}\right)$$

Given the both wire are connected in series due to this the current will be remains same

$$V_1 = IR_1 \quad \text{... (i)}$$
$$V_2 = IR_2 \quad \text{... (ii)}$$

Eqn. (i) ÷ Eqn. (ii), we get

$$\frac{V_1}{V_2} = \frac{R_1}{R_2} = \frac{\left(\frac{\rho l}{\pi D^2}\right)}{\frac{8}{9}\left(\frac{\rho l}{\pi D^2}\right)} = \frac{9}{8}$$

$$\frac{\boldsymbol{V_1}}{\boldsymbol{V_2}} = \frac{9}{8} \quad \text{or} \quad \boldsymbol{V_1 : V_2 = 9 : 8}$$

S40. Let l and A be length and area of cross-section of the conductor respectively.

Now, current density $j = \frac{I}{A} = 2.5 \times 10^6\ Am^{-2}$;

Electric field $E = \frac{V}{l} = 15\,Vm^{-1}$

Now, resistivity, $\rho = R \cdot \frac{A}{l} = \frac{V}{I} \cdot \frac{A}{l} = \frac{15}{2.5 \times 10^6} = 6 \times 10^{-6}\,\Omega\,\text{m}$

S41. Let ρ_{Cu} and ρ_{Mn} be resistivity's of copper and manganin and A_{Cu} and A_{Mn} be the areas of cross-section of the wires made of copper and manganin respectively. Since the two wires have equal lengths and have the same resistance,

$$\rho_{Cu} \frac{l}{A_{Cu}} = \rho_{Mn} \frac{l}{A_{Mn}}$$

or $$\frac{A_{Cu}}{A_{Mn}} = \frac{\rho_{Cu}}{\rho_{Mn}}$$

Since resistivity of copper (ρ_{Cu}) is less than that of manganin (ρ_{Mn}), if follows that area of cross-section of copper wire (A_{Cu}) is less than that of manganin wire (A_{Mn}). Thus, mangnin wire is thicker.

S42. Let l be length and A be area of cross-section of the wire. Then,

$$R = \rho \frac{l}{A} \quad \text{... (i)}$$

When the diameter of the wire is reduced to half of its previous value, its new area of cross-section will become one fourth *i.e.*,

$$A' = A/4$$

If l' is new length of the wire, then volume of the wire remains same

$$l'A' = lA \quad \text{or} \quad \frac{l'\cancel{A}}{4} = l\cancel{A}$$

or $$l' = 4l$$

Therefore, new resistance of the wire,

$$R' = \rho \frac{l'}{A'} = \rho \frac{4l}{A/4}$$

$$R' = 16\left(\rho \frac{l}{A}\right) \quad \text{... (ii)}$$

From the Eqns. (i) and (ii), we get

$$R' = \mathbf{16\,R}.$$

S43. Let l be the length of the wire and A, the area of cross section of the wire. If ρ is the resistivity of copper wire.

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

Suppose the when length of copper wire is increased of

$$l' = l + 0.15l$$
$$= 1.15l$$

Its area cross-section become A' the volumes wires should be remains same

$$Al = A'l'$$

$$A' = \frac{Al}{l'} = \frac{A\cancel{l}}{1.15\cancel{l}} = \frac{A}{1.15}$$

Now new resistances R'

$$R' = \rho\frac{l'}{A'} = \rho\frac{1.15\,l}{\frac{A}{1.15}}$$

$$(1.15)(1.15)\left(\rho\frac{l}{A}\right)$$

$$= 1.3225\,R = 1.3225 \times 100$$

$$= 132.25\%$$

% change $= 132.25 - 100 = 32.25\%$ (Increase).

S44. Given: $R = 32\ \Omega$

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

After melting the wire Resistances R' length $l' = \frac{l}{2}$ and $\rho' = \rho$ volume of the wire remains same

$$Al = A'l'$$

$$A' = \frac{Al}{l'} = \frac{A\cancel{l}}{\cancel{l}/2} = 2A$$

$$A' = 2A$$

New resistance of the wire is

$$R' = \rho'\frac{l'}{A} = \rho\frac{(l/2)}{2A} = \frac{1}{4}\left(\frac{\rho l}{A}\right)$$

$$= \frac{1}{4}(R)$$

$$= 25\%$$

$(100 - 25)\% = 75\%$

75% decrease.

S45. Given: $l = 2\ m$ $r = 0.5\ \text{mm} = 0.5 \times 10^{-3}\ \text{m}$

Now area $A = \pi r^2 = 3.14 \times (0.5 \times 10^{-3})^2 = 7.85 \times 10^{-7}\ \text{m}^2$

We know, $R = \rho \dfrac{l}{A}$

or $\rho = \dfrac{RA}{l} = \dfrac{4 \times 7.85 \times 10^{-7}\ \text{m}^2}{2}$

$\boldsymbol{\rho = 1.57 \times 10^{-6}\ \Omega\text{m}}$

S46. Given:

$l = 1.5\ \text{m}, A = 0.6 \times 10^{-6}\ \text{m}^2.$

$R = 2.4\ \Omega$

We know, $R = \rho \dfrac{l}{A}$

or $\rho = \dfrac{RA}{l}$

Conductivity of the copper wire $\sigma = \dfrac{1}{\rho} = \dfrac{l}{RA}$

$= \dfrac{1.5}{0.6 \times 10^{-6} \times 2.4}$

$\boldsymbol{\sigma = 1.04 \times 10^6\ \text{Sm}^{-1}}$

S47. Resistivity of aluminium, $\rho_{Al} = 2.63 \times 10^{-8}\ \Omega\text{m}$

Relative density of aluminium, $d_1 = 2.7$

Let l_1 be the length of aluminium wire and m_1 be its mass.

Resistance of the aluminium wire = R_1

Area of cross-section of the aluminium wire = A_1

Resistivity of copper, $\rho_{Cu} = 1.72 \times 10^{-8}\ \Omega\text{m}$

Relative density of copper, $d_2 = 8.9$

Let l_2 be the length of copper wire and m_2 be its mass.

Resistance of the copper wire = R_2

Area of cross-section of the copper wire = A_2

The two relations can be written as

$$R_1 = \rho_1 \frac{l_1}{A_1} \quad \text{... (i)}$$

$$R_2 = \rho_2 \frac{l_2}{A_2} \quad \text{... (ii)}$$

It is given that,

$$R_1 = R_2$$

$$\rho_1 \frac{l_1}{A_1} = \rho_2 \frac{l_2}{A_2}$$

And,

$$l_1 = l_2$$

$\therefore$

$$\frac{\rho_1}{A_1} = \frac{\rho_2}{A_2}$$

$$\frac{A_1}{A_2} = \frac{\rho_1}{\rho_2}$$

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

Mass of the aluminium wire, m_1 = Volume $\times$ Density

$$= A_1 l_1 \times d_1 = A_1 l_1 d_1 \quad \text{... (iii)}$$

Mass of the copper wire, m_2 = Volume $\times$ Density

$$= A_2 l_2 \times d_2 = A_2 l_2 d_2 \quad \text{... (iv)}$$

Dividing Eq. (iii) by Eq. (iv), we obtain

$$\frac{m_1}{m_2} = \frac{A_1 l_1 d_1}{A_2 l_2 d_2}$$

For $l_1 = l_2$,

$$\frac{m_1}{m_2} = \frac{A_1 d_1}{A_2 d_2}$$

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

$$\frac{m_1}{m_2} = \frac{2.63}{1.72} \times \frac{2.7}{8.9} = 0.46$$

It can be inferred from this ratio that m_1 is less than m_2. Hence, aluminium is lighter than copper. Since aluminium is lighter, it is preferred for overhead power cables over copper.

S48. Resistivity of material of conductor

$$\rho = \frac{m}{ne^2\tau}$$

where, m = mass of electrons, n = number of free electron per unit volume and

τ = relaxation on time.

Dependence of resistivity of metal on temperature.

With the rise of temperature of metal, on effect occurs in the number density of electrons but relaxation time decreases as collision of electron become more frequent with the increase of their velocities.

S49. Consider a conductor having length l and area of cross-section A. Let n be number of electrons per unit volume in the conductor. If an electric field E is applied across the two ends of the conductor, then drift velocity (in magnitude) of electrons is given by

$$v_d = \frac{eE}{m}\tau$$

The current flowing through the conductor due to drift of electrons is given by

$$I = nAv_d e$$

Substituting for v_d in the above equation, we have

$$I = nA\left(\frac{eE}{m}\tau\right)e$$

or $$I = \frac{nAe^2V\tau}{m}$$

If V is potential difference applied across the two ends of the conductor, then

$$E = \frac{V}{l}$$

Substituting for E in equation, we have

$$I = \frac{nAe^2V\tau}{ml}$$

or $$\frac{V}{I} = \frac{ml}{ne^2\tau A}$$

But according to ohm's law, $\frac{V}{I} = R$, the resistance of the conductor.

$$R = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$$

Comparing the above result with the expression for resistance obtained earlier i.e.

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

it follows that resistivity of the material of a conductor is given by

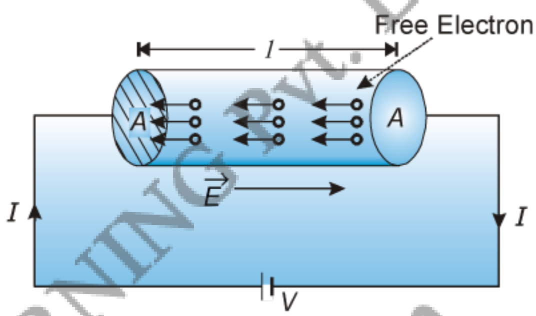
$$\rho = \frac{m}{ne^2 \tau}$$

S50. Let a potential difference V is applied across the conductor. The resulting electric field in the conductor is given by

$$E = \frac{V}{l}$$

Under the influence of this field E, free electrons begin to drift in a direction opposite to that of the field. Time taken by electrons to cross-over the conductor is

$$t = \frac{l}{v_d}$$



Where, v_d is the drift velocity of electrons.

Therefore, current through the conductor is given by

$$I = \frac{Q}{t} = \frac{enAl}{l/v_d}$$

or $$I = enAv_d \quad \text{... (i)}$$

If v_d is drift velocity attained by free electrons on applying electric field E, then electron mobility is is given by

$$\mu = \frac{v_d}{E} \quad \text{... (ii)}$$

Now, $$v_d = \frac{eE}{m}\tau \quad \text{(in magnitude)} \quad \text{... (iii)}$$

From the equations (ii) and (iii), we have

$$\mu = \frac{e\tau}{m} \quad \text{... (iv)}$$

The equations (i) and (iv) are the expressions for electron mobility.

In the equation (i), substituting for v_d (= μE), we have

$$I = nA\mu Ee$$

Now current density $$j = \frac{I}{A} = \frac{nA\mu Ee}{A} = n\mu Ee \quad \text{... (v)}$$

Put the value μ in Eq (v), we get

$$j = \frac{ne^2\tau}{m}E$$

$$j \propto \tau$$

S51. Here, $V = 1.5$ V ; $n = 8.4 \times 10^{28}$ m^{-3}; $l = 0.2$ m;

$A = 0.3$ mm^2 = 0.3×10^{-6} m^2, $I = 2.4$ A;

$m = 9.1 \times 10^{-31}$ kg and e = 1.6 ´ 10^{-19} C

The electric field set up across the conductor,

$$E = \frac{V}{l} = \frac{1.5}{0.2} = 7.5 V\,\text{m}^{-1}$$

The current density in the wire,

$$j = \frac{I}{A} = \frac{2.4}{0.3 \times 10^{-6}} = 8 \times 10^6\ \text{A}\,\text{m}^{-2}$$

Now, $$j = \frac{ne^2\tau}{m}E$$

Therefore, the average relaxation time,

$$\tau = \frac{m\,j}{ne^2E} = \frac{9.1 \times 10^{-31} \times 8 \times 10^6}{8.4 \times 10^{28} \times (1.6 \times 10^{-9})^2 \times 7.5}$$

$$= 4.51 \times 10^{-16} s$$

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Q1. What is the electric energy?

Q2. Define the kWh.

Q3. A current of 5.0 A flows through an electric press of resistance 44 Ω. Calculate the energy consumed by the press in 5 minutes.

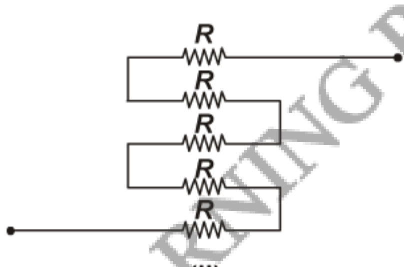
Q4. A heating element is marked 210 V, 630 W. What is the value of the current drawn by the element when connected to a 210 V DC source?

Q5. What is the electric power?

Q6. Given the resistances of 1 Ω, 2 Ω, 3 Ω, how will be combine them to get an equivalent resistance of (a) (11/3) Ω (b) (11/5) Ω, (c) 6 Ω, (d) (6/11) Ω?

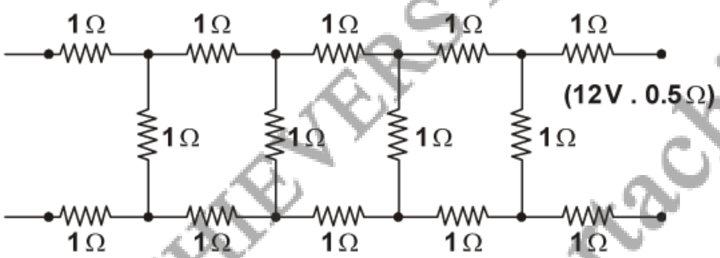
Q7. Determine the equivalent resistance of networks shown in figure.

(i)



(ii)

Q8. Determine the current drawn from a 12 V supply with internal resistance 0.5 Ω by the infinite network shown in figure. Each resistor has 1 Ω resistance.



Q9. Prove that electric energy (W) consumed in a conductor is given by the formula:

$$W = I^2 R t$$

Q10. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage V, consume powers P_1 and P_2, respectively. Deduce the expressions for the power of their combination when they are in turn, connected in parallel.

Q11. A heater coil is rated 100 W, 200 V. It is cut into two identical parts. Both parts are connected together in parallel to the same source of 200 V. Calculate the energy liberated per second in the new combination.

Q12. A lamp of 100 W works at 220 V. What is its resistance and current capacity.

Q13. A 40 W – 220 V bulb and 60 W – 220 V bulb are connected in parallel to main supply bulb will draw more current?

Q14. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage V, consume powers P_1 and P_2, respectively. Deduce the expressions for the power of their combination when they are in turn, connected in series

Q15. (a) Obtain the formula for the power loss in a conductor of resistance R and carrying a current I.

(b) A electric bulb is rated at 200V, 500 watt. What is the resistance of the filament? How much will it cost to light the bulb for 8 hours, if the price of energy is 75 paise per unit.

Q16. An electrical cable having a resistance of 0.02Ω delivers 1 kW at 220 V d.c. to a factory. Find the efficiency of the transmission.

Q17. Define the electric power. Calculate the number of electrons moving per second through the filament of a lamp of 100 watt, operating at 200 volt. Given, charge on electron, $e = 1.6 \times 10^{-19}$ C.

Q18. A house is fitted with 20 lamps of 60 watt each, an electric kettle of resistance $110\,\Omega$. and 10 fans consuming 0.5 A each. If the energy is supplied at 220 volt and costs Rs. 2.50 per kWh, calculate the bill April month for running each appliances for six hours a day.

Q19. Three identical resistors, each of resistance R, when connected in series with a d.c. source, dissipate power X. If the resistors are connected in parallel to the same d.c. source, how much power will be dissipated?

Q20. (a) Define the 'Electric power, writes its unit.

(b) Calculate the number of electrons moving per second through the filament of a lamp of 100 watt, operating at 200 volt.

Date: 20/10/2021

S1. The total work done (or energy supplied) by the source of em.f. in maintaining the electric current in the circuit of a given time is called electric energy consumed in the circuit.

S2. The energy dissipated or consumed in an electric circuit is called one watt hour, if a device of electric power of one watt is used for one hour.

S3. Here $I = 5.0$ A; $R = 44\ \Omega$, $t = 5 \times 60 = 300$ s

Now energy consumed

$$= I^2Rt$$

$$= 5 \times 5 \times 44 \times 300$$

$$= 33 \times 10^4 \text{ Joule}$$

S4. Given that $P = 630$ W and $V = 210$V. In DC source $P = VI$. Therefore, $I = \frac{630}{210} = 3\,A$.

S5. The rate at which work is done by the source of e.m.f. in maintaining the electric current in a circuit is called electric power of the circuit.

S6. Total number of resistors = n

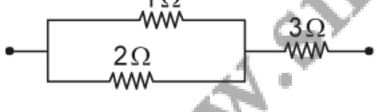
Resistance of each resistor = R

(a) The resistance of the given resistors is,

$$R_1 = 1\,\Omega, \quad R_2 = 2\,\Omega, \quad R_3 = 3\,\Omega 2$$

Equivalent resistance, $R = \frac{11}{3}\,\Omega$

Consider the following combination of the resistors.

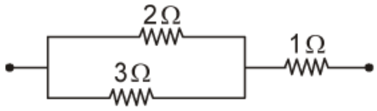


Equivalent resistance of the circuit is given by,

$$R = \frac{2 \times 1}{2+1} + 3 = \frac{2}{3} + 3 = \frac{11}{3}\,\Omega$$

(b) Equivalent resistance, $R = \frac{11}{5}\,\Omega$

Consider the following combination of the resistors.



Equivalent resistance of the circuit is given by,

$$R = \frac{2\times 3}{2+3} + 1 = \frac{6}{5} + 1 = \frac{11}{5}\,\Omega$$

Equivalent resistance, $R' = 6\,\Omega$

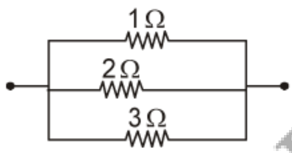
(c) Consider the series combination of the resistors, as shown in the given circuit.

Equivalent resistance of the circuit is given by the sum,

$$R' = 1 + 2 + 3 = 6\,\Omega$$

Equivalent resistance, $R = \frac{6}{11}\,\Omega$

(d) Consider the series combination of the resistors, as shown in the given circuit.



Equivalent resistance of the circuit is given by,

$$R = \frac{1\times 2\times 3}{1\times + 2\times 3 + 3\times 1} = \frac{6}{11}\,\Omega$$

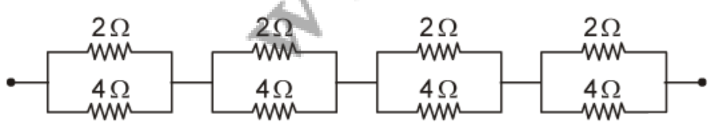
S7. (a) It can be observed from the given circuit that in the first small loop, two resistors of resistance $1\,\Omega$ each are connected in series.

Hence, their equivalent resistance = (1 + 1) = $2\,\Omega$

It can also be observed that two resistors of resistance $2\,\Omega$ each are connected in series.

Hence, their equivalent resistance = (2 + 2) = $4\,\Omega$.

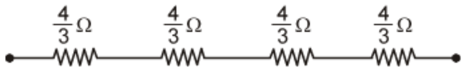
Therefore, the circuit can be redrawn as



It can be observed that 2 Ω and 4 Ω resistors are connected in parallel in all the four loops. Hence, equivalent resistance (R') of each loop is given by,

$$R = \frac{2 \times 4}{2+4} = \frac{8}{6} = \frac{4}{3}\,\Omega$$

The circuit reduces to,



All the four resistors are connected in series.

Hence, equivalent resistance of the given circuit is

$$\frac{4}{3} \times 4 = \frac{16}{3}\,\Omega$$

(b) It can be observed from the given circuit that five resistors of resistance R each are connected in series.

Hence, equivalent resistance of the circuit = $R + R + R + R + R = 5\,R$.

