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?

Answer 3.1:

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?

Answer 3.2:

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,

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

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.

Answer 3. 3.

Answer 3.3 :

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

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

Req = 1 Ω + 2 Ω + 3 Ω = 6 Ω

Thus calculated Req = 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 $r_1 = 1\ \Omega$, $r_2 = 2\ \Omega$ and $r_3 = 3\ \Omega$ are calculated to be

$V_1 = 2 \times 1 = 2$ V

$V_1 = 2 \times 1 = 4$ V

$V_1 = 2 \times 1 = 6$ 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.

Answer 3.4 :

A) Resistors $r_1 = 1\ \Omega$, $r_2 = 2\ \Omega$ and $r_3 = 3\ \Omega$ are combined in parallel

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

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} \quad \frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} \quad \frac{1}{R} = \frac{10+5+4}{20} \quad \frac{1}{R} = \frac{19}{20}$$

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

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

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 :

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

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 resistors is calculated to be :

$$I_1 = 10A \; I_2 = 5A \; I_3 = 4A$$

and the total current is calculated to be, 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}.

Answer 3.5 :

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 ,

$$\alpha = \frac{R_1 - R}{R(T_1 - T)} \; T_1 - T = \frac{R_1 - R}{R\alpha} \; T_1 - 27 = \frac{117 - 100}{100(1.7x10_{-4})} \; T_1 - 27 = 1000$$

$T_1 = 1027$ ° 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?

Answer 3.6 :

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

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

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

Resistivity of the material is given as ρ

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

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

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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.

Answer 3.7 :

Given :

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

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \quad \alpha = \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039°C^{-1}$$

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

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 $1.70 \times 10^{-4}\,°C^{-1}$.

Answer 3.8 :

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

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

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 :

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

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

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 :

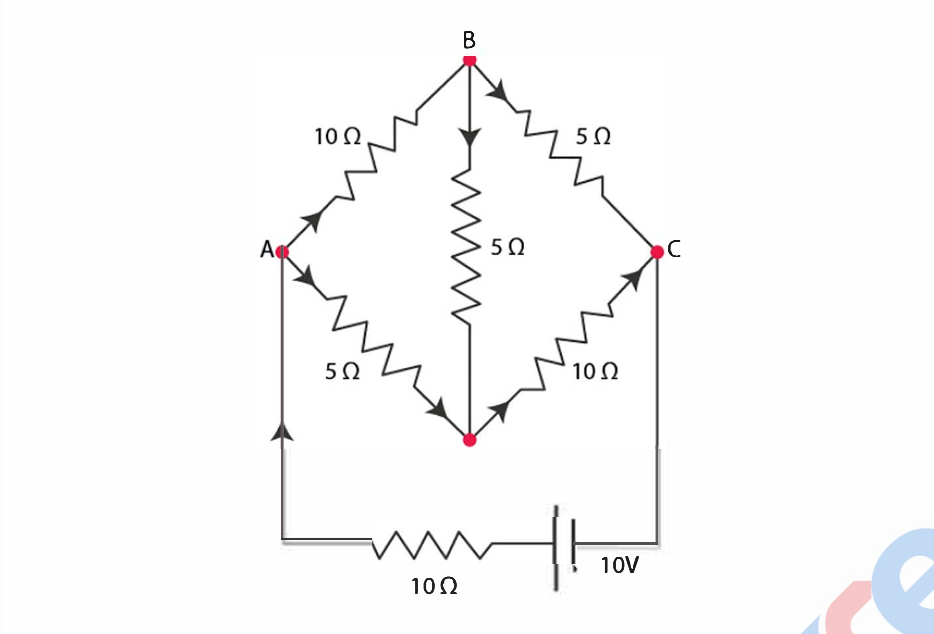
$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \quad T_2 - 27 = \frac{82.14 - 71.87}{71.87x(1.7x10_{-4})} \quad T_2 - 27 = 840.5$$

