Question 3.1:

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

Solution:

In the given question,

The EMF of the battery is given as E = 12 V

The internal resistance of the battery is given as R = 0.4 Ω

The amount of maximum current drawn from the battery is given by = I

According to Ohm's law,

E = IR

Rearranging, we get

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

Substituting values in the above equation, we get

$$I = \frac{12}{0.4} = 30 \text{ A}$$

Therefore, the maximum current drawn from the given battery is 30 A.

Question 3.2:

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?

Solution:

Given:

The EMF of the battery (***E*** = 10 V)

The internal resistance of the battery (***R*** = 3 Ω)

The current in the circuit (***I*** = 0.5 A)

Consider the resistance of the resistor to be ***R***.

The current in the circuit can be found out using Ohm's Law as,

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

Rewriting the above equation, we get

$$R + r = \frac{E}{I} = \frac{10}{0.5} = 20\Omega$$

Therefore,

$$R = 20 - 3 = 17\Omega$$

Consider the Terminal voltage of the resistor to be V.

Then, according to Ohm's law,

V = IR

Substituting values in the equation, we get

V = 0.5 × 17

V = 8.5 V

Therefore, the resistance of the resistor is 17 Ω and the terminal voltage is 8.5 V.

Question 3.3:

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.

Solution:

(a) We know that resistors r_1 = 1 Ω, r_2 = 2 Ω and r_3 = 3 Ω are combined in series.

The total resistance of the above series combination can be calculated by the algebraic sum of individual resistances as follows:

Total resistance = 1 Ω + 2 Ω + 3 Ω = 6 Ω

Thus calculated Total Resistance = 6 Ω

b) Let us consider I to be the current flowing the given circuit

Also,

The emf of the battery is E = 12 V

Total resistance of the circuit (calculated above) = R = 6 Ω

Using Ohm's law, relation for current can be obtained as

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

Substituting values in the above equation, we get

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

Therefore, the current calculated is 2 A

Let the Potential drop across 1 Ω resistor = V_1

The value of V_1 can be obtained from Ohm's law as:

$V_1 = 2 \times 1 = 2$ V

Let the Potential drop across 2 Ω resistor = V_2

The value of V_2 can be obtained from Ohm's law as:

$V_2 = 2 \times 2 = 4$ V

Let the Potential drop across 3 Ω resistor = V_3

The value of V_3 can be obtained from Ohm's law as:

$V_3 = 2 \times 3 = 6$ V

Therefore, the potential drops across the given resistors r_1 = 1 Ω, r_2 = 2 Ω and r_3 = 3 Ω are calculated to be

$V_1 = 2 \times 1 = 2$ V

$V_2 = 2 \times 1 = 4$ V

$V_3 = 2 \times 1 = 6$ V

Question 3.4:

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 emf 20 V and negligible internal resistance, determine the current through each resistor, and the total current drawn from the battery.

Solution:

A) Resistors r_1 = 2 Ω, r_2 = 4 Ω and r_3 = 5 Ω are combined in parallel

Hence the total resistance of the above circuit can be calculated by the following formula:

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

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5}$$

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

$$\frac{1}{R} = \frac{19}{20}$$

Therefore, the total resistance of the parallel combination given above is given by:

$$R = \frac{20}{19}$$

B) Given that emf of the battery, E = 20 V

Let the current flowing through resistor R_1 be I_1

I_1 is given by:

$$I_1 = \frac{V}{R_1}$$

$$I_1 = \frac{20}{2}$$

$$I_1 = 10A$$

Let the current flowing through resistor R_2 be I_2

I_2 is given by:

$$I_2 = \frac{V}{R_2}$$

$$I_2 = \frac{20}{4}$$

$$I_2 = 5A$$

Let the current flowing through resistor R_3 be I_3

I_3 is given by:

$$I_3 = \frac{V}{R_1}$$

$$I_3 = \frac{20}{5}$$

$$I_3 = 4A$$

Therefore, the total current can be found by the following formula:

$I = I_1 + I_2 + I_3 = 10 + 5 + 4 = 19$ A

therefore the current flowing through each resistor is calculated to be:

$$I_1 = 10A$$

$$I_2 = 5A$$

$$I_3 = 4A$$

Therefore, the total current is I = 19 A

Question 3.5:

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 1.70×10^{-4} °C^{-1}.