S8. The resistance of each resistor connected in the given circuit, $R = 1\,\Omega$

Equivalent resistance of the given circuit = R'

The network is infinite. Hence, equivalent resistance is given by the relation,

$$\therefore \qquad R' = 2 + \frac{R'}{(R'+1)}$$

$$(R')^2 - 2R' - 2 = 0$$

$$R' = \frac{2 \pm \sqrt{4+8}}{2}$$

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

Negative value of R' cannot be accepted. Hence, equivalent resistance,

$$R' = (1 + \sqrt{3}) = 1 + 1.73 = 2.73\,\Omega$$

Internal resistance of the circuit, $r = 0.5\,\Omega$

Hence, total resistance of the given circuit = 2.73 + 0.5 = 3.23 Ω

Supply voltage, $V = 12\,\text{V}$

According to Ohm's Law, $$I = \frac{V}{R} = \frac{12}{3.23} = 3.72\text{ A}$$

S9. Consider a resistor of resistance R, across which a potential difference V is applied. According to Ohm's law, the current I flowing through the resistor is given by

$$V = I R$$

Suppose that the steady current I flows through the resistor for a time t. Then, total charge that crosses through the resistor is given by

$$q = I t$$

Since the current† flows from the end A to B, potential of the end A must be higher than that of B by an amount V. From the definition of potential difference, we know that if a unit charge is made to cross the resistor from the end B to A (from the end at lower potential to that at higher potential), work equal to V has to be done. Conversely, if a unit charge flows from the end A to B, then energy equal to V will be gained it. Therefore energy gained by the total charge q passing through the resistor in time t is given by

$$W = Vq = V(I\,t)$$

or $$W = V I t \quad \text{... (i)}$$

we know $V = IR$ put in equation (i)

$$W = (IR)\, It = I^2 Rt$$

S10. When resistance are connected in parallel

$$P_p = \frac{V^2}{R_p}$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{\frac{V^2}{P_1}} + \frac{1}{\frac{V^2}{P_2}} = \frac{P_1}{V^2} + \frac{P_2}{V^2}$$

$$\frac{1}{R_P} = \frac{1}{V^2}(P_1 + P_2)$$

Now, power consumption in parallel combination

$$P_p = \frac{V^2}{R_p} = V^2\left(\frac{1}{R_p}\right)$$

$$P_p = V^2\left[\frac{1}{V^2}(P_1 + P_2)\right]$$

$$P_p = P_1 + P_2$$

S11. Resistance of heater coil $R = \frac{V^2}{P} = \frac{200 \times 200}{100} = 400\ \Omega$

Resistance of each part = $\frac{R}{2}$ = 200 Ω

Equivalent resistance of two parts connected in parallel

$$R_p = \frac{200 \times 200}{200 + 200} = 100\ \Omega$$

$$\text{Current} \quad I = \frac{V}{R_p} = \frac{200}{100} = 2\text{ A}$$

Energy liberated per second = $I^2 R_p = 4 \times 100 = 400$ J

S12. Given: $P = 100\text{W}$; $V = 220$ volt

We know, $P = VI \Rightarrow I = \frac{P}{V} = \frac{100}{220} = 0.0455\text{ A}$

Now, $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$

$$= \frac{(220)^2}{100} = 484\ \Omega$$

$\boldsymbol{R = 484\,\Omega}$

S13. Given $P_1 = 40\,\text{W}$ and $P_2 = 60\,\text{W}$

When both bulb are connected in parallel, the voltage across them same but current are different.

$$P = VI$$

where V is constant

$$P \propto I \quad \text{or} \quad I \propto P$$

Therefore 60 W bulb has draw more current compare to the 40 W bulb.

S14. To deduce the expression for the power of the combination, first the equivalent resistance of the combination in the given conditions.

$\therefore$ $$P_1 = \frac{V^2}{R_1} \Rightarrow R_1 = \frac{V^2}{P_1}$$

$$P_2 = \frac{V^2}{R_2}$$

$\Rightarrow$ $$R_2 = \frac{V^2}{P_2}$$

In series combination

$$R_s = R_1 + R_2 = \frac{V^2}{P_1} + \frac{V^2}{P_2}$$

$$R_s = R_1 + R_2 = V^2\left(\frac{1}{P_1} + \frac{1}{P_2}\right) = V^2\left(\frac{P_1 + P_2}{P_1 P_2}\right)$$

Now, let the power of heating element in series combination be P_s.

$\therefore$ $$P_s = \frac{V^2}{R_1 + R_2} = \frac{V^2}{V^2\left(\frac{P_1 + P_2}{P_1 P_2}\right)} = \frac{P_1 P_2}{P_1 + P_2}$$

$$P_s = \frac{P_1 P_2}{P_1 + P_2}$$

S15. (a) The rate at which work is done by the source of e.m.f. in maintaining the electric current in a circuit is called electric power of the circuit.

If an amount of work W is done in maintaining electric current for a time t in the circuit, then electric power of the circuit,

$$P = \frac{W}{t} \quad \text{... (i)}$$

From equations (i) we have

$$P = VI$$

The SI unit of electric power is watt.

1 watt = 1volt $\times$ 1 ampere or 1W = 1V $\times$ 1A

The electric power of a circuit or a device is said to be one watt, if one ampere of current flows through it, when a constant potential difference of one volt is applied across it.

(b) Here power = 500 watts, potential difference V = 200 volt

Now watt = $V \times I = V^2/R$

$\therefore$ $$R = \frac{V^2}{\text{watt}} = \frac{200 \times 200}{500} = 80 \text{ ohm}$$

Energy consumed in 8 hours = 500 $\times$ 8 = 4000 watt hours = 4 k. watt hours = 4 units

Total cost = 4 $\times$ 0.75 = 3.00 Rs

S16. (a) Here, $R = 0.2\Omega$, $P = 10$ kW, V = 220 V

So, power loss in the cable

$$= I^2R = \left(\frac{P}{V}\right)^2 R = \left(\frac{1000}{220}\right)^2 \times 0.02 = 0.413 \text{ W}$$

Now, $$\text{Efficiency} = \frac{\text{Power delivered by the cable to the factory}}{\text{Power supplied to the cable}}$$

$$= \frac{10}{10 + 0.413} = 0.96$$

or Efficiency = 96%

S17. ***Electric power:*** The rate at which work is done by the source of e.m.f. in maintaining the electric current in a circuit is called ***electric power*** of the circuit.

Its unit is SI unit ***watt*** or ***volt ampere***.

Here, charge on the lamp, $P = 100$ W;

operating voltage, $V = 220$ volt

$$P = VI$$

Now, Therefore, the current capacity of the lamp,

$$I = \frac{P}{V} = \frac{100}{220} = 0.455 \text{ A}$$

Hence, 0.455 C charge is moving per second through the filament of lamp.
Let n number of electrons moving per second.
Therefore, ne = 0.455

$$n = \frac{0.455}{1.6 \times 10^{-19}}$$

$n = 2.844 \times 10^{18}$ electrons per second.

S18. Power of 20 lamps, $P' = 20 \times 60 = 1200$ W

Power of electric kettle,

$$P'' = \frac{V^2}{R} = \frac{220 \times 220}{110} = 440 \text{ W}$$

$$P''' = 10 \times 220 \times 0.5 = 1100\text{W}$$

∴ Total power consumed,

$$P = p' + p'' + p''' = 1200 + 440 + 1100$$

$$= 2740 \text{ W} = 2.74 \text{ kW}$$

So, energy consumed $= 2.74 \times 6 \times 30 = 493.2$ kWh

∴ Bill for the month of April

$$= \text{Rs. } 493.2 \times 2.50$$

$$= \text{Rs. } 1233.00.$$

S19. Let the d.c. source be of potential V volts.

In series: Total resistance $R_s = R + R = 3R$

∴ Current $I = \dfrac{V}{R_s} = \dfrac{V}{3R}$

Power dissipated, $P_s = I_s^2 R_s$

$$= \left(\frac{V}{3R}\right)^2 .3R$$

$$= \frac{1}{3}\frac{V^2}{R} \equiv X \qquad \text{... (i)}$$

When resistors connected in parallel.

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R}$$

Effective resistance, $R_p = \dfrac{R}{3}$

∴ Current $I_p = \dfrac{V}{R_p} = \dfrac{3V}{R}$

Power dissipated, $P_p = I^2{}_p R_p$

$$= \left(\frac{3V}{R}\right)^2 \frac{R}{3}$$

$$= \frac{9V^2}{R^2} . \frac{R}{3}$$

$$= \frac{3V^2}{R} \qquad \text{... (ii)}$$

Dividing (ii) by (i), we get

$$\frac{P_p}{P_s} = \frac{3V^2}{R} . \frac{3R}{V^2} = 9$$

or $P_p = 9X$

Thus if the resistors are connected in parallel to the same d.c. source, power dissipated is 9 times the power dissipated when connected in series.

S20. (a) ***Electric power:*** The rate at which work is done by the source of e.m.f. in maintaining the electric current in a circuit is called ***electric power*** of the circuit.

Its unit is SI unit ***watt*** or ***volt ampere***.

(b) Here $e = 1.6 \times 10^{-19}$C, $P = 100$ W, operating voltage = 200 V

$t = 1$ sec

We know, $P = VI$

$$I = \frac{P}{V} = \frac{100}{200} = 0.5\,A$$

Current, $I = q \times t = ne \times t$

$$\therefore \quad n = \frac{I}{e \times t} = \frac{0.5}{1.6 \times 10^{-19} \times 1} = 3.125 \times 10^{18} \text{ electrons}$$

Date: 20/10/2021

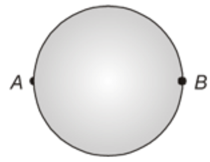
Q1. A wire has a resistance of 90 Ω and it is cut into three pieces having equal lengths. If these are now connected in parallel, find the resistance of the combination so formed.

Q2. The resistance becomes less in parallel combination. Why?

Q3. The resistance becomes more in series combination. Why?

Q4. A student obtains resistances 3, 4, 12 and 16 ohm using two metallic resistance wires, either separately of joined together. What is the value of resistance of each of these wires?

Q5. A wire of resistance 8 *R* is bent in the form of a circle as shown in Fig (a). What is the effective resistance between the ends of the diameter *AB*?



(a)

Q6. Why are resistances connected in series and in parallel?

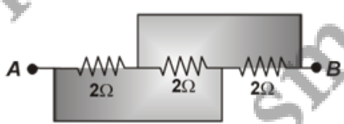
Q7. (a) Three resistors 1 Ω, 2 Ω, and 3 Ω are combined in series. What is the total resistance of the combination?

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

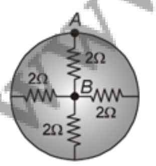
Q8. (a) Three resistors 2 Ω, 4 Ω and 5 Ω are combined in parallel. What is the total resistance of the combination?

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

Q9. Calculate the equivalent resistances of the circuit shown in figure below between point *A* and *B*

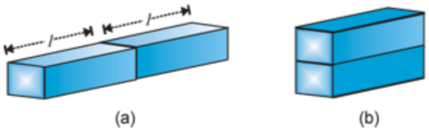


Q10. Calculate the equivalent resistance between point *A* and *B* given circuit shown in figure below.



Q11. A set of an identical resistors, each of resistance *R* Ω, when connected in series have an effective resistance of *X* Ω and when the resistors are connected parallel, *R*, *X* effective resistance is *Y* Ω. Find the relation between *R*, *X* and *Y*.

Q12. Two identical slabs of a given metal are joined together in two different ways as shown in figures (a) and (b).

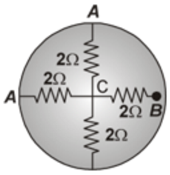


What is the ratio of the resistance of these two combinations?

Q13. Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1 : 2. They are connected (a) in series and (b) in parallel. Compare the drift velocities of electrons in the two wires in both the cases (i) and (ii).

Q14. Two resistance are in the ratio 1 : 4 If these are connected in parallel their total resistance become 20Ω find the value of each resistance:

Q15. Calculate the equivalent resistances between point *A* and *B* shown

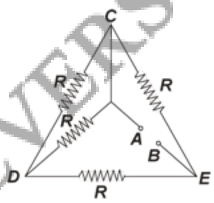


Q16. You are given *n* resistors, each of resistance *R*. These are first connected to get minimum possible resistance. In the second case, these are again connected differently to get maximum possible resistance. Compute the ratio between minimum and maximum values of resistance so obtained.

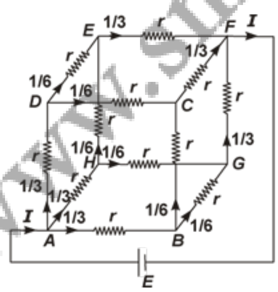
Q17. Parallel combination of three resistor is takes current 5 A form 20 V supply. If two resistors are 12 Ω & 6 Ω find the vales of third one.

Q18. (a) Calcuate the equivalent resistance of the given electrical network between points *A* and *B*.

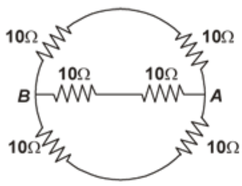
(b) Also calcuate the current through *CD* and *ACB*. if a 10 V d.c. source connected between *A* and *B*, and the value of *R* is assumed as 2 Ω.



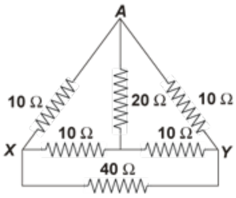
Q19. 12 wires, each of resistance *r* are connected in the form of a skeleton cube. Find the equivalent resistance of the cube, then the current enters at one corner and leaves at the diagonally opposite corner.



Q20. write the wheatstone bridge find the equivalent resistance of the network shown in figure between points *A* and *B*.



Q21. Explain wheat stone Bridge, calculate the resistance between point X and Y in the circuit shown in figure.



Date: 20/10/2021

S1. If the wire having resistance of 90 Ω is cut into three equal pieces, each piece will be resistance 90/3 *i.e.*, 30 Ω. If R_{eq} is resistance of their parallel combination, then

$$\frac{1}{R_{eq}} = \frac{1}{30}+\frac{1}{30}+\frac{1}{30}=\frac{3}{30}=\frac{1}{10}$$

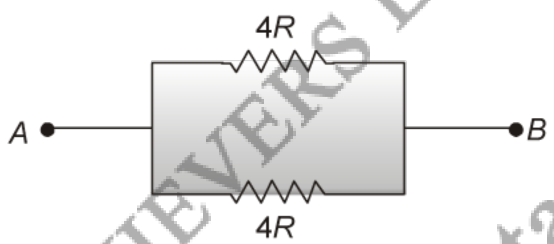
or $R_{eq} = 10\,\Omega$.

S2. In parallel combination the effective area of the resistance will be increase hence the effective resistance is low, because $R \propto {}^1/_A$.

S3. In series combination the effective length of the resistance is increase, when we calculate the effective resistance increase, because $R \propto l$.

S4. When two resistances are connected in series, the equivalent resistance is always greater than the individual resistances. On the other hand, when they are connected in parallel, the equivalent resistance is always less than either of them. Hence, of the measurements 3, 4, 12 and 16 Ω; 16 Ω represent R_s and 3 Ω represents R_p. Obviously, the resistances of the two wires are 4 Ω and 12 Ω.

S5. Given: Fig. (b)



$R_1 = 4R, \quad R_2 = 4R$

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{4R \times 4R}{8R} = \frac{16R^2}{8R} = 2R$$

$R_e = 2R$

S6. The resistances are connected in series to increase the resistance of the circuit; while they are connected in parallel, when resistance of the circuit is to be decreased.

S7. (a) Three resistors of resistances 1 Ω, 2 Ω, and 3 Ω are combined in series. Total resistance of the combination is given by the algebraic sum of individual resistances.

Total resistance = 1 + 2 + 3 = 6 Ω

Current flowing through the circuit = I

Emf of the battery, E = 12 V

Total resistance of the circuit, R = 6 Ω

The relation for current using Ohm's law is,

$$I = \frac{E}{R} = \frac{12}{6} = 2\text{A}$$

Potential drop across 1 Ω resistor = V_1

From Ohm's law, the value of V_1 can be obtained as

$$V_1 = 2 \times 1 = 2\text{V} \qquad \text{... (i)}$$

Potential drop across 2 Ω resistor = V_2

Again, from Ohm's law, the value of V_2 can be obtained as

$$V_2 = 2 \times 2 = 4\text{V} \qquad \text{... (ii)}$$

Potential drop across 3 Ω resistor = V_3

Again, from Ohm's law, the value of V_3 can be obtained as

$$V_3 = 2 \times 3 = 6\text{V} \qquad \text{... (iii)}$$

Therefore, the potential drop across 1 Ω, 2 Ω, and 3 Ω resistors are 2 V, 4 V, and 6 V respectively.

S8. (a) There are three resistors of resistances,

$$R_1 = 2\,\Omega, \quad R_2 = 4\,\Omega \quad \text{and} \quad R_3 = 5\,\Omega$$

They are connected in parallel. Hence, total resistance (R) of the combination is given by,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

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

$$\therefore \qquad R = \frac{20}{19}\,\Omega$$

Therefore, total resistance of the combination is $\frac{20}{19}\,\Omega$.

E.m.f. of the battery, V = 20 V

Current (I_1) flowing through resistor R_1 is given by,

$$I_1 = \frac{V}{R_1} = \frac{20}{2} = 10\,\text{A}$$

Current (I_2) flowing through resistor R_2 is given by,

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

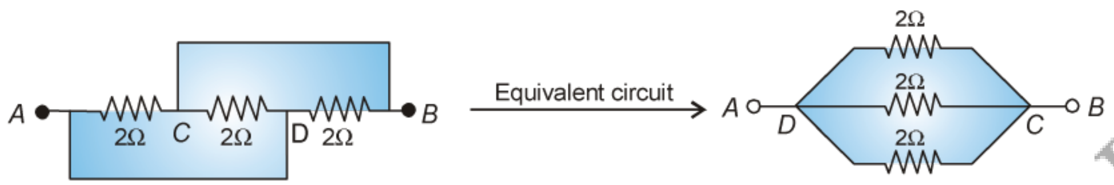
Current (I_3) flowing through resistor R_3 is given by,

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

Total current, $I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19\,A$

Therefore, the current through each resister is 10 A, 5 A, and 4 A respectively and the total current is 19 A.

S9.



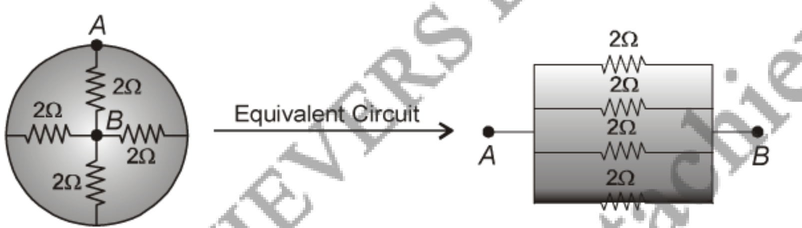
1st the equivalent resistances of circuit is R_{eq} from equivalent circuit all resistances are parallel.

$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$$

or $$\frac{1}{R_{eq}} = \frac{3}{2}$$

$$R_{eq} = \frac{2}{3}\,\Omega$$

S10.



Let equivalent resistance R_{eq} therefore the effective resistances

$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$$

$$= \frac{4}{2} = 2$$

$$\frac{1}{R_{eq}} = 2$$

$$\boldsymbol{R_{eq}} = \frac{1}{2}\,\Omega$$

S11. When n resistors, each of resistance, R are connected in series, then

$$X = nR \qquad \text{... (i)}$$

When n resistors, each of resistance R are connected in parallel, then

$$Y = \frac{R}{n} \qquad \text{... (ii)}$$

Multiplying the Eqns. (i) and (ii), we gate

$$XY = nR \times \frac{R}{n} = R^2$$

or $$R = \sqrt{\boldsymbol{XY}}.$$

S12. Let R be the resistance of the each slab.

According to figure (a), the length of the combination becomes double as that of a single slab without affecting its area becomes double as that of a single slab without affecting its area of cross-section. Thus, it is series combination of the two slabs.

If R_s is the resistance of the combination, then

$$R_s = R + R = 2R$$

According to figure (b), the area of cross-section of the combination becomes double as that a single slab without affecting its length. Thus, it is parallel combination of the two slabs.