$T_2 = 840.5 + 27 = 867.5\,°C$

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

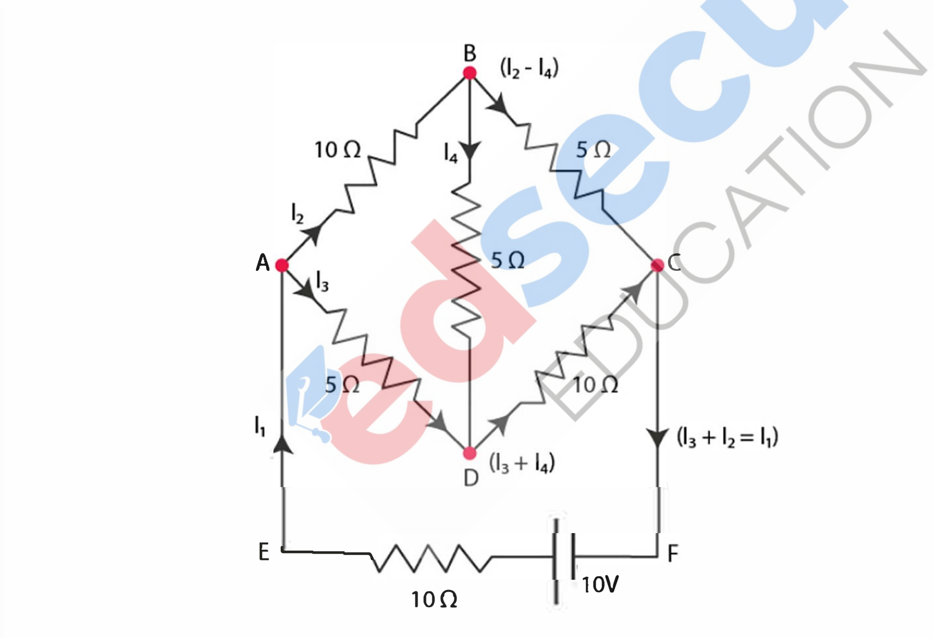
Question 3.9 :

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



Answer 3.9 :

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 BD

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

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

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

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

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

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

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

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

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

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

$I_3 = 4I_3 + 8I_4 + I_4$

$-3I_3 = 9I_4$

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

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

$I_3 = 2I_2 + I_4$

$-4I_4 = 2I_2$

$I_2 = -2I_4$ .... 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

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

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

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

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

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

$17I_4 = -2$

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

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

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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 :

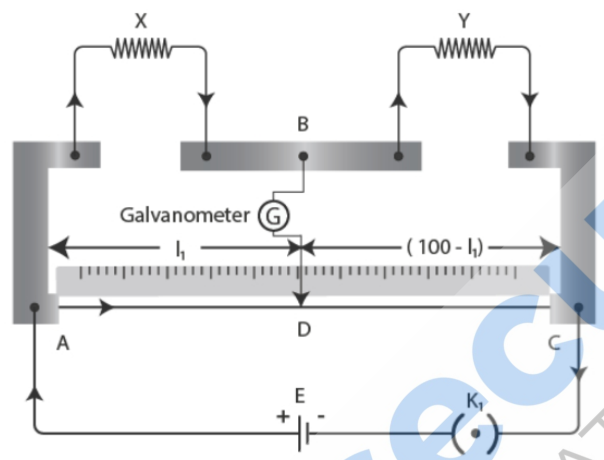
A) In a meter bridge given below, the balance point is found to be at 39.5 cm from the end A, when the resistor S is of 12.5 Ω. Determine the resistance of R. Why are the connections between resistors in a Wheatstone or meter bridge made of thick copper strips?

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?

Answer 3. 10 :

A meter bridge with resistors M and N are shown in the figure.



Meter bridge

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

Given that , L_1 = 39.5 cm

Given that resistance of the resistor N = 12.5 Ω

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

$$\frac{M}{N} = \frac{100 - L_1}{L_1} \quad M = \frac{100 - 39.5}{39.5} \times 12.5 = 8.2\Omega$$

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

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?

Answer 3.11 :

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 ,

$$I = \frac{V^1}{R+r} \quad I = \frac{112}{15.5+5} \quad I = \frac{112}{16} \quad I = 7A$$

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?

Answer 3.12 :

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 ,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} \quad E_2 = E_1 \times \frac{l_2}{l_1} \quad E_2 = 1.25 \times \frac{63}{35} = 2.25V$$

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.

Answer 3.13 :

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 A e V_d

Where,

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

$$V_d = Driftvelocity = \frac{Lengthofthewire(l)}{timetakentocoverl(t)} \quad I = nAe\frac{l}{t} \quad t = \frac{n \times A \times e \times l}{I} \quad t = \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} x 1.6 \times 10^{-19}}{3.0} \quad t = 2.7 \times 10^4 sec$$