Solution:

Given that the room temperature, T = 27 ° C

The heating element has a resistance of R = 100 Ω

Let the increased temperature of the filament be T_1

At T_1, the resistance of the heating element is $R_1 = 117$ Ω

Temperature coefficient of the material used for the element is 1.70×10^{-4} C^{-1}

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

α is given by the relation,

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

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

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

$$T_1 - 27 = 1000$$

$T_1 = 1027\ ° C$

Therefore, the resistance of the element is 117 Ω at $T_1 = 1027\ ° C$

Question 3.6:

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?

Solution:

Given that the length of the wire, L = 15 m

Area of cross – section is given as, a = ***6.0 x 10^{-7} m^2***

Let the resistance of the material of the wire be, R, ie., R = 5.0 Ω

The resistivity of the material is given as ρ

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

$$\rho = \frac{R \times A}{L} = \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}$$

Therefore, the resistivity of the material is calculated to be 2×10^{-7}

Question 3.7:

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

Solution:

Given that temperature $T_1 = 27.5\ ° C$

Resistance R_1 at temperature T_1 is given as:

$R_1 = 2.1\ \Omega$ (at T_1)

Given that temperature $T_2 = 100\ ° C$

Resistance R_2 at temperature T_2 is given as:

$R_2 = 2.7\ \Omega$ (at T_2)

Temperature coefficient of resistivity of silver = α

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

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

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

Question 3.8:

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 × 10^{-4} $°C^{-1}$.

Solution:

In the given problem,

The supply voltage is V = 230 V

The initial current drawn is I_1 = 3.2 A

Consider the initial resistance to be R_1, which can be found by the following relation:

$R_1 = \frac{V}{I}$

Substituting values, we get

$R_1 = \frac{230}{3.2}$ = 71.87 Ω

Value of current at steady state, I_2 = 2.8 A

Value of resistance at steady state = R_2

R_2 can be calculated by the following equation:

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

The temperature coefficient of nichrome averaged over the temperature range involved is 1.70 x 10^{-4} $°C^{-1}$

Value of initial temperature of nichrome, T_1 = 27.0 ° C

Value of steady state temperature reached by nichrome = T_2

This temperature T_2 can be obtained by the following formula:

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

$T_2-27 = \frac{82.14-71.87}{71.87\times(1.7\times10^{-4})}$

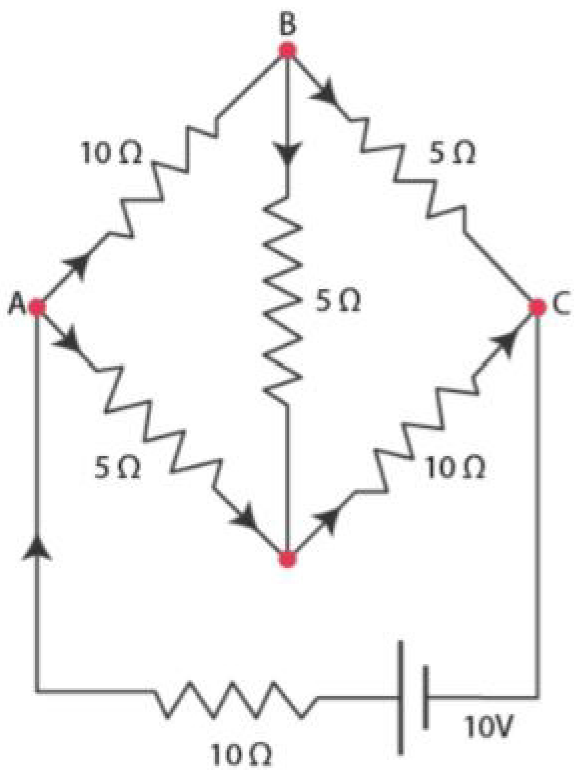
$T_2 - 27 = 840.5$

$T_2 = 840.5 + 27 = 867.5\ °\ C$

Hence, the steady temperature of the heating element is 867.5 ° C

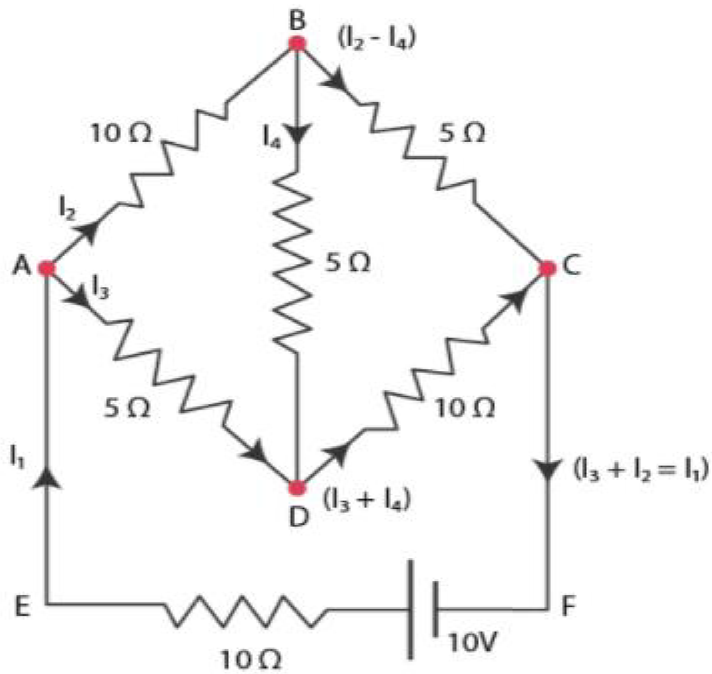
Question 3.9:

Determine the current in each branch of the network shown in the figure:



Solution:

The current flowing through various branches of the network is shown in the figure given below:



Let I_1 be the current flowing through the outer circuit

Let I_2 be the current flowing through AB branch

Let I_3 be the current flowing through AD branch

Let $I_2 - I_4$ be the current flowing through branch BC

Let $I_3 + I_4$ be the current flowing through branch DC

Let us take closed-circuit ABDA into consideration, we know that potential is zero.

i.e , $10 I_2 + 5 I_4 - 5 I_3 = 0$

$2 I_2 + I_4 - I_3 = 0$

$I_3 = 2 I_2 + I_4$ . . . . eq (1)

Let us take closed circuit BCDB into consideration, we know that potential is zero.

i.e , $5 (I_2 - I_4) - 10 (I_3 + I_4) - 5 I_4 = 0$

$5 I_2 - 5 I_4 - 10 I_3 - 10 I_4 - 5 I_4 = 0$

$5 I_2 - 10 I_3 - 20 I_4 = 0$

$I_2 = 2 I_3 - 4 I_4$ . . . . eq (2)

Let us take closed-circuit ABCFEA into consideration, we know that potential is zero.

i.e , $-10 + 10 (I_1) + 10 (I_2) + 5 (I_2 - I_4) = 0$

$10 = 15 I_2 + 10 I_1 - 5 I_4$

$3 I_2 + 2 I_2 - I_4 = 2$ .... eq (3)

From equation (1) and (2), we have:

$I_3 = 2 (2 I_3 + 4 I_4) + I_4$

$I_3 = 4 I_3 + 8 I_4 + I_4$

$- 3 I_3 = 9 I_4$

$- 3 I_4 = + I_3$ .... eq (4)

Putting equation (4) in equation (1) , we have :

$I_3 = 2 I_2 + I_4$

$- 4 I_4 = 2 I_2$

$I_2 = - 2 I_4$ .... eq (5)

From the above equation , we infer that :

$I_1 = I_3 + I_2$ .... eq (6)

Putting equation (4) in equation (1), we obtain

$3 I_2 + 2 (I_3 + I_2) - I_4 = 2$

$5 I_2 + 2 I_3 - I_4 = 2$ .... eq (7)

Putting equations (4) and (5) in equation (7) , we obtain

$5 (- 2 I_4) + 2 (- 3 I_4) - I_4 = 2$

$- 10 I_4 - 6 I_4 - I_4 = 2$

$17 I_4 = - 2$

$$I_4 = \frac{-2}{17} A$$

Equation (4) reduces to

$I_3 = - 3 (I_4)$

$$I_3 = -3 \left(\frac{-2}{17}\right) = \frac{6}{17} A$$

$I_2 = - 2 (I_4)$

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

$$I_2 - I_4 = \frac{4}{17} - \frac{-2}{17} = \frac{6}{17}A$$

$$I_3 + I_4 = \frac{6}{17} - \frac{-2}{17} = \frac{4}{17}A$$

$$I_1 = I_3 + I_2$$

$$I_1 = \frac{6}{17} + \frac{4}{17} = \frac{10}{17}A$$

Therefore, current in each branch is given as:

In branch $AB = \frac{4}{17}A$

In branch $BC = \frac{6}{17}A$

In branch $CD = \frac{-4}{17}A$

In branch $AD = \frac{6}{17}A$

In branch $BD = \frac{-2}{17}A$

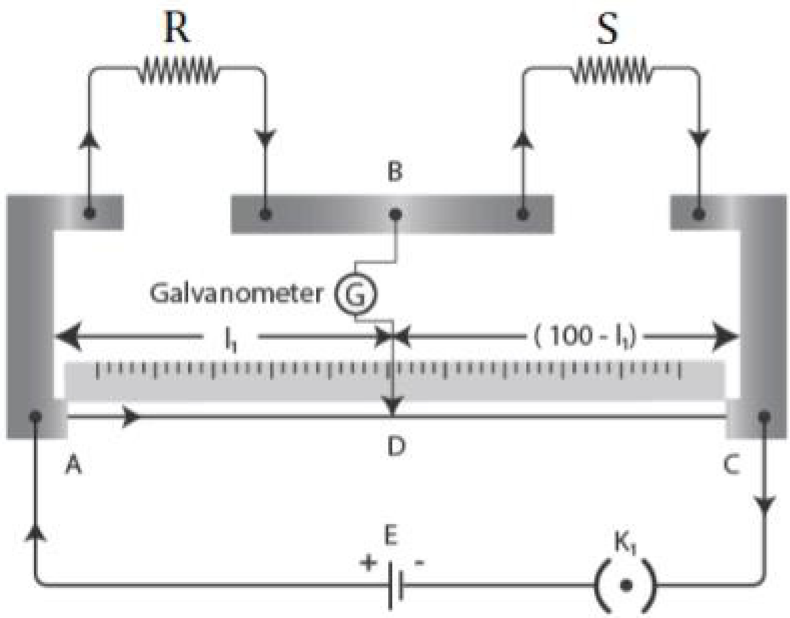
Total current $= \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17} = \frac{10}{17}A$

Question 3. 10:

A) In a meter bridge given below, the balance point is found to be at 39.5 cm from the end A, when the resistor S is of 12.5 Ω. Determine the resistance of R. 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 R and S 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?



Meter bridge

Solution:

(a) Let L_1 be the balance point from end A,

Given that, L_1 = 39.5 cm

Given that resistance of the resistor S = 12.5 Ω

We know that condition for the balance is given by the equation:

$$\frac{R}{S} = \frac{100 - L_1}{L_1}$$

$$R = \frac{100 - 39.5}{39.5} \times 12.5 = 8.2\Omega$$

Thus calculated the resistance of the resistor R, R = 8.2Ω

(b) If R and S are interchanged, then the lengths will also be interchanged.

Hence, the length modifies to

l = 100 – 39.5 = 60.5 cm.

(c) If the galvanometer and the cell are interchanged, the position of the balance point remains unchanged. Therefore, the galvanometer will show no current.

Question 3.11:

A storage battery of emf 8.0 V and internal resistance 0.5 Ω is being charged by a 120 V dc supply using a series resistor of 15.5 Ω. What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?

Solution:

Given:

The EMF of the given storage battery is E = 8.0 V

The Internal resistance of the battery is given by r = 0.5 Ω

The given DC supply voltage is V = 120 V

The resistance of the resistor is R = 15.5 Ω

Effective voltage in the circuit = V^1

R is connected to the storage battery in series.

Hence, it can be written as

$V^1 = V - E$

$V^1 = 120 - 8 = 112$ V

Current flowing in the circuit = I, which is given by the relation,

$$I = \frac{V^1}{R+r}$$

$$I = \frac{112}{15.5+5}$$

$$I = \frac{112}{16}$$

$$I = 7A$$

We know that Voltage across a resistor R given by the product,

I x R = 7 × 15.5 = 108.5 V

We know that,

DC supply voltage = Terminal voltage + voltage drop across R

Terminal voltage of battery = 120 – 108.5 = 11.5 V

A series resistor, when connected in a charging circuit, limits the current drawn from the external source.

The current will become extremely high in its absence. This is extremely dangerous.

Question 3.12:

In a potentiometer arrangement, a cell of emf 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 emf of the second cell?

Solution:

Emf of the cell, $E_1 = 1.25$ V

The balance point of the potentiometer, $l_1 = 35$ cm

The cell is replaced by another cell of emf E_2.

New balance point of the potentiometer, $l_2 = 63$ cm

The balance condition is given by the relation,

$$\frac{E_1}{E_2} = \frac{I_1}{I_2}$$

$$E_2 = E_1 \times \frac{I_2}{I_1}$$

$$E_2 = 1.25 \times \frac{63}{35} = 2.25V$$

Question 3.13:

The number density of free electrons in a copper conductor estimated in Example 3.1 is 8.5 × 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 × 10^{-6} m^2 and it is carrying a current of 3.0 A.