If R_p is the resistance of the combination, then

$$R_p = \frac{R \times R}{R \times R} = \frac{R}{2}$$

Now, $$\frac{R_s}{R_p} = \frac{2R}{R/2} = \mathbf{4}.$$

S13. Let v_d and v'_d be the drift velocities of electrons in the two wires. Further, let A and A' be the cross-sectional areas of the two wires. Let common factor of area A is

Now, $$A' = 2\text{A}$$

(a) When the two wires are connected in series, the same amount of current flows through them *i.e.*,

$$nAv_d e = n\text{A}'v'_d e$$

Here, n is number of free electrons per unit volume in the wires and e is charge on the electron.

$$\therefore \qquad \frac{v_d}{v'_d} = \frac{neA'}{neA} = \frac{2\,(neA)}{(neA)} = 2$$

(b) When the two wires are connected in parallel, the potential difference across the two wires is same. If l is length and ρ, the resistivity of the material of the two wires, then

$$nAv_d e\rho\frac{l}{A} = nA'v'_d e\rho\frac{l}{A'} \quad \text{or} \quad \frac{v_d}{v'_d} = \frac{(ne\rho l)}{(ne\rho l)}$$

$$\frac{v_d}{v'_d} = 1.$$

S14. Let common factor of the resistance ration R. Now resistance $R_1 = R$ and resistance $R_2 = 4R$ equivalent resistance is $R_{eq} = 20$.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{20} = \frac{1}{R} + \frac{1}{4R}$$

or $$\frac{1}{20} = \frac{5}{4R}$$

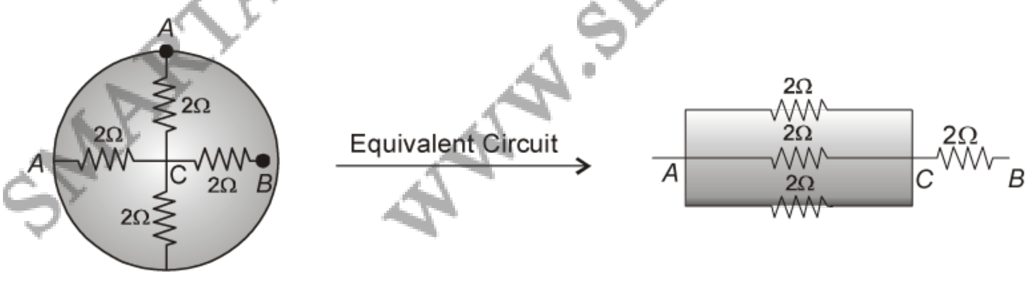
$$R = \frac{5 \times 20}{4} = 5 \times 5 = 25\Omega$$

$R_1 = R \Rightarrow \boldsymbol{R_1 = 25\ \Omega}$

$R_2 = 4 \times R = 4 \times 25$

$\boldsymbol{R_2 = 100\,\Omega}$

S15.



Let the equivalent resistance of the circuit R_{eq}

Equivalent resistances between A and C

$$\frac{1}{R_{AC}} = \frac{1}{2}+\frac{1}{2}+\frac{1}{2}=3/2$$

$$R_{AC} = 2/3$$

$$R_{eq} = R_{AC} + R_{CB}$$

$$= 2/3+2$$

$$R_{eq} = 8/3\,\Omega$$

S16. The resistance will be maximum, when resistors are connected in series. Therefore, maximum resistance,

$$R_{max} = R + R + R + \dots n \text{ times} = nR$$

The resistance will be minimum, when resistors are connected in parallel. Therefore, minimum resistance,

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

or $R_{min} = R/n$

Now, $\dfrac{R_{max}}{R_{min}} = \dfrac{nR}{R/n} = \boldsymbol{n^2}$.

S17. Given: $E = 20\,\text{V} \quad I = 5\,\text{A}$

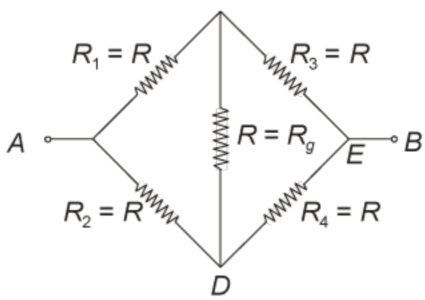
$$R_{eq} = \frac{E}{I} = \frac{20}{5} = 4\,\Omega$$

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{12} + \frac{1}{6}$$

$$\frac{1}{4} = \frac{1}{R} + \frac{1}{12} + \frac{1}{6}$$

$$\boldsymbol{R = 0\,\Omega}$$

S18. (a) Given circuit can be drawn as

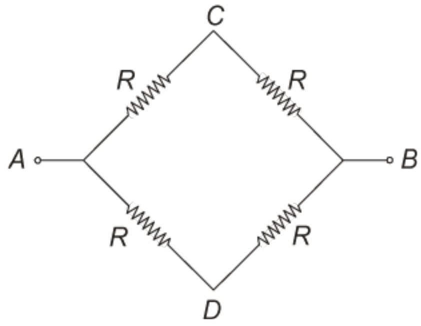


As $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

Circuit is balanced wheatstone bridge.

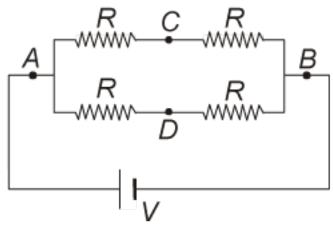
$$V_C = V_D \text{ and } I_{CD} = 0$$

Equivalent circuit is



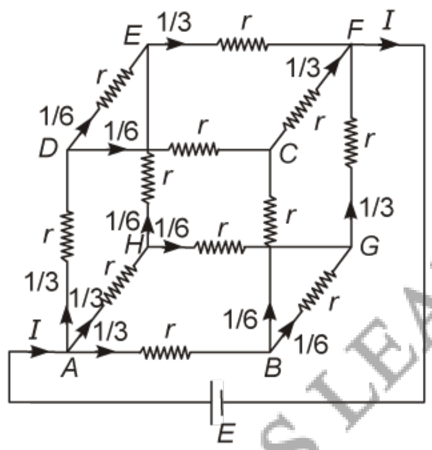
Thus $$R_{AB} = \frac{(2R)(2R)}{4R} = R\Omega$$

(b) Being a balanced wheatstone bridge



$$I_{CD} = 0$$
$$V = 10$$
$$R = 2\Omega$$
$$V_{AB} = 10 \text{ volt}$$
$$R_{ACB} = 4\Omega$$
$$I_{ACB} = \frac{10}{4} = 2.5\,A$$

S19. Consider a skeleton cube *ABCDEFGH* made of 12 wires as shown in figure below:



In order to find its resistance, connect a battery of e.m.f. *E* across the diagonal corners *A* and *F* as shown in the above figure.

Suppose that the current I enters the skeleton cube at the corner *A* and leaves at the diagonally opposite corner *F*. The current I will divide in three equal parts each equal to $I/3$ along the wires *AB*, *AD* and *AH*.

The currents in *AB*, *AD* and *AH* will further divide along different wires as explained below:

(a) The part $I/3$ flowing along the wire *AB* will divide in two equal parts ($I/6$ each) along *BC* and *BG*.

(b) Similarly, the part $I/3$ flowing along the wire *AD* will divide in two equal parts ($I/6$ each) along *DC* and *DE*.

(c) Similarly, the part $I/3$ flowing along the wire *AH* will divide in two equal parts along *HE* and *HG*.

From the symmetry considerations, it follows that wires *CF*, *EF* and *GF*, so that a net current equal to I may leave the skeleton cube at the corner *F*.

Applying Kirchhoff's second law to the **closed part *ABGFA* of the circuit**:

$E = P.D.$ across AB + $P.D.$ across BG + $P.D.$ across GF

$$E = \frac{I}{3}r + \frac{I}{6}r + \frac{I}{3}r = \frac{5I}{6}r \quad \text{... (i)}$$

If R is effective resistance of the skeleton cube, then

$$E = IR \quad \text{... (ii)}$$

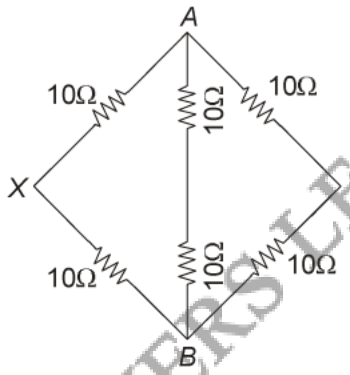
From the equations (i) and (ii), we have

$$IR = \frac{5I}{6}r \quad \text{or} \quad \mathbf{R} = \frac{\mathbf{5}}{\mathbf{6}}\boldsymbol{r}.$$

S20. A wheatstone bridge is an arrangement of four resistances used for measuring one of them in terms of other. The condition for the bridge to be balanced is

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

The given circuit may be arranged shown in the figure.



Let R_1 is the resistance between A and B

$$R_1 = 10+10 = 20\ \Omega$$

R_2 is the resistance between A and B

$$R_2 = 10 + 10 = 20\ \Omega$$

Equivalent resistance between A and B is R_{AB}

$$\frac{1}{R_{AB}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{AB}} = \frac{1}{20} + \frac{1}{20}$$

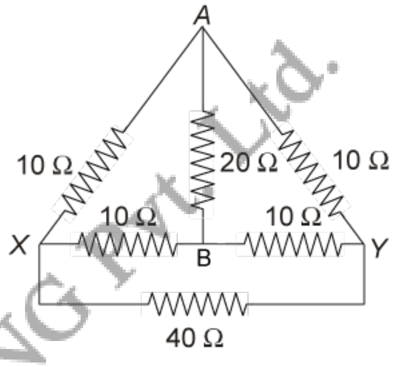
$$\frac{1}{R_{AB}} = \frac{2}{20} = \frac{1}{10}$$

$$R_{AB} = 10\ \Omega$$

S21. A wheatstone bridge is an arrangement of four resistances used for measuring one of them in terms of other. The condition for the bridge to be balanced is

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

The part *AXBYA* of the given circuit is an arrangement of balanced wheatstone bridge and therefore resistance in the branch *AB* may be treated as an open path.



Resistance of the branch *XAY*,

$$R_1 = 10 + 10 = 20\Omega$$

Resistance of the branch *XBY*,

$$R_2 = 10 + 10 = 20\ \Omega$$

Therefore, effective resistance between the points *X* and *Y* is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{40} = \frac{1}{20} + \frac{1}{20} + \frac{1}{40} = \frac{5}{40}$$

$$R = 8\ \Omega$$

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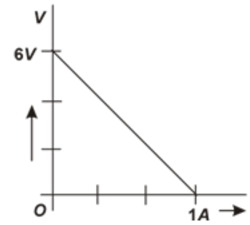
Q1. **In what respect, does a nearly discharged lead acid secondary cell differ mainly from a freshly charged cell in its e.m.f. or in its internal resistance?**

Q2. **Two conducting wires *X* and *Y* of same diameter but different materials are joined in series across a battery. If the number density of electrons in *X* is twice that in *Y*, find the ratio of drift velocity of electrons in the two wires.**

Q3. **A car battery is of 12 V. Eight dry cells of 1.5 V connected in series can give 12 V. But such cells are not used in starting a car. Why?**

Q4. **A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0.5 A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?**

Q5. **The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown here. What is the e.m.f. of each cell?**



Q6. **Why a high voltage supply (H.T.) must have a very large internal resistance.**

Q7. **A cell of e.m.f. *E* and internal resistance *r* is connected across an external resistance *R*. Plot a graph showing the variation of potential difference, across *R* verses *V*.**

Q8. **A high tension (HT) supply of, say, 6 kV must have a very large internal resistance. Why?**

Q9. **On what factors does the internal resistance of a cell depend?**

Q10. **Under what conditions will the terminal potential difference of a cell be greater than its e.m.f.?**

Q11. **A cell of e.m.f. 1.5 V and internal resistance 0.1 Ω is connected to a 3.9 Ω external resistance. What will be the potential difference across the terminals of the cell?**

Q12. **A resistance *R* is connected across a cell of e.m.f. *E* and internal resistance *r*. A potentiometer now measures the potential difference between the terminals of the cell as *V*. Write the expression for in terms of *E*, *V* and *R*.**

Q13. **A simple voltaic cell has an e.m.f. equal to 1.5 V. When the circuit is open, is there a net field which would give rise to a force on a test charge. Inside the electrolyte of the cell.**

Q14. **Why a low voltage supply, from which one needs high currents, must have very low resistance.**

Q15. **Two electric bulbs *M* and *N* are marked 220 V – 100 W and 220 V – 40 W. Out of the two which bulb has higher resistance?**

Q16. Define electromotive force (e.m.f.) of a cell?

Q17. Two identical cells, each of emf E, having negligible internal resistance, are connected in parallel with each other across an external resistance R. What is the current through this resistance?

Q18. n identical cells are connected in parallel. Find an expression for the current through an external resistance R.

Q19. n identical cells are connected in series. Find an expression for the current through an external resistance R.

Q20. What is the e.m.f. of a cell? On what factors does it depends?

Q21. (a) Six lead-acid type of secondary cells each of emf 2.0 V and internal resistance 0.015 Ω are joined in series to provide a supply to a resistance of 8.5 Ω. What are the current drawn from the supply and its terminal voltage?

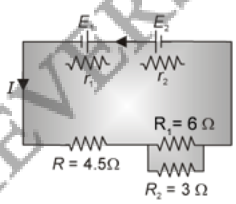
(b) A secondary cell after long use has an emf of 1.9 V and a large internal resistance of 380 Ω. What maximum current can be drawn from the cell? Could the cell drive the starting motor of a car?

Q22. Plot a graph showing the variation of terminal potential difference across a cell of e.m.f. E and internal resistance r with current drawn from it. Using this graph, how does one determine the e.m.f. of the cell?

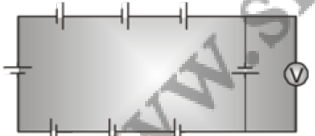
Q23. A battery of e.m.f. E and internal resistance r is connected to a variable external resistance R. Find the value of R so that (a) current in the circuit is maximum and (b) terminal potential across the battery is maximum.

Also, find the maximum value of current in case (a) and maximum terminal potential difference in case (b).

Q24. Two cells E_1 and E_2 in the circuit shown in figure below, have e.m.f. of 5 V and 9 V and internal resistance of 0.3 Ω and 1.2 Ω respectively. Calculate the value of current through the resistance of 3 Ω.



Q25. In the circuit shown in figure, each battery is of 5 V and has an internal resistance of 0.2 Ω. What will be the reading of an ideal voltmeter connected across a battery?



Q26. Four identical cells, each of e.m.f. 2 V, are joined in parallel providing supply of current to external circuit consisting of two 15 Ω resistors joined in parallel. The terminal voltage of the cells as read by an ideal voltmeter is 1.6 V. Calculate the internal resistance of each cell.

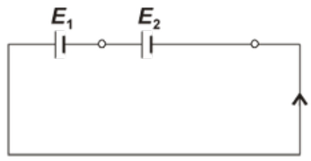
Q27. A number of identical cells in each of e.m.f. E, internal resistance r connected in series are charged by a d.c. source of e.m.f. E, using a resister R

(a) Draw the circuit diagram

(b) Deduce the expression for the charging current

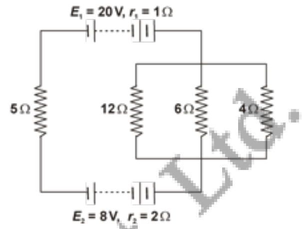
(c) Deduce the expression for the potential difference across the combination.

Q28. The circuit in figure shows cells connected in opposite to each other. Cell E_1 is of e.m.f. 6V and internal resistance 2Ω, the cell E_2 is of e.m.f. 4 V and internal resistance 8 Ω. Find the potential difference between the points A and B.



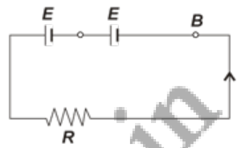
Q29. A 20 V battery of internal resistance 1 Ω is connected to three coils of 12 Ω, 6 Ω and 4 Ω in parallel, a resistor of 5 Ω and a reversed battery (e.m.f. 8 V and internal resistance 2 Ω) as shown in figure below.

Calculate (a) the current in the circuit, (b) current in resistor of 12 Ω coil and (c) potential difference across each battery.

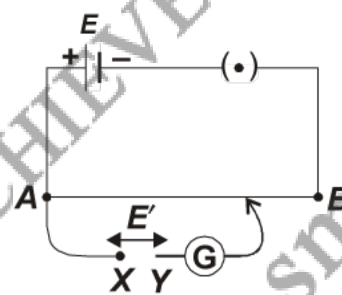


Q30. Three identical cells each of e.m.f 4 V and internal resistance r are connected in series to a 6 Ω resistor. If the current flowing in the circuit is 1.5 A, Calculate (a) internal resistance of each cell and (b) the internal voltage across the cells.

Q31. Two cells of same emf E but internal resistance r_1 and r_2 are connected in series to an external resistor R. What should be the value of R so that the potential difference across the terminals of the first cell becomes zero?



Q32. Define internal resistance and e.m.f. of a cell for the potentiometer circuit shown in the given figure, points X and Y represent the two terminals of an unknown emf E'. A student observed that when the jockey is moved from the end A to the end B of the potentiometer wire, the defection in the galvanometer remains in the same directions.



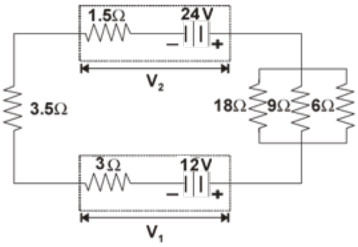
What may be the two possible faults in the circuit that could result in this observation?

If the galvanometer deflection at the end B is (a) more (b) less, than that at the end A, which of the two faults, listed above, would be there in the circuit?

Given reasons in support of your answer in each case

Q33. What is e.m.f. of a cell? Write its units, state the factor on which its value depends. Derive a relation between e.m.f. E, contact potential V, internal resistance r and external resistance R. Prove that e.m.f. is more than potential.

Q34. Define the terminal potential difference. A 24 V battery of internal resistance 1.5 Ω is connected to three coils 18 Ω, 9 Ω and 6 Ω in parallel, a resistor of 3.5 Ω and a reversed battery (e.m.f. = 12 V and internal resistance = 3Ω) as shown. Calculate (a) the current in the circuit, (b) current in resistor of 18 Ω coil, and (c) p.d. across each battery.



Date: 20/10/2021

S1. It mainly differs in internal resistance. A nearly discharged lead acid secondary cell possesses a very high internal resistance in addition to a lower value of e.m.f.

S2. The drift velocity of electrons in a conductor,

$$v_d = \frac{1}{neA}$$

Since the two conductors are joined in series across a battery, the same current will pass through them. Also, as the two wires are of same diameters, their areas of cross-section will also be the same. If n_X and n_Y are the numbers of free electrons per unit volume in the two conductors, then $n_X = 2n_Y$

$$\frac{(v_d)_X}{(v_d)_Y} = \frac{I}{n_X eA} \times \frac{n_Y eA}{I} = \frac{n_Y}{n_X} = \frac{n_Y}{2n_Y} = \frac{1}{2}$$

S3. To start a car, a very high current is required. A car battery can provide the required high current du to very low value of its internal resistance. When eight dry cells are joined in series, the internal resistance of the combination of the cells becomes very high. Due to high value of internal resistance, the current that can be drawn from the cells is very small. Hence, such cells cannot be used to start a car.

S4. Emf of the battery, $E = 10\,\text{V}$

Internal resistance of the battery, $r = 3\,\Omega$

Current in the circuit, $I = 0.5\,\text{A}$

Resistance of the resistor = R

The relation for current using Ohm's law is,

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

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

$$= \frac{10}{0.5} = 20\,\Omega$$

$$\therefore \quad R = 20 - 3 = 17\,\Omega$$

Terminal voltage of the resistor = V

According to Ohm's law,

$$V = IR$$
$$= 0.5 \times 17$$
$$= 8.5\text{ V}$$

Therefore, the resistance of the resistor is 17 Ω and the 8.5 V.

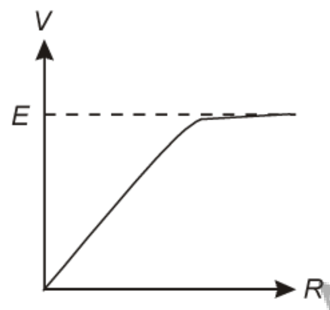
S5. 2 volts

If $I = 0, \quad E = V$

Therefore, e.m.f. of each cell = $\frac{\cancel{6}}{\cancel{3}} = 2$ volts.

S6. If the circuit containing the H.T. supply gets short circuited accidentally, the current in the circuit will not exceed the safe limit, in case the internal resistance of H.T. supply is very large.

S7.



S8. In order to prohibit the current from exceeding the safety limit, a high tension supply must have a very large internal resistance. If the internal resistance is not large, then the current drawn can exceed the safety limits in case of a short circuit.

S9. The internal resistance of a cell depends of the different factors:

(a) The distance between electrodes

(b) The area of electrodes inside the electrolyte.

(c) The nature of electrodes

(d) The nature of electrolyte

S10. As $V = E - Ir$ *i.e.*, when current is drawn from cell. If $I =$ positive; *i.e.*, charges are flowing in same direction, as intended, then potential difference would exceed e.m.f.

S11. Given e.m.f. of cell E = 1.5 V, internal resistance r = 0.1 Ω and R = 3.9 Ω

The terminal potential difference is

$$V = \left(\frac{E}{R+r}\right)R = \frac{1.5 \times 3.9}{3.9 + 0.1} = \mathbf{1.46\ V}.$$

S12.

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

S13. Inside the cell there is no net field, the electrostatic field due to the plates is balanced by the field of non-electrostatic origin. If this was not so, charge carriers inside the cell would constitute a current even when the circuit is open.

S14. We know,

$$I_{\max} = \frac{E}{r}$$

Hence, $I_{\max}$ will be large, if r is small.