Solution:

Given that Number density of free electrons in a copper conductor, n = 8.5 x 10^{28} m^{-3}

Let the Length of the copper wire be l

Given, l = 3.0 m

Let the area of cross – section of the wire be A = 2.0 x 10^{-6} m^2

Value of the current carried by the wire, I = 3.0 A, which is given by the equation,

$I = n AeV_d$

Where,

e = electric charge = 1.6 x 10^{-19} C

$$V_d = Driftvelocity = \frac{Lengthofthewire(l)}{timetakentocoverl(t)}$$

$I = nAe\frac{l}{t}$

$t = \frac{n \times A \times e \times l}{I}$

$t = \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$

$t = 2.7 \times 10^{4} sec$

Question 3.14:

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.)

Solution:

Surface charge density of the earth, $\sigma=10^{-9}$ cm^{-2}
Potential difference between the top of the atmosphere and the surface, V= 400 kV
Current over the entire globe, I=1800 A
Radius of the earth, $r=6.37\times10^{6}$ m
Surface area of the earth, $A=4\pi r^{2}$

$= 4 \times 3.14 \times (6.37\times10^{6})^{2}=5.09\times10^{14}$ m^{2}

Charge on the earth surface, $q=\sigma A= 10^{-9} \times 5.09\times10^{14}$

$= 5.09\times10^{5}$ C

Time taken to neutralize the earth's surface, t = q/I

$\Rightarrow t=5.09\times10^{5}/1800=283$ s

Question 3.15:

(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 is 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?

Solution:

(a) Emf of the secondary cells, ε = 2.0 V

Number of secondary cells, n = 6

Total EMF, E= nε= 6 x 2 = 12 V

Internal resistance of the secondary cells, r= 0.015 Ω

Resistance to which the secondary cells are connected, R = 8.5 Ω
Total resistance in circuit R_{total} = nr+ R = 6×0.015+8.5=8.59Ω

Current drawn from the supply, I=E/R_{total} =12/8.59 = 1.4 A
Terminal voltage, V= IR = 1.4×8.5=11.9 V

(b) Emf of the secondary cell, ε = 1.9 V

Internal resistance, r = 380 Ω
Maximum current drawn from the cell, I =ε/r = 1.9/380=0.005A.

The current required to start a motor is 100 Amp. Here, the current produced is 0.005 A, so the starting motor of the car cannot be started with this current.

Question 3.16:

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. (ρ_{Al} = 2.63 × 10^{-8} Ω m, ρ_{Cu} = 1.72 × 10^{-8} Ω m, Relative density of Al = 2.7, of Cu = 8.9.)

Solution:

Length of aluminium = l_1

Resistance of aluminium = R

Resistivity of aluminium, ρ_{Al} =ρ_1= 2.63×10^{-8} Ωm

Relative density of aluminium, d_1 =2.7

Area of cross-section of the aluminium wire =A_1

Length of copper = l_2

Resistance of copper = R_2

Resistivity of copper, ρ_{cu} =ρ_2=1.72 × 10^{-8} Ω m

Relative density of copper, d_2 = 8.9

Area of cross-section of the copper wire =A_2

Therefore,

$$R_1 = \rho_1 \frac{l_1}{A_1} \quad \text{——(1)}$$

$$R_2 = \rho_2 \frac{l_2}{A_2} \quad \text{——(2)}$$

It is given that $R_1 = R_2$
Therefore,

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

Given $l_1 = l_2$

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

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

$= (2.63 \times 10^{-8})/(1.72 \times 10^{-8})$
$= 1.52$

Mass of aluminium, m_1 = Volume x density

$= A_1 l_1 \times d_1$

Mass of copper = m_2 = Volume x density

$= A_2 l_2 \times d_2$

$m_1/m_2 = (A_1 l_1 \times d_1 / A_2 l_2 \times d_2)$
Since $l_1 = l_2$

$m_1/m_2 = (A_1 d_1 / A_2 d_2)$

$m_1/m_2 = (1.52) \times (2.7/8.9)$

$= (1.52) \times (0.303)$

$m_1/m_2 = 0.46$

The mass ratio of aluminium to copper is 0.46. Since aluminium is lighter, it is preferred for long suspensions of cables

Question 3.17:

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

Solution:

Ohm's law is valid to high accuracy. This means that the resistivity of the alloy manganin is nearly independent of temperature.

Question 3.18:

Answer the following questions:
(a) A steady current flows in a metallic conductor of the non-uniform cross-section. Which of these quantities is constant along the conductor: current, current density, electric field, drift speed?
(b) Is Ohm's law universally applicable for all conducting elements? If not, give examples of elements that do not obey Ohm's law.
(c) A low voltage supply from which one needs high currents must have very low internal resistance. Why?
(d) A high tension (HT) supply of, say, 6 kV must have a very large internal resistance. Why?