S15. We know

Power $\qquad P = \frac{V^2}{R}$

Where, $\qquad V_m = V_n = 220\,\text{V}$

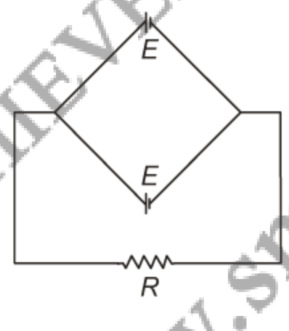
$$P \propto \frac{1}{R}$$

or $\qquad R \propto \frac{1}{P}$

Hence, 220 V – 40 W bulb has the high resistance.

S16. The potential difference between two poles of a cell, when no current is drawn from it, is called e.m.f. of the cell.

S17. The cells are arranged as shown in the circuit diagram given below

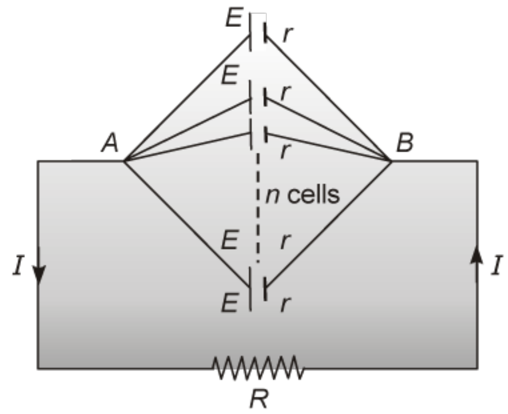


As the internal resistance is negligible, so total resistance of the circuit = R

So, current through the resistance, $I = \frac{E}{R}$.

(In parallel combination, potential is same as the single cell)

S18. Shown in figure below, a combination of n cells each of e.m.f. E and internal resistance r connected in parallel so as to send a current I through an external resistance R. In parallel connection, positive terminals of all the cells are connected together at one point (A in the figure) and their negative terminals at another point (B in the figure).



Total internal resistance r_p is given by

$$\frac{1}{r_p} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \ldots \text{ up to } n \text{ terms}$$

$$= \frac{n}{r}$$

or $$r_p = \frac{r}{n}$$

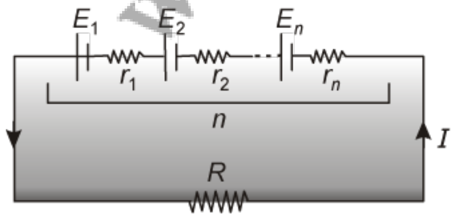
$\therefore$ Total resistance in the circuit = $R + \frac{r}{n}$

In parallel combination, the effective e.m.f. in the circuit is equal to the e.m.f. due to a single cell.

$\therefore$ Current through R is given by

$$I = \frac{E}{R + \frac{r}{n}} = \frac{nE}{nR + r}.$$

S19. Shown in figure below, a combination of n cells each of e.m.f. E and internal resistance r connected in series so as to send current through an external resistance R.



When the cells are connected in series, the effective e.m.f. of the combination is equals to the sum of the e.m.f. s of the individual cells. Thus, effective e.m.f. of the combination = nE.

When cells are connected in series, the internal resistances of the cells are added up. Thus, total internal resistance of the cells = nr.

Therefore, total resistance of the circuit = $R + nr$.

∴ Current through R is given by

$$I = \frac{nE}{R + nr}.$$

S20. E.m.f. (electromotive force) of a cell is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell or cell is in the open circuit. It is not a force but is maximum work done per unit charge in taking a test charge from one point to another.

The e.m.f. of a cell depends on the following factors:

(a) Nature of electrodes.

(b) Nature and concentration of electrolyte used in the cell.

(c) Temperature of the cell.

S21. Number of secondary cells, $n = 6$

E.m.f. of each secondary cell, $E = 2.0\,V$

Internal resistance of each cell, $r = 0.015\,\Omega$

Series resistor is connected to the combination of cells.

Resistance of the resistor, $R = 8.5\,\Omega$

(a) Current drawn from the supply = I, which is given by the relation,

$$I = \frac{nE}{R + nr}$$

$$= \frac{6 \times 2}{8.5 + 6 \times 0.015}$$

$$= \frac{12}{8.59} = 1.39\,A$$

Terminal voltage, $V = IR = 1.39 \times 8.5 = 11.87\,A$

Therefore, the current drawn from the supply is 1.39 A and terminal voltage is 11.87 A.

(b) After a long use, emf of the secondary cell,

$$E = 1.9\,\text{V}$$

Internal resistance of the cell, $r = 380\,\Omega$

Hence, Maximum current = $\frac{E}{r} = \frac{1.9}{380} = 0.005\ A$

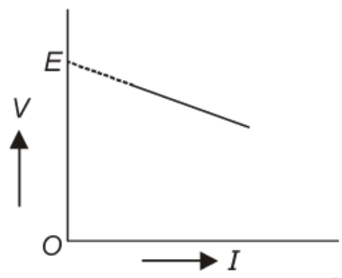
Therefore, the maximum current drawn from the cell is 0.005 A. Since a large current is required to start the motor of a car, the cell cannot be used to start a motor.

S22. The terminal potential difference across a cell,

$$V = E - Ir$$

or $$V = -rI + E$$

Comparing the above relation with the equation of a straight line *i.e.* $y = mx + c$, it follows that graph between I (along X-axis) and V (along Y-axis) will be a straight line having slope equal to $-r$ and making intercept equal to E on V-axis.



Therefore, as shown in figure, the intercept, which the graph makes on V-axis, gives the value of the e.m.f. of the cell.

S23. (a) The current in the circuit,

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

It follows that current in the circuit will be maximum, when $R + r$ is minimum *i.e.*, **R = 0**.

The maximum value of current,

$$I_{max} = \frac{E}{R+r} = \frac{\boldsymbol{E}}{\boldsymbol{r}}$$

(b) The terminal potential difference across the battery,

$$V = E - Ir = E - \frac{Er}{R+r}$$

It follows that the terminal potential across the battery will be maximum, when $Er/(R + r)$ is minimum i.e. $R = \infty$.

The maximum value of terminal potential difference,

$$V_{max} = E - \frac{Er}{\infty + r} = E - 0 = \boldsymbol{E}$$

S24. Let R' be the resistance of the parallel combination of R_1 and R_2. Then,

$$R' = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6 \times 3}{6 + 3} = 2\Omega$$

Since the two cells oppose each other, the net e.m.f. of the circuit,

$$E = E_2 - E_1 = 9 - 5 = 4\,\text{V}$$

The current through the main circuit is given by

$$I = \frac{E}{R + R' + r_1 + r_2}$$

$$= \frac{4}{4.5 + 2 + 0.3 + 1.2} = 0.5A$$

Hence, the current through the 3Ω resistance

$$= I \times \frac{R_1}{R_1 + R_2} = 0.5 \times \frac{6}{6 + 3} = \mathbf{0.33A}\,.$$

S25. Given, e.m.f. of each battery, E = 5V and internal resistance of each battery, r = 0.2 Ω

Let I be the current in the circuit. Then,

$$I = \frac{\text{total e.m.f. of all the eight batteries}}{\text{total internal resistance of all the batteries}}$$

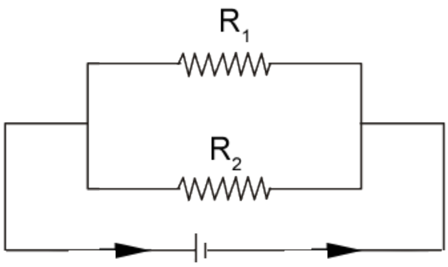
$$= \frac{8 \times 5}{8 \times 0.2} = 25\,\text{A}$$

Now, the reading of the voltmeter,

$$V = E - Ir = 5 - 25 \times 0.2 = 5 - 5 = \mathbf{0\ volt}.$$

Hence, no deflection in voltmeter.

S26. The four cells are connected in parallel to the parallel combination of two 15 Ω resistors as shown in figure below



Let r be the internal resistance of each cell and I, the current in the circuit. Since the cells are connected in parallel, total e.m.f. in the circuit = e.m.f. of one cell = 2 V.

Further, total internal resistance of the cells is given by

$$\frac{1}{r'} = \frac{1}{r}+\frac{1}{r}+\frac{1}{r}+\frac{1}{r}=\frac{4}{r}$$

or $\qquad r' = r/4.$

Let R be the resistance of the parallel combination of two 15 Ω resistors. Then, the total external resistance,

$$R = \frac{15\times 15}{15+15} = \mathbf{7.5\ \Omega}.$$

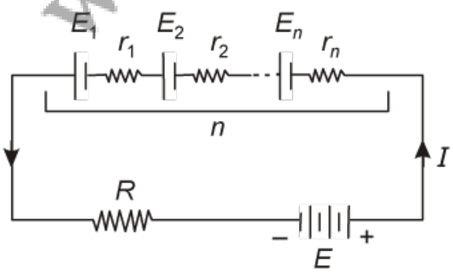
Also, the internal resistance of the parallel combination of the cells is given by

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

or $$\frac{r}{4} = \left(\frac{2}{1.6}-1\right)\times 7.5$$

or $\qquad r = \mathbf{7.5\,\Omega}.$

S27. (a)



(b) From the circuit arrangement the net resistance of the circuit is

$$R_{eq} = R + r_1 + r_2 + ... + r_n$$

$$R_{eq} = R + nr \quad \text{where} \quad r_1 = r_2 = r_3 = ... = r_n = r$$

The total e.m.f. of the cell is

$$E_t = E_1 + E_2 + ... + E_n$$

$$= nE \quad \text{where} \quad E_1 = E_2 = E_3 = ... = E_n = E$$

effective e.m.f. of the circuit is

$$\text{effective e.m.f.} = E' - nE$$

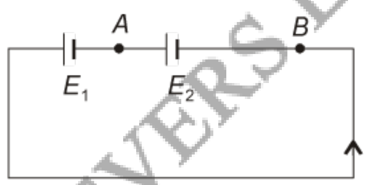
Charging current $\quad I = \dfrac{E' - nE}{R + nr}$

(c) The potential difference across the combination of cells

$$V = nE - I(nr) \quad \text{\{by Kirchhoff's second law\}}$$

$$V = \boldsymbol{n(E - Ir)}.$$

S28. $I = \dfrac{6-4}{2+8} = 0.2\,A$



P.D. across $E_1 = 6 - (0.2)\,2 = 5.6$ V

P.D. across $E_2 = V_{AB} = 4 + (0.2)\,8 = 5.6$ V

Point B is at a higher potential than A.

S29. Given, $E_1 = 20\,\text{V}$; $r_1 = 1\,\Omega$; $E_2 = 8\,\text{V}$ and $r_2 = 2\,\Omega$

(a) Let I be the current in the circuit.

$$E = E_1 - E_2 = 20 - 8 = 12\,\text{V}$$

Let R' be the resistance of the parallel combination of the coils of resistances $12\,\Omega$, $6\,\Omega$ and $4\,\Omega$. Then,

$$\frac{1}{R'} = \frac{1}{12} + \frac{1}{6} + \frac{1}{4} = \frac{1}{2} \quad \text{or} \quad R' = 2\,\Omega.$$

Therefore, total resistance of the circuit,

$$R = R' + r_1 + r_2 + 5 = 2 + 1 + 2 + 5 = 10\,\Omega$$

Hence, the current in the circuit,

$$I = \frac{E}{R} = \frac{12}{10} = \mathbf{1.2\,A}.$$

(b) Let the currents through $12\,\Omega$, $6\,\Omega$ and $4\,\Omega$ resistances be I_1, I_2 and I_3 respectively.

Then, $I_1 + I_2 + I_3 = 1.2$ ... (i)

Also, $I_1 \times 12 = I_2 \times 6 = I_3 \times 4$ ... (ii)

From the equation (ii), we have

$$I_2 = 2I_1 \quad \text{and} \quad I_3 = 3I_1$$

Therefore, the Eqn. (i) becomes

$$I_1 + 2I_1 + 3I_1 = 1.2 \quad \text{and} \quad I_1 = \mathbf{0.2\,A}$$

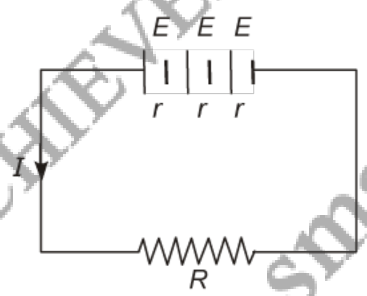
(c) The terminal potential difference across 20 V battery,

$$V_1 = E_1 - Ir_1 = 20 - 1.2 \times 1 = \mathbf{18.8\,V}.$$

Since the potential drop across internal resistance of 8 V battery aids its e.m.f., the terminal potential difference across 8 V battery,

$$V_2 = E_2 + Ir_2 = 10 + 1.2 \times 2 = \mathbf{10.4\,V}.$$

S30. The three cells are connected in series to the external resistance R as shown in figure below



(a) Given, $E = 4\,V$; $I = 1.5\,A$ and $R = 6\,\Omega$

The total e.m.f in the circuit, $E' = 3E = 3 \times 4 = 12\,V$

Total resistance of the circuit, $R' = R + 3r = 6 + 3r$

Therefore, the current in the circuit,

$$I = \frac{E'}{R'} \quad \text{or} \quad 1.5 = \frac{12}{6+3r}$$

or $$r = \frac{2}{3}\,\Omega.$$

(b) The terminal voltage across each cell,

$$V = E - Ir = 4 - 1.5 \times \frac{2}{3} = \mathbf{3\,V}.$$

S31.

$$I = \frac{E + E}{R + r_1 + r_2}$$

$$V_1 = E - Ir_1$$

$$= E - \frac{2Er_1}{r_1 + r_2 + R} = 0$$

$$E = \frac{2Er_1}{r_1 + r_2 + R}$$

$$1 = \frac{2r_1}{r_1 + r_2 + R}$$

$$r_1 + r_2 + R = 2r_1$$

$$R = r_1 - r_2$$

S32. The resistance offered by the electrolyte of the cell, when the electric current flows through it, is known as internal resistance of the cell. It is denoted by r.

The potential difference between the two poles of the cell in an open circuit (when no current is drawn from the cell) is called the electromotive force. (*e.m.f.*) of the cell.

(a) Two possible faults are

(i) *e.m.f.* (E) applied across AB is less than the unknown e.m.f. E'

(ii) –ve terminal is joined with end A of the wire.

(b) The galvanometer deflection at the end B is more, means source of unknown *e.m.f.* have been joined with its –*ve* terminal to end A. Current gets divided at point A and combines at point B. The galvanometer deflection at the end B is less than at the end A, means the e.m.f applied is less than the unknown e.m.f. used. Current get combined at end A and divided at end B.

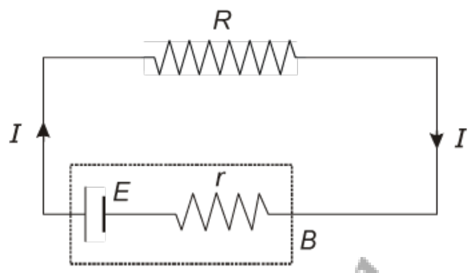
S33. The potential difference between the two poles of the cell in an open circuit (when no current is drawn from the cell) is called the electromotive force. (*e.m.f.*) of the cell.

SI unit e.m.f. is Bold, consider a cell of e.m.f. E and internal resistance r connected to external resistance R, as shown in figure. When a current I flows through the circuit, the cell does work to transfer charges from A to B.

From Ohm's law, voltage drop V' across internal resistance is given by

$$V' = Ir$$

Voltage drop across resistance R,



$$V = IR$$

$$E = V + V'$$

$$= IR + Ir = I(R + r)$$

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

The terminal potential difference

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

It is clear from the above expression that $E > V$.

S34. The potential difference between the two poles of a cell in a closed circuit (when current is drawn from the cell) is called the terminal potential difference of the cell.

Net external resistance $R_{ex} = (3 + 3.5)\ \Omega = 6.5\ \Omega$

Net internal resistance of cells = 1.5 + 3.0 = 4.5 Ω

Total resistance of circuit R = 11.0 Ω

Net e.m.f. of circuit, E = 24 – 12 = 12 volt

(a) Current in circuit, $I = \frac{12}{11} A$

(b) Current in resistor of 18 Ω coil

$$I_1 = \frac{36}{11 \times 18} = \frac{2}{11} A$$

(c) Potential drop across battery of e.m.f. 12 volt

$$V_1 = 12 + 3 \times \frac{12}{11} = \frac{168}{11} \text{ volt}$$

Date: 20/10/2021

Q1. Give the name of two practical applications of Wheatstone bridge

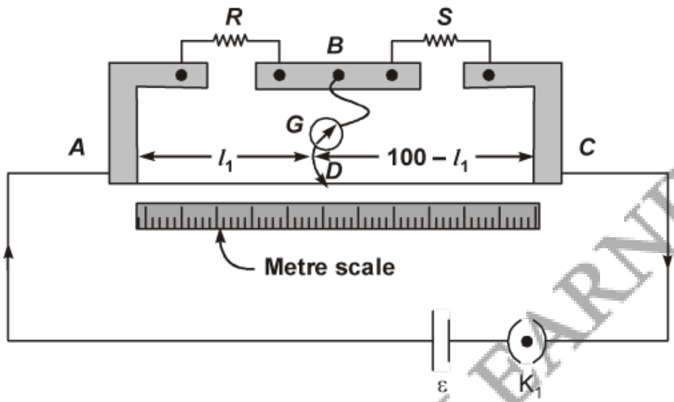
Q2. State the basic concept on which Kirchhoff's first law is based?

Q3. Sketch the circuit diagram of a Wheatstone bridge.

O4. What is the Kirchhoff's second law?

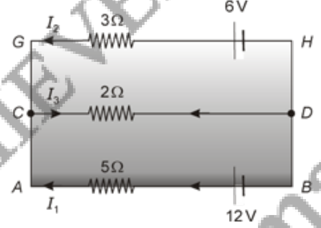
Q5. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38Ω as shown in the figure. Find the value of the current in circuit.

Q6. In a metre bridge (see figure), the null point is found at a distance of 33.7 cm from A. If now a resistance of 12 Ω is connected in parallel with *S*, the null point occurs at 51.9 cm. Determine the values of *R* and *S*.

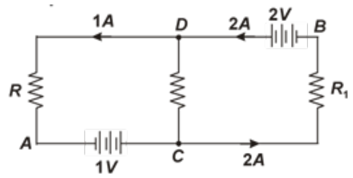


Q7. State Kirchhoff's Rules for electrical network.

Q8. Using Kirchhoff's laws in the given network shown in the figure. Calculate the values of I_1, I_2 and I_3.



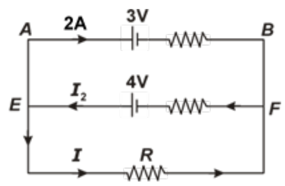
Q9. In the given circuit, assuming point *A* to be at zero potential, use Kirchhoff's rules to determine the potential at point *B*.



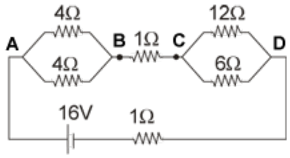
Q10. Using Kirchhoff's rules in the given circuit, determine

(a) the voltage drop across the unknown resistor *R* and

(b) the current *I* in the arm *EF*.



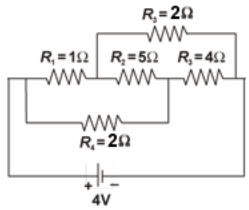
Q11. A network of resistors is connected to a 16 V battery of internal resistance of 1Ω as shown in the figure.



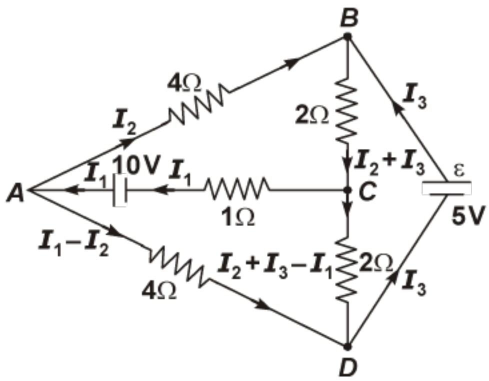
(a) Compute the equivalent resistance of the network.

(b) Obtain the voltage drops V_{AB} and V_{CD}.

Q12. Calculate the current drawn from the battery in the given network.



Q13. Determine the current in each branch of the network shown in figure.



Q14. Using Kirchhoff's rules determine the value of the current I_1 in the electric circuit given below.

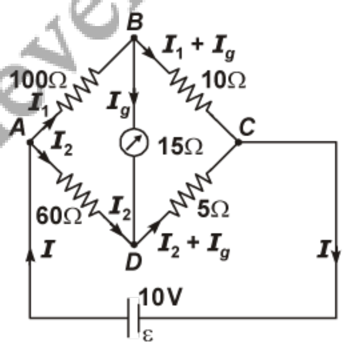
Q15. State Kirchhoff's rules. Use Kirchhoff's rules to show that no current flows in the given circuit. When any one of the cells is connected with reverse polarity.

Q16. The four arms of a Wheatstone bridge (see figure) have the following resistances:

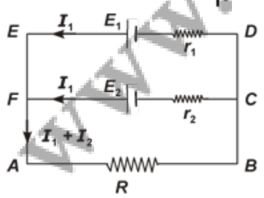
AB = 100 Ω, *BC* = 10 Ω,

CD = 5 Ω, and *DA* = 60 Ω.

A galvanometer of 15 Ω resistance is connected across *BD*. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across *AC*.

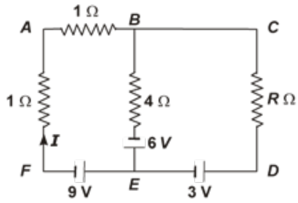


Q17. In the network shown in figure below, E_1 = 6 V, E_2 = 4 V, R_1 = 2 Ω, R_2 = 3 Ω and R_3 = 5 Ω. find the currents passing through the resistors R_1, R_2 and R_3.

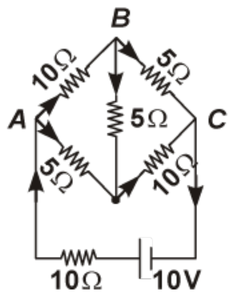


Q18. Two cells of e.m.f. 1.5 V and 2.0 V and internal resistances 1 Ω and 2 Ω respectively are connected in parallel so as to send current in the same direction through a resistance of 5 Ω. (a) Draw the circuit diagram. (b) Using Kirchhoff's laws, find current through each branch of the circuit and potential across the 5 Ω resistance.

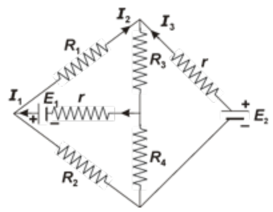
Q19. **Using the Kirchhoff's rules determine the value of unknown resistance *R* in the circuit so that no current flow through 4 Ω resistance. Also find the potential difference between *A* and *D***



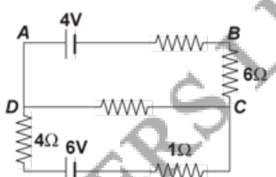
Q20. **Determine the current in each branch of the network shown in figure:**



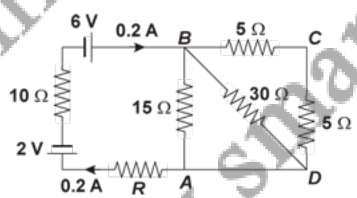
Q21. **State the two rules that serve as general rules for analysis of electrical circuits.**
Use these rules to wire the three equations that may be used to obtain the values of the three unknown currents in the branches (shown) of the circuit given below.



Q22. **State Kirchhoff's laws for an electrical network. Using Kirchhoff's laws, calculate the potential difference across the 8Ω resistor.**



Q23. **Write the Kirchhoff's laws. Calculate the value of the resistance *R* in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points *A* and *B*?**



Q24. **State Kirchhoff's laws, find the relation between the resistances of four arms of a Wheatstone bridge when the bridge is balance. Draw a circuit diagram to determine the unknown resistance of a metallic conductor using a meter bridge.**

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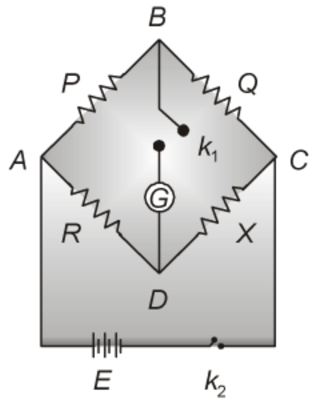
S1. (a) It can because to measure unknown temperature by measuring the resistance of a conductor at 0 °C, 100 °C and the unknown temperature

(b) It can be used to measure an unknown resistance or to compare two unknown resistances.

S2. It is based on the concept that any point in an electric circuit can neither be as source of charge can accumulate at that point.

$$I = \sum_{i=1}^{n} I_i = 0$$

S3.



S4. It states that any close conducting loop the algebraic sum of the e.m.f. is equal to the algebraic sum of the products of the resistances and current flowing through them

$$\sum E = \sum IR$$

S5. Since the positive terminal of the batteries are connected together, so the equivalent emf of the batteries is given by $E = 200 - 10 = 190$ V.

Hence, the current in the circuit is given by

$$I = \frac{E}{R} = \frac{190}{38} = 5A$$

S6. From the first balance point, we get

$$\frac{R}{S} = \frac{33.7}{66.3} \quad \text{... (i)}$$

After S is connected in parallel with a resistance of 12 Ω, the resistance across the gap changes from S to S_{eq}, where

$$S_{eq} = \frac{12S}{S+12}$$

and hence the new balance condition now gives

$$\frac{51.9}{48.1} = \frac{R}{S_{eq}} = \frac{R(S+12)}{12S} \tag{3.88}$$

Substituting the value of R/S from Eq. (i), we get

$$\frac{51.9}{48.1} = \frac{S+12}{12} \cdot \frac{33.7}{66.3}$$

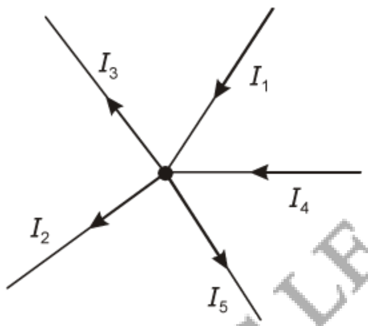
which gives $S = 13.5\,\Omega$. Using the value of R/S above, we get

$$R = 6.86\,\Omega.$$

S7. **Kirchhoff's first law or Junction rule:** The algebraic sum of the currents meeting at a point in an electric circuit is always zero. This law is based on the principle of conservation of charge.

Let us consider the circuit shown in the figure below. The current flowing towards the point O is taken as positive and current flowing away from the point O is taken as negative.

Hence, currents I_1 and I_4 flowing towards the point O are positive, while the currents I_2, I_3 and I_5 are negative.



Thus, according to Kirchhoff's first law

$$\Sigma I = 0$$

or $$I_1 + (-I_2) + (-I_3) + I_4 + (-I_5) = 0$$

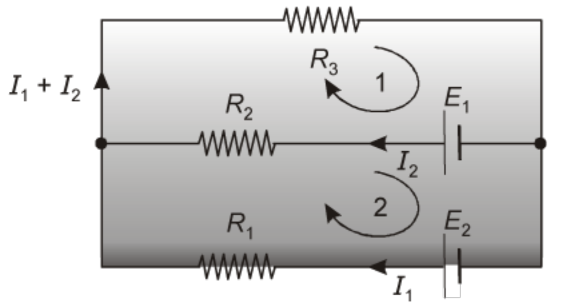
or $$I_1 - I_2 - I_3 + I_4 - I_5 = 0$$

or $$I_1 + I_4 = I_2 + I_3 + I_5$$

Incoming current = Outgoing current.

Kirchhoff's second law or loop rule: In any closed loop of an electrical circuit, the algebraic sum of the e.m.f. is equal to the algebraic sum of the products of the resistances and currents flowing through them. Thus,

$$\Sigma E = \Sigma IR$$



For the electrical circuit shown in above figure

Loop 1: $E_2 = I_2 R_2 + (I_1 + I_2) R_3$

Loop 2: $E_1 - E_2 = I_1 R_1 - I_2 R_2$.]

S8. Applying Kirchhoff's first law at the point *C*, we get

$$I_1 - I_3 + I_2 = 0$$

$$I_3 = I_1 + I_2$$

Using Kirchhoff's second law for the mesh *ABDCA*, we get

$$12 - 5I_1 - 2I_3 = 0$$

or $$12 - 5I_1 - 2(I_1 - I_2) = 0$$

or $$7I_1 - 2I_2 = 12 \quad \text{... (i)}$$

Applying second law to the mesh *ABDHGCA*, we get

$$12 - 5I_1 + 3I_2 - 6 = 0$$

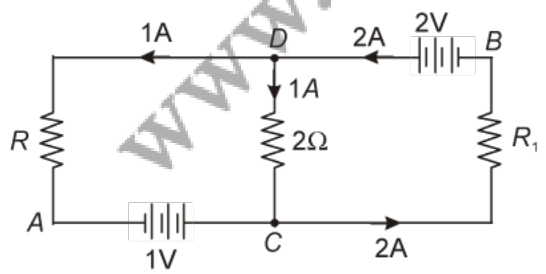
or $$5I_1 - 3I_2 = 6 \quad \text{... (ii)}$$

Solving the two equations for I_1 and I_2, we get

$$I_1 = \frac{48}{31}A \quad \text{and} \quad I_2 = \frac{18}{31}A$$

$$I_3 = \frac{48}{31} + \frac{18}{31} = \frac{66}{31}A.$$

S9.



By Kirchhoff's first law at *D*

$$I_{DC} = 1\text{A} \quad (I_{DC} + 1 = 2)$$

Along $ACDBA$,

$$V_A + 1\,\text{V} + 1 \times 2 - 2 = V_B$$

$$V_A = 0,$$

$$V_B = 1 + 2 - 2 = 1\text{V}$$

$$V_B = 1\ \text{V}$$

S10. (a) Applying Kirchhoff's second rule in the closed mesh $ABEFA$

$$V_B - 0.5 \times 2 + 3 = V_A$$

$$\Rightarrow \quad V_B - V_A = -2$$

$$V = V_A - V_B = +2\ \text{V}$$

Potential drop across R is 1 V as R, EF and upper row are in parallel.

(b) Applying Kirchhoff's first rule at E

$$0.5 + I_2 = I$$

where, I is current through R.

Now, Kirchhoff's second rule in closed mesh

$$AEFB,\ \Sigma E + \Sigma IR = 0$$

$$-4 + 2I_2 - 0.5 \times 2 + 3 = 0$$

$$2I_2 - 2 = 0$$

$$I_2 = 1\text{A}$$

The current in arm EF = 1A.

S11. (a) $\because$ 4Ω and 4Ω are in parallel combination.

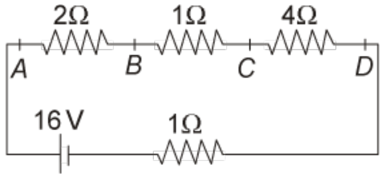
$\therefore$ Equivalent resistance $R_{AB} = \dfrac{4}{2} = 2\Omega$

Similarly, equivalent resistor of 12Ω and $6\ \Omega$ resistor

$$\frac{1}{R_{BC}} = \frac{1}{12} + \frac{1}{6} \Rightarrow \frac{1}{R_{BC}} = \frac{1+2}{12}$$

$$\Rightarrow \quad R_{BC} = 4\Omega$$

Now the circuit can be redrawn as



Now, 2Ω, 4Ω, and 1Ω, 1Ω arein series combination.

∴ Equivalent resistance of the network

$$R_{eq} = 2\Omega + 1\Omega + 4\Omega,\ 4\Omega = 8\Omega$$

(b) ∴ Current drawn from the battery

$$I = \frac{V}{R} = \frac{16}{8} = 2\,A$$

This current will flow from A to B and C to D. So, the potential difference in between AB and CD can be calculated as

Now, $V_{AB} = IR_{AB} = 2 \times 2 = 4\text{V}$ and $V_{CD} = IR_{CD} = 2 \times 4 = 8\text{V}$

S12. The given circuit can be redrawn as given below.

Wheatstone bridge is balanced. So, there will no current in the diagonal resistance R_2

Here, $$\frac{R_1}{R_5} = \frac{R_4}{R_3}$$

$$\frac{1}{2} = \frac{2}{4}$$

Wheatstone bridge is balanced. So, there will no current in the diagonal resistance R_2 or it can be withdrawn from the circuit.

The equivalent resistance would be equivalent to a parallel combination of two rows which consists of series combination of R_1 and R_5 and R_4 and R_3, respectively.

$$\frac{1}{R} = \frac{1}{1+2} + \frac{1}{2+4} = \frac{1}{3} + \frac{1}{6}$$

$$R = \frac{18}{9} = 2\Omega$$

$$I = \frac{V}{R} = \frac{4}{2} = 2\,\text{A}$$

$$I = 2\text{A}.$$

S13. Each branch of the network is assigned an unknown current to be determined by the application of Kirchhoff's rules. To reduce the number of unknowns at the outlet, the first rule of Kirchhoff is used at every junction to assign the unknown current in each branch. We then have three unknowns I_1, I_2 and I_3 which can be found by applying the second rule of Kirchhoff to three different closed loops. Kirchhoff's second rule for the closed loop *ADCA* gives,

$$10 - 4(I_1 - I_2) + 2(I_2 + I_3 - I_1) - I_1 = 0 \quad \text{... (i)}$$

that is, $7I_1 - 6I_2 - 2I_3 = 10$

For the closed loop *ABCA*, we get

$$10 - 4I_2 - 2(I_2 + I_3) - I_1 = 0$$

that is, $I_1 + 6I_2 + 2I_3 = 10$ ... (ii)

For the closed loop *BCDEB*, we get

$$5 - 2(I_2 + I_3) - 2(I_2 + I_3 - I_1) = 0$$

that is, $2I_1 - 4I_2 - 4I_3 = -5$ ... (iii)

Equations (i), (ii) and (iii) are three simultaneous equations in three unknowns. These can be solved by the usual method to give

$$I_1 = 2.5\,\text{A}, \quad I_2 = \frac{5}{8}\,\text{A}, \quad I_3 = 1\frac{7}{8}\,\text{A}$$

The currents in the various branches of the network are:

$$AB: \frac{5}{8}\,\text{A}, \quad CA: 2\frac{1}{2}\,\text{A}, \quad DEB: 1\frac{7}{8}\,\text{A}$$

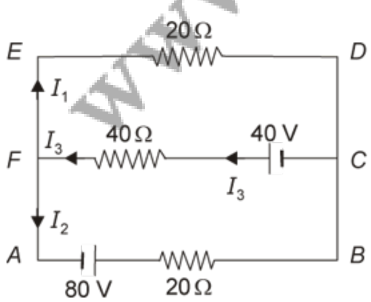
$$AD: 1\frac{7}{8}\,\text{A}, \quad CD: 0\,\text{A}, \quad BC: 2\frac{1}{2}\,\text{A}$$

It is easily verified that Kirchhoff's second rule applied to the remaining closed loops does not provide any additional independent equation, that is, the above values of currents satisfy the second rule for every closed loop of the network. For example, the total voltage drop over the closed loop *BADEB*

$$5\,\text{V} + \left(\frac{5}{8} \times 4\right)\text{V} - \left(\frac{15}{8} \times 4\right)\text{V}$$

equal to zero, as required by Kirchhoff's second rule.

S14.



According to Kirchhoff's current law at junction *F*:

$$I_3 = I_1 + I_2 \quad \text{... (i)}$$

Taking loop *CFEDC* and applying the Kirchhoff's voltage law

$$20 I_1 + 40 I_3 = 40$$

$$I_1 + 2I_3 = 2 \quad \text{... (ii)}$$

Taking loop *CFABC* and applying the Kirchhoff's voltage law

$$-40 I_3 - 20 I_2 = -40 - 80$$

$$4I_3 + 2I_2 = 12$$

$$2I_3 + I_2 = 6 \quad \text{... (iii)}$$

Substituting value of I_2 from Eq. (i) in Eq. (iii)

$$2I_3 + (I_3 - I_1) = 6$$

$$3I_3 - I_1 = 6 \quad \text{... (iv)}$$

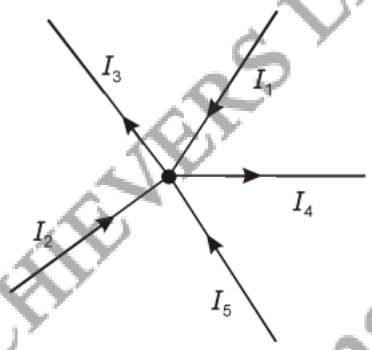
On solving Eq. (ii) and (iv), we get

$$I_1 = -1.2\,\text{A}, \quad I_3 = 1.6\,\text{A}$$

and $$I_2 = I_3 - I_1 = 1.6 + 1.2$$

$$\boldsymbol{I_2 = 2.8\,\text{A}}.$$

S15. (a) **Kirchhoff's current law:** At any junction in a circuit the algebraic sum of currents is zero.

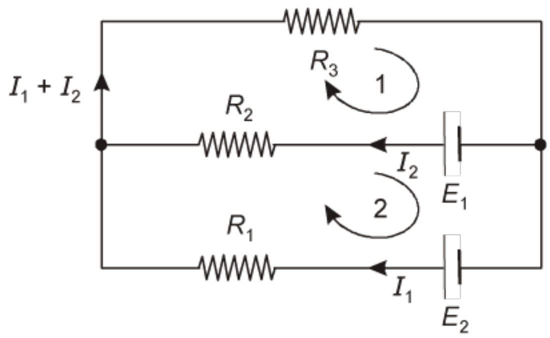


$$I_1 + I_2 - I_3 - I_4 + I_5 = 0$$

$$\sum_{i=0}^{n} I_i = 0$$

(b) **Kirchhoff's voltage law:** In any closed conducting loop of an electrical circuit, the algebraic sum of the e.m.f.s is equal to the algebraic sum of the products of the resistances and currents flowing through them. Thus,

$$\sum E = \sum IR$$



Using the Kirchhoff's rule in the loop we get,

Loop 1: $E_2 = I_2 R_2 + (I_1 + I_2) R_3$

Loop 2: $E_1 - E_2 = I_2 R_2 + (I_1 + I_2) R_3$

S16. Considering the mesh *BADB*, we have

$$100 I_1 + 15 I_g - 60 I_2 = 0$$

or $$20 I_1 + 3 I_g - 12 I_2 = 0 \quad \text{... (i)}$$

Considering the mesh *BCDB*, we have

$$10 (I_1 - I_g) - 15 I_g - 5 (I_2 + I_g) = 0$$

$$10 I_1 - 30 I_g - 5 I_2 = 0$$

$$2 I_1 - 6 I_g - I_2 = 0 \quad \text{... (ii)}$$

Considering the mesh *ADCEA*,

$$60 I_2 + 5 (I_2 + I_g) = 10$$

$$65 I_2 + 5 I_g = 10$$

$$13 I_2 + I_g = 2 \quad \text{... (iiii)}$$

Multiplying Eq. (ii) by 10

$$20 I_1 - 60 I_g - 10 I_2 = 0 \quad \text{... (iv)}$$

From Eqs. (iv) and (i), we have

$$63 I_g - 2 I_2 = 0$$

$$I_2 = 31.5 I_g \quad \text{... (v)}$$

Substituting the value of I_2 into Eq. (iii), we get

$$13 (31.5 I_g) + I_g = 2$$

$$410.5 I_g = 2$$

$$I_g = 4.87 \text{ mA.}$$

S17. Suppose that due to the battery of e.m.f. E_1, current I_1 flows through the resistor R_1 and that due to E_2, the current I_2 flows through the resistor R_2. Then according to Kirchhoff's first law, current $(I_1 + I_2)$ will flow through the resistor R_3 as shown in figure as above.

In closed loop *ABDEA* of the circuit applying the Kirchhoff's voltage law:

$$I_1 R_1 + (I_1 + I_2) R_3 = E_1 \quad \text{Or} \quad I_1 \times 2 + (I_1 + I_2) 5 = 6$$

or $$7 I_1 + 5 I_2 = 6 \qquad \text{... (i)}$$

In closed loop *ABCFA* of the circuit applying the Kirchhoff's voltage law:

$$I_2 R_2 + (I_1 + I_2) R_3 = E_2 \quad \text{Or} \quad I_2 \times 2 + (I_1 + I_2) 5 = 4$$

or $$5 I_1 + 8 I_2 = 4 \qquad \text{... (ii)}$$

Multiplying the equation (i) by 8, the equation (ii) by 5 and then subtracting, we have

$$(7 I_1 + 5 I_1)\ 8 - (5 I_1 + 8 I_2)\ 5 = 6\ \ 8 - 4\ \ 5$$

or $$31 I_1 = 28$$

or $$I_1 = \mathbf{\frac{28}{31}\ A}.$$

Substituting for I_1 in the Eqn. (i), we get

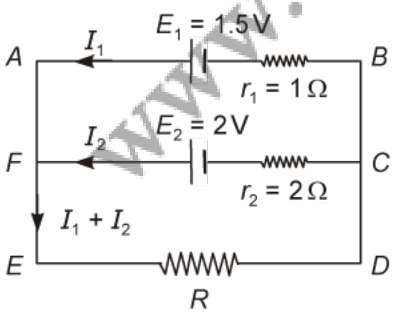
$$7 \times \frac{28}{31} + 5 I_2 = 6$$

or $$I_2 = \mathbf{-\frac{2}{31}\ A}.$$

The current through resistor R_3,

$$I_1 + I_2 = \frac{28}{31} + \left(\frac{-2}{31}\right) = \mathbf{\frac{26}{31}\ A}.$$

S18. (a) **Circuit diagram:** Let the e.m.f. of two cells be represented by E_1 and E_2 and their internal resistances be r_1 and r_2 respectively. The two cells have been connected in parallel to the external resistance R as shown in figure below.