Solution:

(a) Current is given to be steady. Therefore, it is a constant. The current density, electric field, drift speed depends on the area of cross-section inversely.
(b) No, examples of non-ohmic elements are vacuum diode, semiconductor diode etc.
(c) Because the maximum current drawn from a source = ε/r.
(d) If the circuit is shorted (accidentally), the current drawn will exceed safety limits if internal resistance is not large.

Question 3. 19:

Choose the correct alternative:
(a) Alloys of metals usually have (greater/less) resistivity than that of their constituent metals.
(b) Alloys usually have much (lower/higher) temperature coefficients of resistance than pure metals.
(c) The resistivity of the alloy manganin is nearly independent of/ increases rapidly with increase of temperature.
(d) The resistivity of a typical insulator (e.g., amber) is greater than that of a metal by a factor of the order of (10^{22}/10^{23}).

Solution:

(a) greater

(b) lower

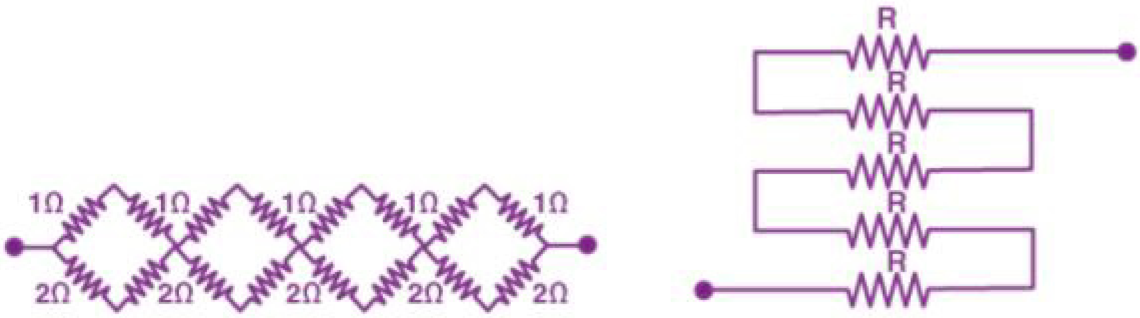
(c) nearly independent of

(d) 10^{22}

Question3.20)

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

(b) Given the resistances of 1 Ω, 2 Ω, 3 Ω, how will be combine them to get an equivalent resistance of (i) (11/3) Ω (ii) (11/5) Ω, (iii) 6Ω, (iv) (6/11) Ω?
(c) Determine the equivalent resistance of networks shown in figure



(a) (b)

Solution:

(a) Total number of resistors = n

Resistance of each resistor = R

(i) The maximum effective resistance is got when the resistors are connected in series. The effective resistance R_1 = nR

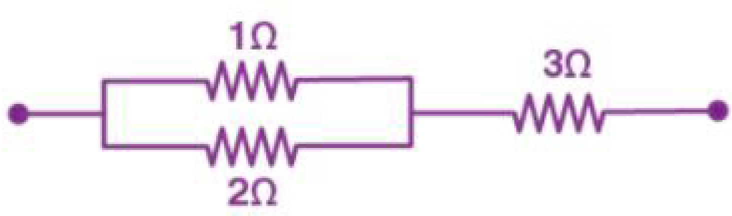
(ii) The minimum effective resistance is got when the resistors are connected in parallel, the effective resistance R_2 = R/n

The ratio of maximum resistance to minimum resistance = nR/(R/n) = n^2

(b) The resistance given are 1 Ω, 2 Ω, 3 Ω

(i) 11/3 Ω

Consider the following combination



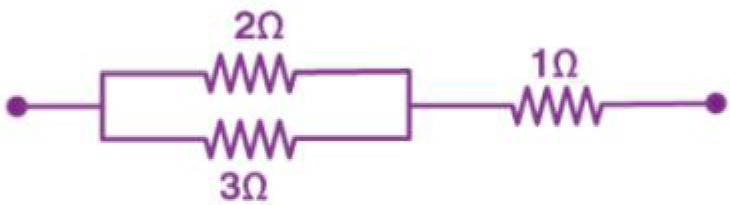
The resistors of resistance 1 Ω and 2 Ω are parallel. Therefore, effective resistance $\frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2}\right] = 3/2$

R' = 2/3 Ω

These resistors are connected in series with 3 Ω. Therefore the effective resistance R = R’ + 3 = (2/3) +3 = 11/3 Ω

(ii) 11/5 Ω

Consider the following combination



The resistors of resistance 2 Ω and 3 Ω are parallel. Therefore, effective resistance $\frac{1}{R'} = \left[\frac{1}{2} + \frac{1}{3}\right] = 5/6$