(b) Given, $E_1 = 1.5\,V$; $E_2 = 2.0\,V$; $r_1 = 1\,\Omega$; $r_2 = 2\,\Omega$; $R = 5\,\Omega$.

Let I_1 and I_2 be the currents due to the cells E_1 and E_2 respectively. As the currents I_1 and I_2 flow into point F; according to Kirchhoff's current law, the current $I_1 + I_2$ will flow out from the point F and pass through the resistance R.

Applying Kirchhoff's voltage law to the closed loop $EABDE$ of the circuit, we get

or $\quad E_1 = I_1 r_1 + (I_1 + I_2) R \quad$ or $\quad 1.5 = I_1 \times 1 + (I_1 + I_2) \times 5$

$$6I_1 + 5I_2 = 1.5 \qquad \text{... (i)}$$

Applying Kirchhoff's voltage law to the closed loop $FCDEF$ of the circuit, we get

$$E_2 = I_2 r_2 + (I_1 + I_2) R$$

or $$2.0 = I_2 \times 2 + (I_1 + I_2) \times 5$$

or $$5I_1 + 7I_2 = 2.0.$$

After solving the Eqn. (i) and (ii), we get

$$I_1 = \mathbf{0.0294\,A} \quad \text{and} \quad I_2 = \mathbf{0.2647\,A}.$$

The potential difference across resistance R is

$$V = (I_1 + I_2) R$$

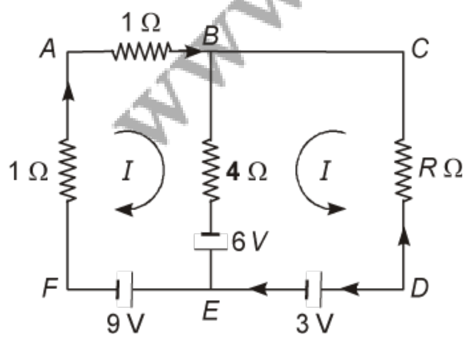
$$= (0.0294 + 0.2647) \times 5 = \mathbf{1.4705\,V.}$$

S19. Applying the Kirchhoff's voltage law in loop $ABEFA$

$$-9 + 6 + (I - I) + 1I + 1I = 0$$

$$2I - 3 = 0$$

$$I = 3/2 = \mathbf{1.5\,A}.$$



Take the second loop *EDCBE*

$$4(I - I) - 6 + 3 + IR = 0$$

$$IR = 3$$

$$R = \frac{\cancel{3} \times 2}{\cancel{3}} = 2$$

$$R = 2\,\Omega$$

Potential difference between *A* and *D*

$$V_{AD} = V_{AF} + V_{FE}$$

$$= 1 \times 1.5 + 1 \times 1.5$$

$$V_{AD} = \mathbf{3\,V}.$$

S20. Current flowing through various branches of the circuit is represented in the given figure.

I_1 = Current flowing through the outer circuit

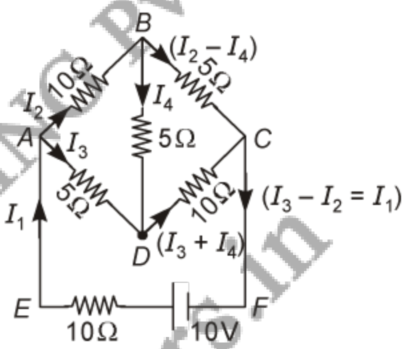
I_2 = Current flowing through branch *AB*

I_3 = Current flowing through branch *AD*

$I_2 - I_4$ = Current flowing through branch *BC*

$I_3 + I_4$ = Current flowing through branch *CD*

I_4 = Current flowing through branch *BD*



For the closed circuit *ABDA*, potential is zero *i.e.*,

$$10I_2 + 5I_4 - 5I_3 = 0$$

$$2I_2 + I_4 - I_3 = 0$$

$$I_3 = 2I_2 + I_4 \qquad \dots \text{(i)}$$

For the closed circuit *BCDB*, potential is zero *i.e.*,

$$5(I_2 - I_4) - 10(I_3 + I_4) - 5I_4 = 0$$

$$5I_2 + 5I_4 - 10I_3 - 10I_4 - 5I_4 = 0$$

$$5I_2 - 10I_3 - 20I_4 = 0$$

$$I_2 = 2I_3 + 4I_4 \qquad \dots \text{(ii)}$$

For the closed circuit *ABCFEA*, potential is zero *i.e.*,

$$-10 + 10(I_1) + 10(I_2) + 5(I_2 - I_4) = 0$$

$$10 = 15I_2 + 10I_1 - 5I_4$$

$$3I_2 + 2I_1 - I_4 = 2 \qquad \dots \text{(iii)}$$

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

$$I_3 = 2(2I_3 + 4I_4) + I_4$$

$$I_3 = 4I_3 + 8I_4 + I_4$$

$$3I_3 = 9I_4$$

$$3I_4 = + I_3 \quad \ldots \text{(iv)}$$

Putting Eq. (iv) in Eq. (i), we obtain

$$I_3 = 2I_2 + I_4$$

$$4I_4 = 2I_2$$

$$I_2 = -2I_4 \quad \ldots \text{(v)}$$

It is evident from the given figure that,

$$I_1 = I_3 + I_2 \quad \ldots \text{(vi)}$$

Putting Eq. (6) in Eq. (i), we obtain

$$3I_2 + 2(I_3 + I_2) - I_4 = 2$$

$$5I_2 + 2I_3 - I_4 = 2 \quad \ldots \text{(vii)}$$

Putting Eqs. (iv) and (v) in Eq. (vii), we obtain

$$5(-2\ I4) + 2(-3I_4) - I_4 = 2$$

$$10I_4 - 6I_4 - I_4 = 2$$

$$17I_4 = -2$$

$$I_4 = \frac{-2}{17} A$$

Equation (iv) reduces to

$$I_3 = -3(I_4) = -3\left(\frac{-2}{17}\right) = \frac{6}{17} A$$

$$I_2 = -2(I_4) = -2\left(\frac{-2}{17}\right) = \frac{4}{17} A$$

$$I_2 - I_4 = \frac{4}{17} - \left(\frac{-2}{17}\right) = \frac{6}{17} A$$

$$I_3 + I_4 = \frac{6}{17} + \left(\frac{-2}{17}\right) = \frac{4}{17} A$$

$$I_1 = I_3 + I_2 = \frac{6}{17} + \frac{4}{17} = \frac{10}{17} A$$

Therefore, current in branch

In branch $BC = \frac{6}{17} A$

In branch $CD = \frac{-4}{17} A$

In branch $AD = \frac{6}{17} A$

In branch $BD = \left(\frac{-2}{17}\right) A$

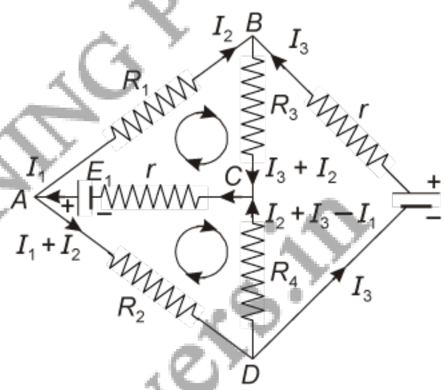
$$\text{Total current} = \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17} = \frac{10}{17} A.$$

S21. ***Kirchhoff's current law:*** At any junction in a circuit the algebraic sum of currents is zero.

$$\sum_{i=0}^{n} I_i = 0$$

Kirchhoff's voltage law: In any closed conducting loop of an electrical circuit, the algebraic sum of the e.m.f. is equal to the algebraic sum of the products of the resistances and currents flowing through them. Thus,

$$\sum E = \sum IR$$



In loop *ABCA* (Clockwise)

$-I_1R_1 - (I_2 + I_3) R_3 - I_1r + E_1 = 0$

$I_1r + I_1(R_1 + R_3) + I_1 - R_3 = E_1$ .... (i)

In loop *ACDA*(Clockwise)

$-E_1 + I_1r - (I_3 + I_2 + I_1) R_4 + (I_2 - I_1) R_2 = 0$

$I_1(r + R_4 - R_2) + I_2 (R_2 - R_4) - I_3R_4 = E_1$ ... (ii)

In loop *ABCDA*(Clockwise)

$-I_2R_1 + I_3r_1 - E_2 + (I_1 + I_2) R_2 = 0$

$I_1R_2 - I_2(R_1 + R_2) + I_3r_1 = E_2$ ... (iii)

S22. ***Kirchhoff's current law:*** At any junction in a circuit the algebraic sum of currents is zero.

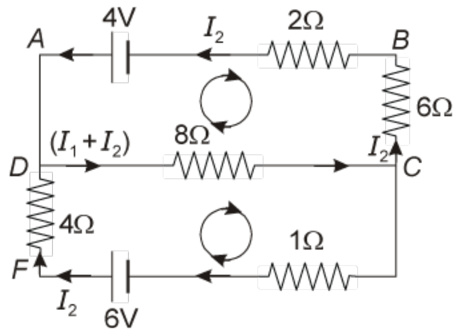
$$\sum_{i=0}^{n} I_i = 0$$

Kirchhoff's voltage law: In any closed conducting loop of an electrical circuit, the algebraic sum of the e.m.f. is equal to the algebraic sum of the products of the resistances and currents flowing through them. Thus,

$$\sum E = \sum IR$$

Using Kirchhoff's first law, electric current is distributed in all branches of circuit diagram.

Applying Kirchhoff's second law in



(a) loop *ABCD* (clockwise)

$$-4 + 2I_2 + 6I_2 + 8(I_1 + I_2) = 0$$

$$8I_1 + 16I_2 = 4$$

$$2I_1 + 4I_1 = 1$$

(b) In loop *DCEF* (clockwise)

$$-(I_1 + I_2) \times 8 - I_1 \times 1 + 6 - I_1 \times 4 = 0$$

$$13I_1 + 8I_2 = 6 \quad \text{... (ii)}$$

Solving Eqs. (i) and (ii), we get

$$I_1 = \frac{4}{9} A, I_2 = \frac{1}{36} A$$

∴ Current through 8Ω resistor = $I_1 + I_2$

$$= \frac{4}{9} + \frac{1}{36} = \frac{17}{36} A$$

∴ Potential difference across 8 Ω resistor

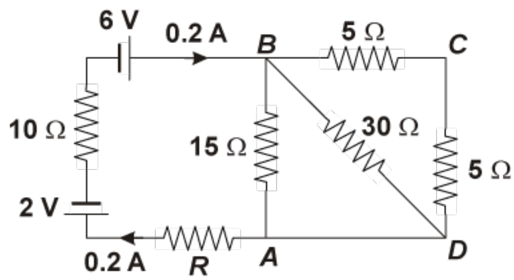
$$V = IR = \frac{17}{36} \times 8 = \frac{34}{9} V = \frac{34}{9} V$$

S23. (a) ***Kirchhoff's current law:*** At any junction in a circuit the algebraic sum of currents is zero.

$$\sum_{i=0}^{n} I_i = 0$$

(b) ***Kirchhoff's voltage law:*** In any closed conducting loop of an electrical circuit, the algebraic sum of the e.m.f.s is equal to the algebraic sum of the products of the resistances and currents flowing through them. Thus,

$$\sum E = \sum IR$$



For *BCD*, equivalent resistance

$$R_1 = 5Ω + 5Ω = 10Ω$$

Across *BA*, equivalent resistance R_2

$$\frac{1}{R_2} = \frac{1}{10} + \frac{1}{30} + \frac{1}{15}$$

$$= \frac{3+1+2}{30} = \frac{6}{30} = \frac{1}{5}$$

$\Rightarrow$ $R_2 = 5\Omega$

Potential difference

$$V_{BA} = I \times R_2$$

$$= 0.2 \times 5$$

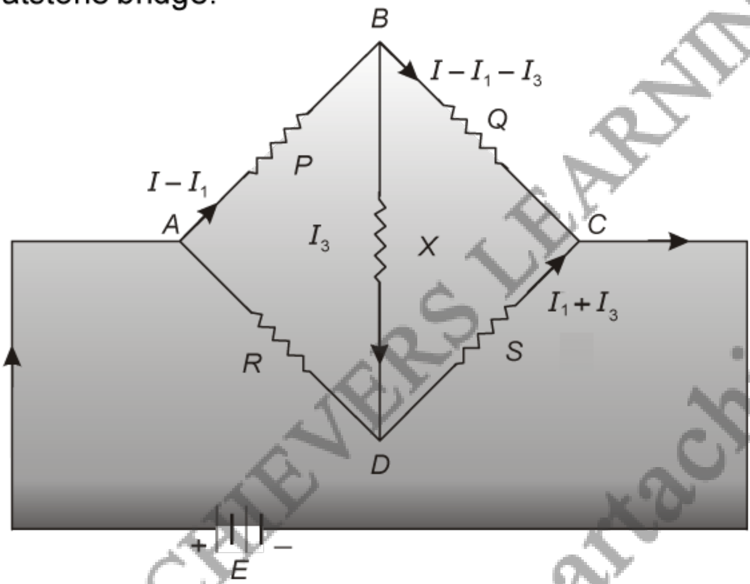
$$V_{BA} = 1\text{ V}$$

$$V_{AB} = 1\text{ V}$$

S24. **Kirchhoff's junction rule:** At any junction of several circuit elements the sum of currents entering the junction must be equal to the sum of currents leaving it.

Kirchhoff's loop rule: The algebraic sum of potential drop around any closed resistor loop must be zero.

Consider a Wheatstone bridge.



Take loop *ABDA*

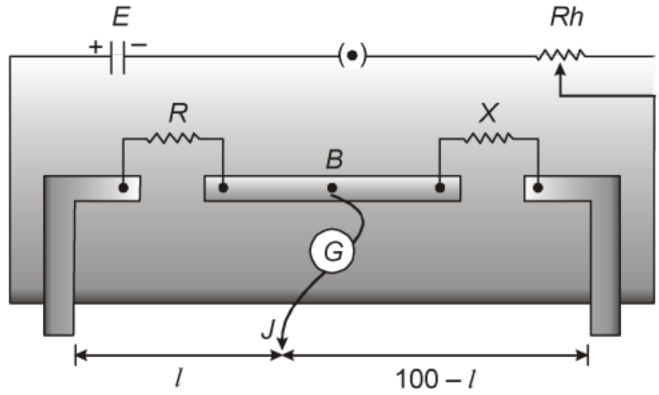
$$P(I - I_1) + XI_3 - RI_1 = 0 \qquad \text{... (i)}$$

Take loop *BCDB*

$$Q(I - I_1 - I_3) - S(I_1 + I_3) - XI_3 = 0$$

$$Q(I - I_1) - QI_3 - SI_1 - (S + X)I_3 = 0 \qquad \text{... (ii)}$$

When point *B* and *D* are at same potential the Bridge is said to be balanced.



As in balanced state $I_3 = 0$. From Eqn. (i) and (ii), we get,

$$P(I - I_1) = RI_1$$

$$Q(I - I_1) = SI_1$$

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

(unknown resistance) $$X = \frac{100 - l}{l} R.$$

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Q1. Which has greater resistance, milliammeter or ammeter and millivoltmeter or voltmeter?

Q2. The variation of potential difference *V* with length *l* in case of two potentiometers *P* and *Q* is as shown. Which one of these two will you prefer for comparing e.m.f.s of two primary cells?

Q3. Sometimes balance point may not be obtained on the potentiometer wire. Explain.

Q4. Why is a slide wire bridge also called a metre bridge?

Q5. In an experiment of meter bridge, if the balancing length *AC* is '*l*', what would be its value, when the radius of the meter bridge wire *AB* is doubled? Justify your answer.

Q6. What is the principle of a metre bridge?

Q7. The resistance in the left gap of a metre bridge is 15 Ω and the balance point is 30 m from the left end. Calculate the value of the unknown resistance.

Q8. Name the device used for measuring the e.m.f. of a cell.

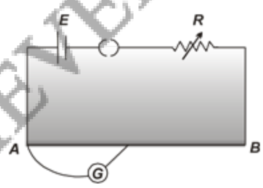
Q9. Which material is a potentiometer wire normally made?

Q10. Can we increase the sensitivity of a potentiometer, How?

Q11. The Wheatstone bridge method considered unsuitable for the measurement of very high resistances. Why?

Q12. Why the wire of potentiometer should be of uniform area of cross-section?

Q13. *AB* is a potentiometer wire. If the value of *R* is increased, in which direction will the balance point *J* shift?



Q14. Name the device used for measuring the internal resistance of a secondary cell.

Q15. In a metre bridge, two unknown resistances *R* and *X*, when connected the two gaps, give a null point is 40 cm from one end. What is the ratio of *R* and *X*?

Q16. Potentiometer named as potentiometer. Why?

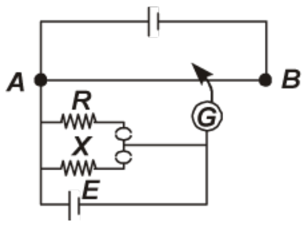
Q17. Describe the principle of a potentiometer.

Q18. The electric current should not be passed through potentiometer wire for a long time continuously. Why?

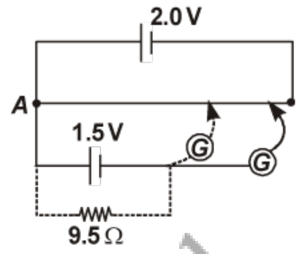
Q19. Which material is used for potentiometer wire and why?

Q20. In a potentiometer arrangement, a cell of e.m.f. 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the e.m.f. of the second cell?

Q21. The figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistor $R = 10.0\,\Omega$ is found to be 58.3 cm, while that with the unknown resistance X is 68.5 cm. Determine the value of X. What might you do if you failed to find a balance point with the given cell of e.m.f. ε?

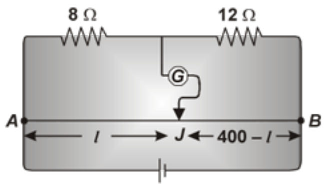


Q22. The figure shows a 2.0 V potentiometer used for the determination of internal resistance of a 1.5 V cell. The balance point of the cell in open circuit is 76.3 cm. When a resistor of 9.5 Ω is used in the external circuit of the cell, the balance point shifts to 64.8 cm length of the potentiometer wire. Determine the internal resistance of the cell.



Q23. Using Kirchhoff's laws, derive the condition for balance of a Wheatstone bridge circuit.

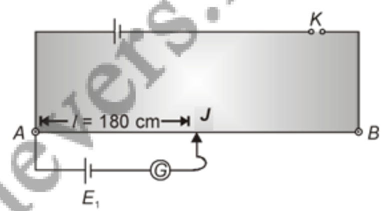
Q24. The wire AB of a side wire bridge shown in figure below is 400 cm long. Where should the free end of the galvanometer be connected on AB, so that the galvanometer shown zero deflection?



Q25. In the circuit shown in figure below, AB is a resistance wire of uniform cross-section in which a potential gradient of 0.01 V cm^{-1} exists.

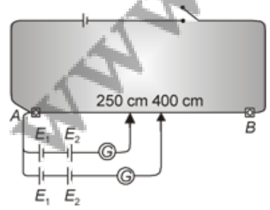
(a) If the galvanometer G shows zero deflection, what is the e.m.f. E_1 of the cell used?

(b) If the internal resistance of the driver cell increases on some account, how will it change the balance point in the experiment?



Q26. In a potentiometer arrangement, a cell of e.m.f. 1.20 V gives a balance point at 30 cm length of the wire. This cell is now replaced by another cell if unknown e.m.f. If the ratio of the e.m.f.s of the two cells is 1.5, calculate the difference in the balancing length of the potentiometer wire in the two cases.

Q27. Two primary cells of e.m.fs. E_1 and E_2 are connected to the potentiometer wire AB as shown in the figure below



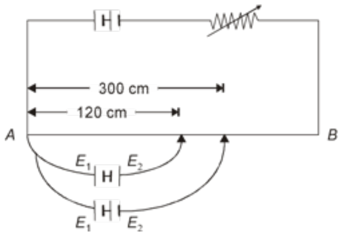
If the balancing length for the combinations of the cells are 250 cm and 400 cm, find the ratio of E_1 and E_2.

Q28. Balance condition in terms of the resistances of four of wheat stone bridge.
In the meterbridge experimental set up, the null point *D* is obtained at a distance of 40 cm from end *A* of the meterbridge wire.
If a resitance of 10Ω is connected in series with R_1, null point is obtained at *AD* = 60 cm. Calculate the values of R_1 and R_2.

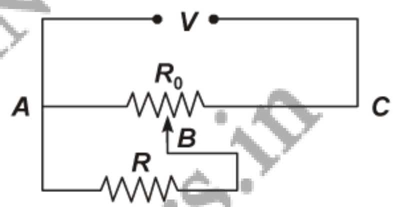
Q29. In what respect is the potentiometer battery than a moving coil voltmeter in comparing the e.m.fs. of two cells?
Why is the use of a potentiometer preferred over that of a voltmeter for measurement of e.m.f. of a cell?

Q30. Why we prefer a potentiometer with a longer bridge wire?

Q31. In the figure a long uniform potentiometer wire *AB* is having a constant potential gradient along its length. The null points for the two primary cells of e.m.f.s E_1 and E_2 connected in the manner shown are obtained at a distance of 120 cm and 300 cm from the end *A*. Find (a) E_1/E_2 and (b) position of null point for the cell E_1. How is the sensitivity of a potentiometer increased?



Q32. A resistance of *R*Ω draws current from a potentiometer. The potentiometer has a total resistance R_0Ω (see figure). A voltage *V* is supplied to the potentiometer. Derive an expression for the voltage across *R* when the sliding contact is in the middle of the potentiometer.

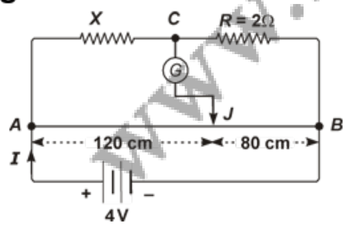


Q33. (a) In a metre bridge [see figure], the balance point is found to be at 39.5 cm from the end *A*, when the resistor *Y* is of 12.5 Ω. Determine the resistance of *X*. Why are the connections between resistors in a Wheatstone or meter bridge made of thick copper strips?

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

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

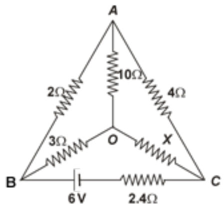
Q34. Find the value of the unknown resistance *X* and the current drawn by the circuit from the battery, it no current flows through the galvanometer as shown in the figure below. Assume the resistance per unit length of the wire *AB* to be 0.01 Ω cm^{-1}.



Q35. Describe the method to determine the specific resistance of a wire in the laboratory.
Draw the circuit diagram and write the formula used.
Write any two important precautions you would observe while performing the experiment.

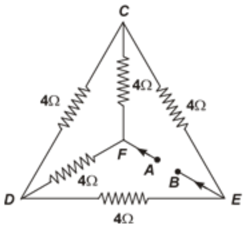
Q36. A 10 m long wire of uniform cross-section and 20 Ω resistance is used in a potentiometer. The wire is connected in series with a battery of 5 V along with an external resistance of 480 Ω. If an unknown e.m.f. *E* is balanced at 6.0 m length of the wire, calculate (a) the potential gradient of the potentiometer wire and (b) the value of unknown e.m.f.

Q37. Find the value of unknown resistance *X* in the circuit shown in the figure below, if no current flows through the section *AO*, Calculate the current drawn by the circuit from the battery of e.m.f 6 V and negligible internal resistance.

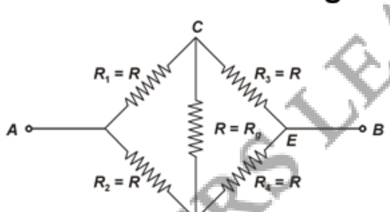


Q38. State the principle of potentiometer with the help of circuit diagram, describe a method to find the internal resistance of a primary cell.

Q39. A potential difference of 4 volt is applied between the points *A* and *B* shown in the network drawn in the figure. Calculate (a) equivalent resistance of the network across the points *A* and *B* and (b) the magnitudes of currents flowing in arms *AFCEB* and *AFDEB*.

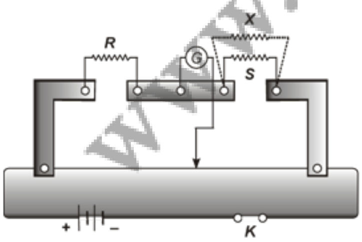


Q40. (a) Calculate the equivalent resistance of the given electrical network between points *A* and *B*.



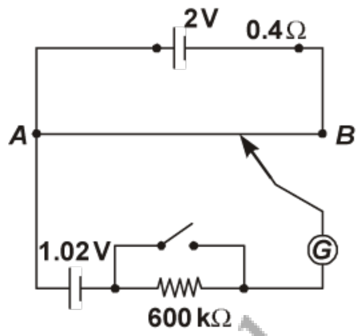
(b) Also calculate the current through *CD* and *ACB*, if a 10 V d.c. source is connected between *A* and *B*, and the value of *R* is assumed as 2 Ω.

Q41. When two known resistances *R* and *S* are connected in the left and right gaps of a metre bridge, the balance point is found at a distance l_1 from the zero end of the metre bridge wire. An unknown resistances *X* is now connected in parallel to the resistance *S* and the balance point is now found at a distance l_2 from the zero end of the metre bridge wire as shown in figure below. Obtain a formula for *X* in terms of l_1, l_2 and *S*.



Q42. State the principle of potentiometer. Draw a circuit diagram used to compare the e.m.f. of two primary cells. Write the formula used. How can he sensitivity of a potentiometer be increased?

Q43. The figure shows a potentiometer with a cell of 2.0 V and internal resistance 0.40 Ω maintaining a potential drop across the resistor wire *AB*. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents up to a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf ε and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



(a) What is the value ε?

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

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

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

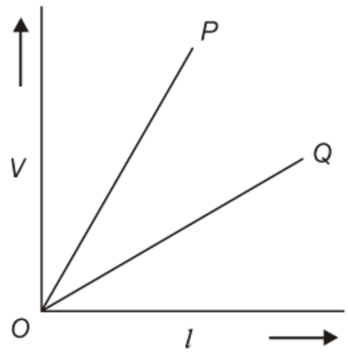
(e) Would the method work in the above situation if the driver cell of the potentiometer had an e.m.f. of 1.0 V instead of 2.0 V?

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

Date: 20/10/2021

S1. Milliammeter.

S2. The prefer potentiometer with lesser value of the potential gradient, the potential gradient in plot show the slope of the line *P* and *Q* slope of the *Q* is lesser *i.e.*, *Q* is preferred.

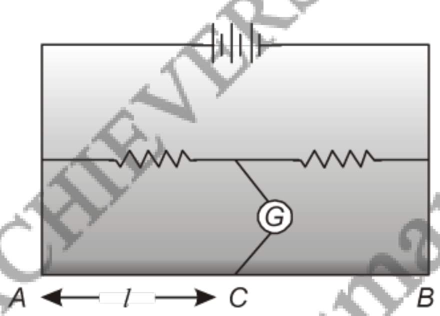


$$\text{Slope } E = -\frac{V}{l}.$$

S3. The balance point may not be obtained on the potentiometer wire, in case the e.m.f. of the auxiliary battery (battery used to maintain constant current through the potentiometer wire) is less than the e.m.f. of the cell to be measured.

S4. The length of the wire in a slide wire bridge is one metre.

S5. At the balance point *C*



From Wheatstone bridge

$$\frac{P}{Q} = \frac{P}{X}$$

where, $P = R_1$ $Q = R_2$

$R = l$ $X = 100 - l$

$$\frac{R_1}{R_2} = \frac{l}{100 - l}$$

Hence, R_1 and R_2 ratio remains same then l and $100 - l$ ratio will be also same *i.e.*, It will not depend upon the radius of the wire.

S6. Metre bridge work on the same principle of Wheatstone.

S7. Given $l = 30$ cm; $R = 15\,\Omega$

We know $\frac{P}{Q} = \frac{R}{X}$

$$\frac{P}{Q} = \frac{l}{100 - l}$$

$$X = R\left(\frac{100 - l}{l}\right)$$

$$= 15\left(\frac{100 - 30}{30}\right) = \cancel{15} \times \frac{70}{\cancel{30}_2} = 35\,\Omega$$

$$X = 35\,\Omega$$

S8. A potentiometer can be used to measure the e.m.f. of a cell.

S9. A Leclanche cell should be used in the main circuit of the potentiometer. This is because of the fact that Leclanche cell is useful, when the current is drawn for a short time.

S10. Yes, by reducing potential gradient. Potential gradient can be reduced by (a) reducing current in the main circuit; (b) increasing length of the wire.

S11. The Wheatstone bridge method for measuring high resistances, all other resistances forming the bridge should be high so that the meter bridge is sensitive. But this reduce the current through the galvanometer to make it insensitive.

S12. If the resistance per unit length of the wire is uniform, then the fall of potential per unit length of the wire will also be uniform on passing constant current through it. Only then, it satisfies the requirement of the principle of a potentiometer.

S13. If R is increased, the current through the wire will decrease and hence the potential gradient will also decrease, which will result in increase in balance length. So J will shift towards B.

S14. A potentiometer can be used to measure the internal resistance of a secondary cell.

S15. Given Null point is $l = 40$ cm.

We know $\frac{P}{Q} = \frac{R}{X}$

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

$$= \frac{40}{60} = \frac{2}{3}$$

S16. Because, it is used to measure the potential different between two poles of cell.

S17. It is based on the principle that if a constant current is passed through a wire of uniform cross-section, the potential difference cross any segment of the wire is proportional to its length.

S18. In case current is passed for a long time continuously, the resistance of potentiometer wire will increase due to the heating effect of current. Due to this, fall of potential per unit length of the wire will not remain the same (decrease).

S19. The potentiometer wire is usually of constantan or manganin. The material of the wire should have (i) high specific resistance (ii) low temperature coefficient of resistance.

S20. E.m.f. of the cell, $E_1 = 1.25\,\text{V}$

Balance point of the potentiometer, $l_1 = 35$ cm

The cell is replaced by another cell of e.m.f. E_2.

New balance point of the potentiometer, $l_2 = 63$ cm

The balance condition is given by the relation,

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

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

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

Therefore, e.m.f. of the second cell is 2.25 V.

S21. Resistance of the standard resistor, $R = 10.0\,\Omega$

Balance point for this resistance, $l_1 = 58.3$ cm

Current in the potentiometer wire = i

Hence, potential drop across R, $E_1 = iR$

Resistance of the unknown resistor = X

Balance point for this resistor, l_2 = 68.5 cm

Hence, potential drop across X, $E_2 = iX$

The relation connecting emf and balance point is,

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

$$\frac{iR}{iX} = \frac{l_1}{l_2}$$

$$X = \frac{l_1}{l_2} \times R = \frac{68.5}{58.3} \times 10 = 11.75\,\Omega.$$

Therefore, the value of the unknown resistance, X, is $11.75\,\Omega$.

If we fail to find a balance point with the given cell of e.m.f., ε, then the potential drop across R and X must be reduced by putting a resistance in series with it. Only if the potential drop across R or X is smaller than the potential drop across the potentiometer wire AB, a balance point is obtained.

S22. Internal resistance of the cell = r

Balance point of the cell in open circuit, l_1 = 76.3 cm

An external resistance (R) is connected to the circuit with $R = 9.5\,\Omega$

New balance point of the circuit, l_2 = 64.8 cm

Current flowing through the circuit = I

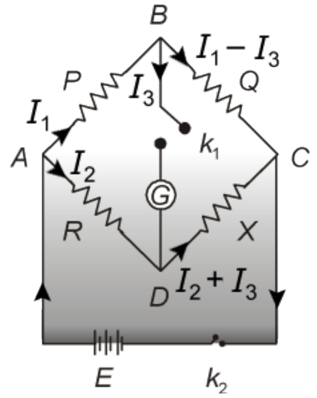
The relation connecting resistance and e.m.f. is,

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

$$= \frac{76.3 - 64.8}{64.8} \times 9.5 = 1.68\,\Omega$$

Therefore, the internal resistance of the cell is $1.68\,\Omega$.

S23. As shown in the figure below, let us consider four resistances P, Q, R, X connected in the form of a Wheatstone bridge. G is a galvanometer connected between points B and D. Currents flowing through different path.



Applying Kirchhoff's second law in the loop *ABDA*

$$I_1 P + I_3 G - I_2 R = 0 \quad \text{... (i)}$$

For closed loop *BCDB*

$$(I_1 - I_3) Q - (I_2 + I_3) X - I_3 G = 0 \quad \text{... (ii)}$$

Under the balance condition, there is no current through the galvanometer *i.e.*, $I_3 = 0$, thus

From Eqn. (i), we get

$$I_1 P - I_2 R = 0$$

or $$I_1 P = I_2 R \quad \text{... (iii)}$$

Putting $I_3 = 0$ in Eqn. (ii), we get

$$I_1 Q = I_2 X = 0$$

or $$I_1 Q = I_2 X \quad \text{... (iv)}$$

Dividing Eqn. (iii) by Eqn. (iv), we get

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

This is the balance condition of a Wheatstone bridge.

S24. Suppose the galvanometer shows zero deflection, when the free end of the galvanometer is connected at *J*. If the length of the portion of wire $AJ = l$, then

$$JB = 400 - l$$

Since the bridge is balanced, we have

$$\frac{l}{400 - l} = \frac{8}{12}$$

$$l = \textbf{160 cm}.$$

S25. (a) E_1 = Potential drop across the wire *A J*

$$= 180 \times 0.01 = 1.8 \textbf{ V}.$$

(b) When the internal resistance of the driver cell increases, the current through the wire *AB* and hence potential gradient along the wire *AB* will decrease.

As such, the cell of e.m.f. E_1 = (1.8 V) will be balanced across a length greater than 180 cm *i.e.*, the balance point *J* will shift towards right.

S26. Given:

$$E_1 = 1.20\text{ V};\ \frac{E_1}{E_2} = 1.5 \text{ and } l = 30\text{ cm} = 0.3\text{ m}$$

$$E_2 = \frac{E_1}{1.5} = \frac{1.20}{1.5} = \mathbf{0.8}.$$

According to potentiometer principle

$$E_1 = k\,l_1 \qquad \text{... (i)}$$

$$1.20 = \text{k}\,(0.3) \text{ or } k = \frac{1.20}{0.3} = 4$$

we know,

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

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

$$l_2 = \frac{0.8 \times 30}{1.20} = 20\text{ cm}$$

$$\Delta l = l_1 - l_2 = 30 - 20 = \mathbf{10\ cm}.$$

S27. Given: l_1 - 250 cm and l_2 = 400 cm

We know, $E = kl$

$$E_1 - E_2 = k \times 250 \qquad \text{... (i)}$$

and

$$E_1 + E_2 = k \times 400 \qquad \text{... (ii)}$$

Adding the equations (i) and (ii), we get

$$2\,E_1 = 650\,k$$

or

$$E_1 = 325\,k \qquad \text{... (iii)}$$

On subtracting the equation (i) form (ii), we obtain

$$2E_2 = 150\,k$$

$$E_2 = 75\,k \qquad \text{. (iv)}$$

Now, dividing Eqn. (iii) and Eqn. (iv), we get

Hence, $$\frac{E_1}{E_2} = \frac{325\,k}{75\,k} = \mathbf{4.33}.$$

S28. Considering both the situations and writing them in the form of equations

Let R' be the resistance per unit length of the poential meter wire,

$$\frac{R_1}{R_2} = \frac{R' \times 40}{R'\,(100-40)} = \frac{40}{60} = \frac{2}{3}$$

$$\frac{R_1 + 10}{R_2} = \frac{R' \times 60}{R'\,(100-60)} = \frac{60}{40} = \frac{3}{2}$$

$$\frac{R_1}{R_2} = \frac{2}{3} \qquad \text{... (i)}$$

$$\frac{R_1 + 10}{R_2} = \frac{3}{2} \qquad \text{... (iii)}$$

Putting the values of R1 from Eq. (i) and Substituting in Eq. (ii).

$$\frac{2}{3} + \frac{10}{R_2} = \frac{3}{2}, R = 12\Omega$$

Recalling Eq. (i) again

$$\frac{R_1}{12} = \frac{2}{3}, R_1 = 8\,\Omega.$$

S29. When a voltmeter is connected across the two poles of a cell, it has drawn a small current from the cell. As a result, the voltmeter measures terminal potential difference across the two poles of the cell, which is always less than the e.m.f. of the cell.

On the other hand, when a potentiometer is used for the measurement of e.m.f. of a cell, it does not drawn any current from the cell. Hence, it measures e.m.f. of the cell

For these reasons, a potentiometer is preferred over a voltmeter for measuring e.m.f. of a cell.

S30. The smallest potential difference, which a potentiometer can measure gives the sensitivity of the potentiometer. Hence, for a potentiometer to be more sensitive, the potential drop per unit length of its wire should be as small as possible. Obviously, if the potentiometer has a longer bridge wire, the potential drop per unit length will be lesser and hence it will be able to measure very small potential differences.

S31. Given: l_1 = 120 cm and l_2 = 300 cm

We know, $E = kl$

(a) According to the circuit

$E_1 + E_2 = 300\,k$ ... (i)

$E_1 - E_2 = 120\,k$ ... (ii)

Adding the Eq. (i) and (ii), we get

$2E_1 = 420\,k$

$E_1 = 210\,k$

Put the value E_1 in Eq. (i), we get

$$210\,k + E_2 = 300\,k$$

$$E_2 = 90\,k$$

$$\frac{E_1}{E_2} = \mathbf{\frac{7}{3}}.$$

(b) Now, balancing length for cell of E_1 is 210 cm.

$$k = \frac{V}{l} \quad \text{(where } k \text{ is potential gradient)}$$

Lesser is the value of potential gradient more sensitive is the potentiometer.

Thus, sensitivity of potentiometer can be increased by

(i) increasing length of potentiometer wire

(ii) reducing potential difference across the wire.

S32. While the slide is in the middle of the potentiometer only half of its resistance ($R_0/2$) will be between the points A and B. Hence, the total resistance between A and B, say, R_1, will be given by the following expression:

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{(R_0/2)}$$

$$R_1 = \frac{R_0 R}{R_0 + 2R}$$

The total resistance between A and C will be sum of resistance between A and B and B and C, *i.e.*, $R_1 + R_0/2$

$\therefore$ The current flowing through the potentiometer will be

$$I = \frac{V}{R_1 + R_0/2} = \frac{2V}{2R_1 + R_0}$$

The voltage V_1 taken from the potentiometer will be the product of current I and resistance R_1,

$$V_1 = IR_1 = \left(\frac{2V}{2R_1 + R_0}\right) \times R_1$$

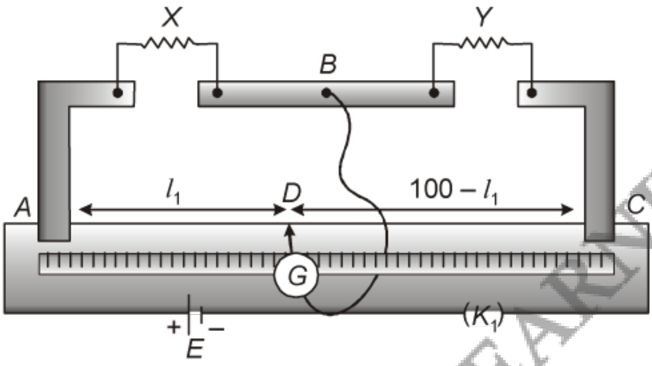
Substituting for R_1, we have a

$$V_1 = \frac{2V}{2\left(\frac{R_0 \times R}{R_0 + 2R}\right) + R_0} \times \frac{R_0 \times R}{R_0 + 2R}$$

$$V_1 = \frac{2VR}{2R + R_0 + 2R}$$

or $$V_1 = \frac{2VR}{R_0 + 4R}.$$

S33. (a) A metre bridge with resistors X and Y is represented in the given figure.



Balance point from end A, $l_1 = 39.5$ cm

Resistance of the resistor $Y = 12.5\,\Omega$

Condition for the balance is given as,

$$\frac{X}{Y} = \frac{l_1}{100 - l_1}$$

$$X = \frac{39.5}{100 - 39.5} \times 12.5 = 8.2\,\Omega$$

Therefore, the resistance of resistor X is $8.2\,\Omega$.

(b) The connection between resistors in a Wheatstone or metre bridge is made of thick copper strips to minimize the resistance, which is not taken into consideration in the bridge formula.

If X and Y are interchanged, then l_1 and $100 - l_1$ get interchanged.