R’ = 6/5 Ω

These resistors are connected in series with 3 Ω. Therefore the effective resistance R = R’ + 3 = (6/5) +1 = 11/5 Ω

(iii) 6 Ω

When the resistors with resistance 1 Ω, 2 Ω, 3 Ω are connected in series the effective resistance is given by

1 Ω +2 Ω + 3 Ω = 6 Ω

(iv) (6/11) Ω

When the resistors are connected in parallel the effective resistance is $\frac{1}{R'} = \left[\frac{1}{1} + \frac{1}{2} + \frac{1}{3}\right] = 11/6\Omega$

R’ = (6/11) Ω

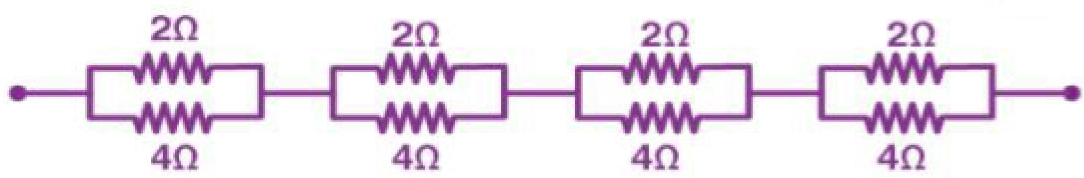
(c) (a) In all the loops, two resistors of resistance 1Ω are connected in series. Therefore, the effective resistance is (1+1) = 2 Ω

Similarly, In all the loops, two resistors of resistance 2Ω are connected in series. Therefore, the effective resistance is (2+2) = 4 Ω

The 2Ω and 4Ω resistors are connected in parallel in all four loops. Therefore, the effective resistance = $\frac{1}{R'} =$

$$\left[\frac{1}{2} + \frac{1}{4}\right] = 3/4\Omega$$

R’ = 4/3 Ω

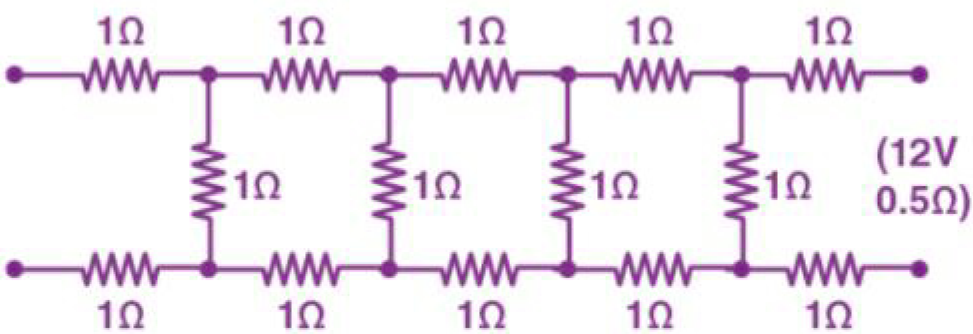


All the four resistors are connected in series. Hence the equivalent resistance R each are (4/3) x 4 = 16/3 Ω

(c) (b) The resistors are connected in series. Therefore, the effective resistance is R+R+R+R+R = 5R

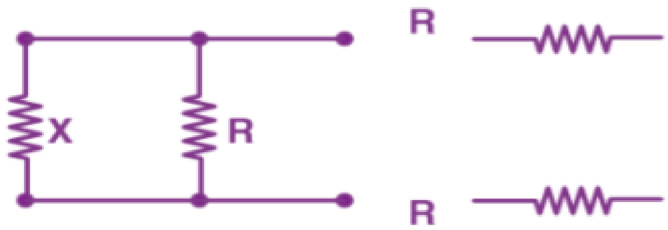
Question 3.21)

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



Solution:

Let the effective resistance of the infinite network be X. Since it is an infinite network, adding three resistors of 1 Ω resistance will not change the total resistance. i.e., it will remain X. The circuit will look like this if three resistors are added.



The equivalent resistance of this network is R' = R + (equivalent resistance when X and R are parallel) + R

= R + [XR/(X+R)] + R

R' = 2R + [XR/(X+R)]

As said above, since it is an infinite network, adding three resistors of 1 Ω resistance will not change the total resistance.