The balance point of the bridge will be $100 - l_1$ from A.

$$100 - l_1 = 100 - 39.5 = 60.5\text{ cm}$$

Therefore, the balance point is 60.5 cm from A.

(c) When the galvanometer and cell are interchanged at the balance point of the bridge, the galvanometer will show no deflection. Hence, no current would flow through the galvanometer.

S34. Given: $K = 0.01\,\Omega\,\text{cm}^{-1}$

$$l_1 = 120 \text{ cm}$$

$$l_2 = 80 \text{ cm}$$

Let P and Q be the resistances of the two portions AJ and JB of the wire respectively.

Then, $P = 120 \times 0.01 = 1.2\,\Omega$

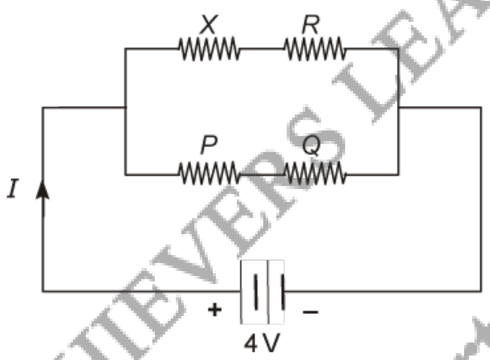
and $Q = 80 \times 0.01 = 0.8\,\Omega$.

$\because$ the bridge is balanced,

$$\frac{X}{R} = \frac{P}{Q} \quad \text{or} \quad X = R \times \frac{P}{Q}$$

or $$X = \frac{2 \times 1.2}{0.8} = \mathbf{3\,\Omega}.$$

As no current flows through the galvanometer, the path between points C and J acts as an open path. Therefore, the given circuit is equivalent of the circuit drawn as shown in the figure below



Let R_1 be the resistance of series combination of X and R and R_2 of the series combination of P and Q. Then,

$$R_1 = X + R = 3 + 2 = 5\,\Omega$$

and $$R_2 = P + Q = 1.2 + 0.8 = 2\,\Omega.$$

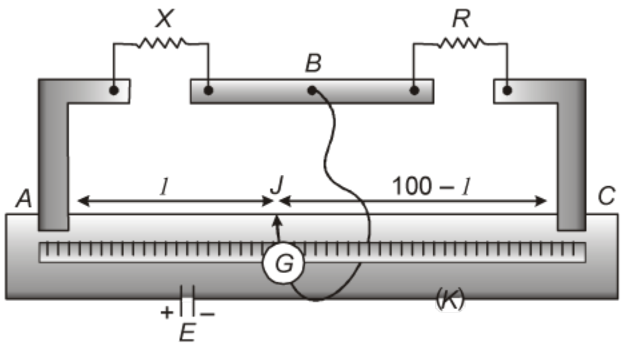
Therefore, the effective resistance of the circuit,

$$R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{5 \times 2}{5 + 2} = \frac{10}{7}\,\Omega$$

Hence, the current drawn by the circuit from the battery,

$$I = \frac{E}{R'} = \frac{4}{10/7} = \mathbf{2.8\,A}. \qquad (\because\ E = 4\,V)$$

S35. Specific resistance is calculated by using meter bridge



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

$$X = \left(\frac{l}{100 - l}\right)R$$

$\therefore$ Specific resistance (ρ) = $\frac{X\pi r^2}{L}$;

$\rho = \frac{XA}{L}$. Here 'L' is the length of the wire whose resistance is 'X'.

(c) **Two precautions:**

(i) Null point should be near the centre of the metre bridge wire.

(ii) Two resistances (A and R) of comparable value.

S36. Given, e.m.f. of battery = 5 V;

resistance of the potentiometer wire, $R = 20\ \Omega$;

length of the potentiometer wire, $L = 10$ m;

external resistance $R' = 480\ \Omega$.

(a) If I is current through the potentiometer wire, then

$$I = \frac{E'}{R + R'} = \frac{5}{20 + 480} = \frac{5}{500} = 0.01\,A$$

Now, potential drop along the potentiometer wire, we get

$$V = I \times R = 0.01 \times 20 = 0.2\,V.$$

Hence, potential gradient along the potentiometer wire, we get

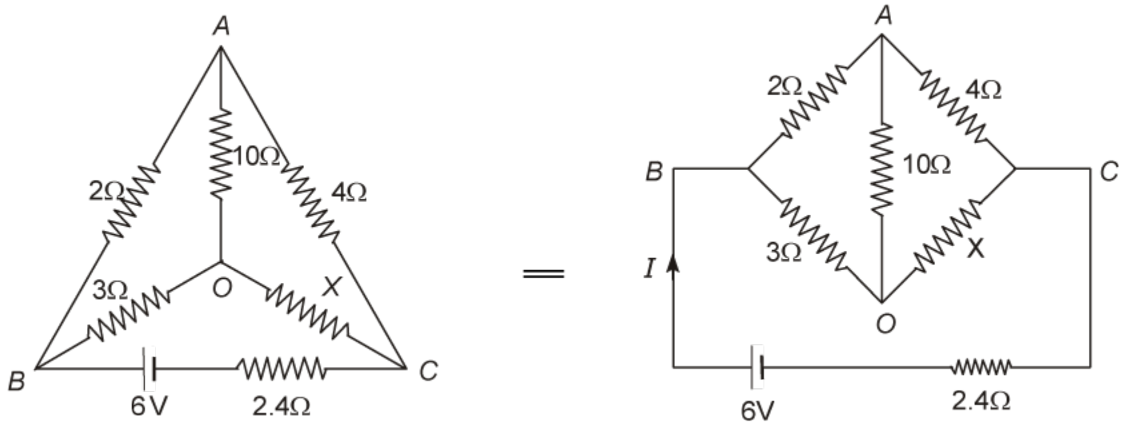
$$\frac{V}{L} = \frac{0.2}{10} = 0.02\,Vm^{-1}$$

(b) The length of the wire at which unknown e.m.f. E is balanced,

$$l = 6.0\ m$$

$$\therefore \qquad E = \frac{V}{L} \times l = 0.02 \times 6.0 = \mathbf{0.12\,V}.$$

S37. The given circuit is equivalent to the circuit shown in the figure below, because no current flow AO element:

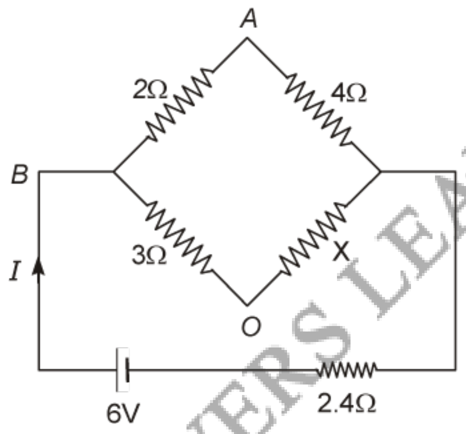


Let I be the current drawn by the circuit from the battery.

As no current flows through the branch AO of the circuit the circuit is a balanced Wheatstone bridge. Therefore,

$$\frac{2}{4} = \frac{3}{X} \quad \text{and} \quad X = \frac{4 \times 3}{2} = 6\,\Omega$$

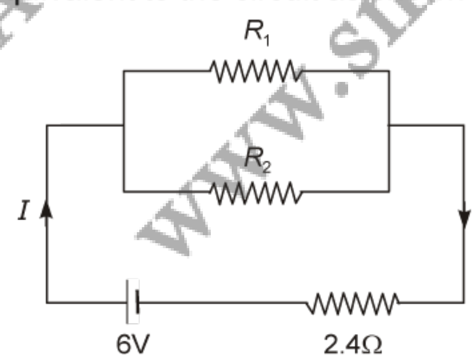
Since the branch AO acts as an open path (no current flows along the branch AO), the resistance of $10\,\Omega$ between the points A and O of the circuit is ineffective. Hence, the network is equivalent to the circuit as shown in the figure below:



Let R_1 and R_2 be resistances of the paths BAC and BOC of the circuit. Then,

$$R_1 = 2 + 4 = 6\,\Omega \quad \text{and} \quad R_2 = 3 + 6 = 9\,\Omega.$$

The given circuit is now equivalent to the circuit as shown in the figure below:



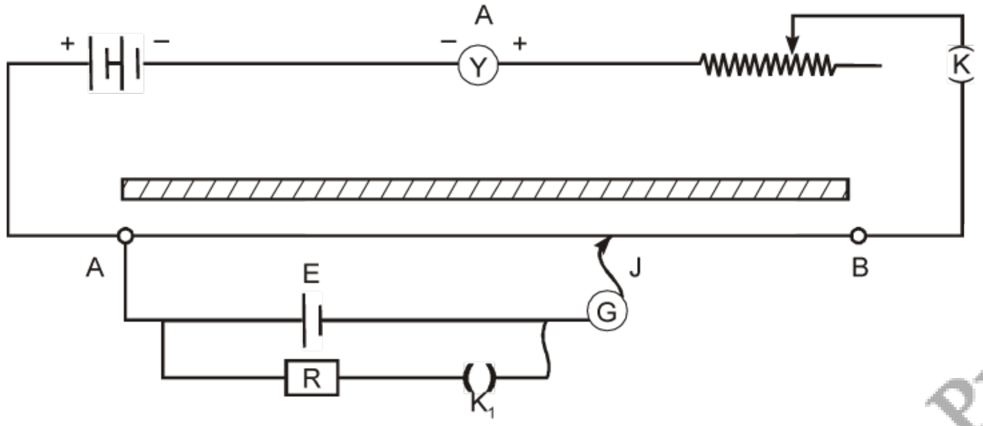
I follows that the effective resistance of the circuit,

$$R = \frac{R_1 R_2}{R_1 + R_2} + 2.4 = \frac{6 \times 9}{6 + 9} + 2.4 = 3.6 + 2.4 = 6\,\Omega$$

Hence, current drawn by the circuit from the battery,

$$I = \frac{E}{R} = \frac{6}{6} = \mathbf{1\ A}.$$

S38. Principle: The working of a potentiometer is based on the principle that the fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross-section and a constant current is flowing through it.



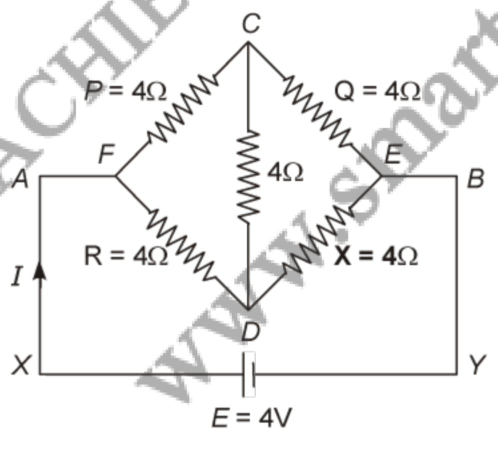
Take balancing lengths with key K_1 off an on respectively we get

$$E = kl_1$$

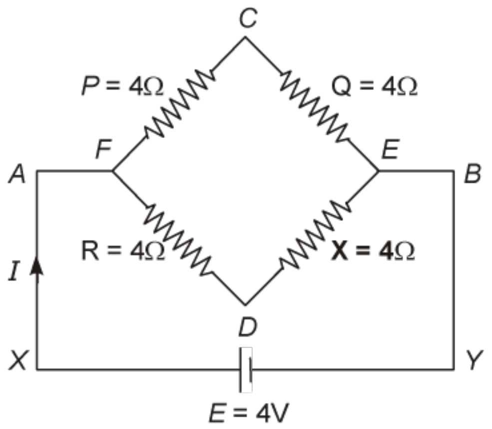
$$V = kl_2$$

Thus, internal resistance $r = \left(\frac{E}{V} - 1\right)R = \left(\frac{l_1}{l_2} = 1\right)R.$

S39. After connecting a battery of e.m.f. $E = 4$ V between the points A and B, the given network can be redrawn as shown in figure below



The given network is a Wheatstone bridge arrangement. Further, as $P/Q = R/X$. the bridge is in balanced slate. As such, no current can flow along the path CD. In other words, CD can be treated as an Open path as shown in the figure below



(a) Now, the path *FCE* contains two resistance, (each of 4 Ω) connected in series. If R_1 is resistance of the path *FCE*, then

$$R_1 = P + Q = 4 + 4 = 8\,\Omega.$$

Similarly, if R_2 is resistance of the path *FDE*, then

$$R_2 = R + X = 4 + 4 = 8\,\Omega.$$

Now, the path *FCE* of resistance R_1 and *FDE* of resistance R_2 are connected in parallel. If R' is equivalent resistance of the given network between the points *A* and *B*, then

$$\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{8} + \frac{1}{8} = \frac{1}{4}$$

or $$R' = \mathbf{4\,\Omega}.$$

(b) Let I be the current in the main circuit due to the battery.

Then, $$I = \frac{E}{R'} = \frac{4}{4} = 1\text{A}.$$

Further, suppose that I_1 and I_2 are currents along the paths *FCE* and *FDE* respectively. Since the two paths *FCE* and *FDE* are of equal resistance, the current I in the main circuit will divide equally along the two paths *i.e.*, current in the arms *AFCEB* and *AFDEB* are given by

$$I_1 = I_2 = I/2 = 1/2 = \mathbf{0.5\ A}.$$

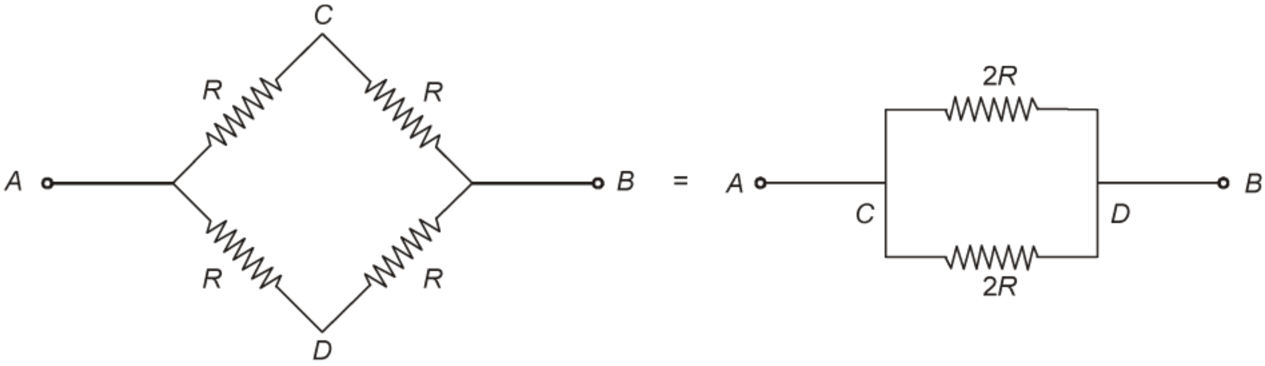
S40. (a) Given circuit can be redrawn as

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

Circuit is balanced Wheatstone bridge.

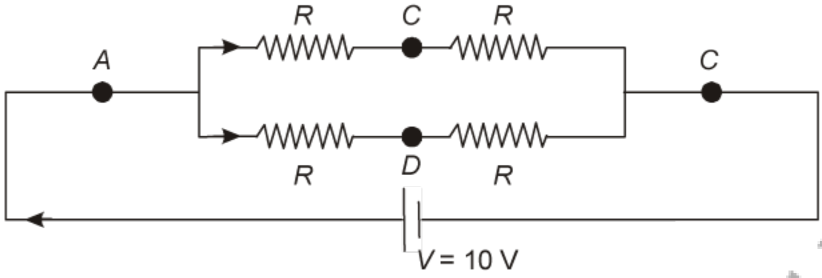
$\because$ $V_C = V_D$ $\quad\therefore\ I_{CD} = 0$

Equivalent circuit is



Thus, $R_{AB} = \frac{(2R)(2R)}{4R} = R\Omega$.

(b) Being a balanced Wheastone bridge



$$I_{CD} = 0$$

$$V = 10\,\text{volt}$$

$$R = 2\ \Omega$$

$$V_{AB} = 10\,\text{volt}$$

$$R_{ACB} = 4\ \Omega$$

$$I_{ACB} = \frac{10}{4} = \mathbf{2.5\ A}.$$

S41. When resistances *R* and *S* are connected:

Since balance point is found at a distance $l1$ from the zero end,

$$R \propto l_1 \quad \text{and} \quad S \propto (100 - l_1)$$

$$\frac{R}{S} = \frac{l_1}{(100 - l_1)} \qquad \text{... (i)}$$

When unknown resistance X is connected in paralled to *S*:

The effective resistance in the right gap,

$$S' = \frac{SX}{S + X} \qquad \text{... (ii)}$$

Since balance point is obtained at a distance l_2 from the zero end,

$$R \propto l_2 \quad \text{and} \quad S' \propto (100 - l_2)$$

$$\frac{R}{S'} = \frac{l_2}{(100 - l_2)} \qquad \text{... (iii)}$$

Substituting the value of S', we have

$$\frac{R(S + X)}{SX} = \frac{l_2}{(100 - l_2)} \qquad \text{... (iv)}$$

Dividing the equation (iii) by (i), we have

$$\frac{S + X}{X} = \frac{l_2}{(100 - l_2)} \times \frac{(100 - l_1)}{l_1}$$

or $$\frac{S}{X} + 1 = \frac{l_2 (100 - l_1)}{l_1 (100 - l_2)}$$

or $$\frac{S}{X} = \frac{l_2 (100 - l_1)}{l_1 (100 - l_2)} - 1 = \frac{100 l_2 - l_1 l_2 - 100 l_1 + l_1 l_2}{l_1 (100 - l_2)}$$

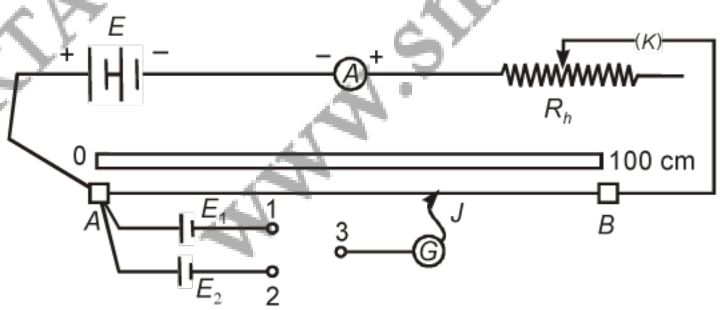
or $$X = \frac{\mathbf{l_1 (100 - l_2)}}{\mathbf{100 (l_2 - l_1)}} \mathbf{S}.$$

S42. **Principle:** The working of a potentiometer is based on the principle that the fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross-section and a constant current is flowing through it.

$$V = IR \qquad \{\because R = \rho l/A\}$$

$$V = I\rho \frac{l}{A}.$$

Circuit diagram to compare e.m.f. of two primary cells:



$$E_1 = k l_1 \qquad \text{... (i)}$$

$$E_2 = k l_2 \qquad \text{... (ii)}$$

Eqn. (i) ÷ (ii), we get

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

where l_1 and l_2 are balancing lengths for the cells of e.m.f. E_1 and E_2 respectively.

We can increase the sensitivity of a potentiometer by reducing the value of potential gradient.

i.e., $$K = \frac{V}{l}$$

We can do so by

(a) increasing the length of potentiometer wire

(b) by joining a resistance in series with the driving cell.

S43. (a) Constant emf of the given standard cell,

$$E_1 = 1.02\,\text{V}$$

Balance point on the wire, $l_1 = 67.3\,\text{cm}$

A cell of unknown emf, ε, replaced the standard cell. Therefore, new balance point on the wire, $l = 82.3\,\text{cm}$

The relation connecting emf and balance point is,

$$\frac{E_1}{l_1} = \frac{\varepsilon}{l}$$

$$\varepsilon = \frac{l}{l_1} \times E_1 = \frac{82.3}{67.3} \times 1.02 = 1.247\,\text{V}$$

The value of unknown e.m.f. is 1.247 V.

(b) The purpose of using the high resistance of 600 kΩ is to reduce the current through the galvanometer when the movable contact is far from the balance point.

(c) The balance point is not affected by the presence of high resistance.

(d) The point is not affected by the internal resistance of the driver cell.

(e) The method would not work if the driver cell of the potentiometer had an e.m.f. of 1.0 V instead of 2.0 V. This is because if the emf of the driver cell of the potentiometer is less than the emf of the other cell, then there would be no balance point on the wire.

(f) The circuit would not work well for determining an extremely small e.m.f. As the circuit would be unstable, the balance point would be close to end A. Hence, there would be a large percentage of error.

The given circuit can be modified if a series resistance is connected with the wire *AB*. The potential drop across *AB* is slightly greater than the emf measured. The percentage error would be small.