R' = X

⇒ 2R + [XR/(X+R)] = X

Since R = 1Ω we get

2 x 1 + [X x 1/(X+1)] = X

$X^2 - 2X - 2 = 0$

$$X = \frac{(-2) \pm \sqrt{(-2)^2 - 4 \times 1 \times (-2)}}{2}$$

$$X = 1 \pm \sqrt{3}$$

The value of resistance cannot be negative. Therefore, X= 1+√3 = 2.732 Ω

Given E = 12 V; r = 0.5 Ω

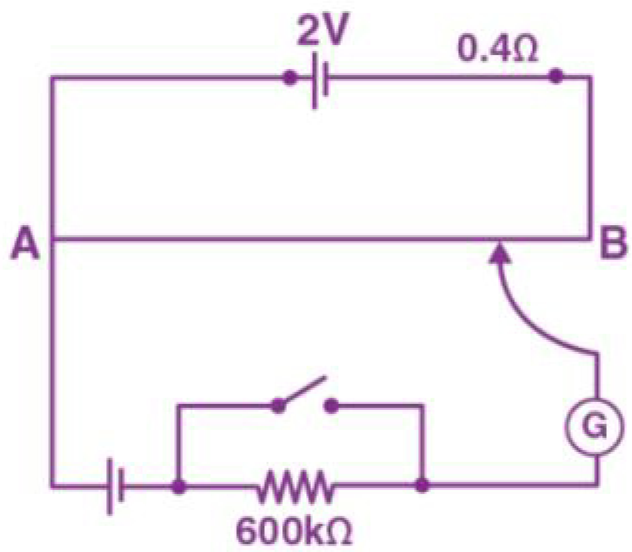
If I is the current drawn by the network, then

I = E/(X+r) = 12/(2.732+ 0.5) = 3.713 A

Question 3. 22)

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 upto a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then

replaced by a cell of unknown emf ε and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



(a) What is the value ε?

(b) What purpose does the high resistance of 600 kΩ have?

(c) Is the balance point affected by this high resistance

(d) Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0V instead of 2.0V?

(e) Would the circuit work well for determining an extremely small emf, say of the order of a few mV (such as the typical emf of a thermo-couple)? If not, how will you modify the circuit?

Solution:

(a) Constant emf of the standard cell, $E_1 = 1.02$ V

The balance point on the wire, $l_1 = 67.3$ cm

The standard cell is then replaced by a cell of unknown emf ε and the balance point changes to $l = 82.3$ cm

The relation between Emf and the balancing point

$(E_1/l_1) = (\varepsilon/l)$

$\varepsilon = (l \times E_1/l_1) = (82.3 \times 1.02)/67.3 = 1.247$ V

(b) The purpose of using high resistance of 600 kΩ is to reduce current through the galvanometer when the movable contact is far from the balance point.

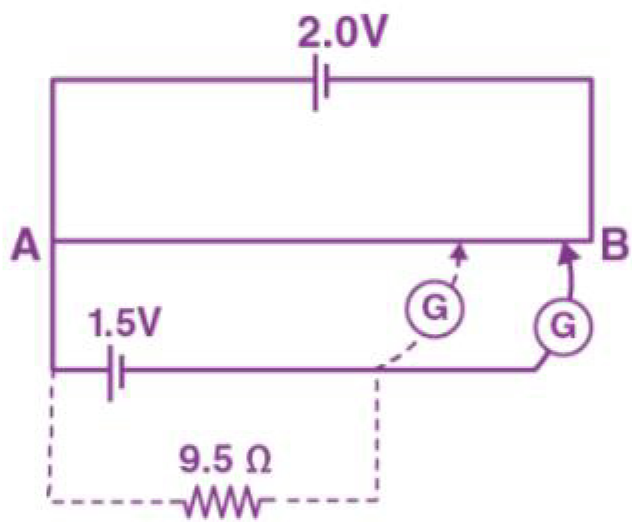
(c) No.

(d) No. If ε is greater than the emf of the driver cell of the potentiometer, there will be no balance point on the wire AB.

(e) The circuit will not be suitable, because the balance point (for ε of the order of a few mV) will be very close to the end A and the percentage of error in the measurement will be very large. The circuit can be modified by putting a suitable resistor R in series with the wire AB so that the potential drop across AB is only slightly greater than the emf to be measured. Then, the balance point will be at a larger length of the wire and the percentage error will be much smaller.

Question 3. 23:

Figure below 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.



Solution:

Internal resistance of the cell, r = 1.5 V cell

Balance point of the cell in open circuit, l = 76.3 cm

External resistance, R = 9.5 Ω

New balance point, l_1 = 64. 8 cm

The expression for internal resistance is given as

$$r = R\left[\frac{l}{l_1} - 1\right]$$

$$r = 9.5\left[\frac{76.3}{64.8} - 1\right] = 1.69\Omega$$