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B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

Class: 12
Subject: Physics
Topic: Current electricity
No. of Questions: 30

1. The storage battery of a car has an emf of 12 V. If the internal resistance of the battery is 04Ω, what is the maximum current that can be drawn from the battery?

   Sol.
   Emf of the battery, E = 12 V
   Internal resistance of the battery, r = 0.4 Ω
   Maximum current drawn from the battery = I
   According to Ohm's law,
   E =Ir

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

   $= \frac{12}{04} = 30A$

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

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?

   Sol.

   Emf of the battery, E = 10 V

   Internal resistance of the battery, r = 3 Ω

   Current in the circuit, $I = 0.5\ A$

   Resistance of the resistor $= R$

   The relation for current using Ohm's law is,

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

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

   $= \frac{10}{0.5} = 20\Omega$

   $\therefore R = 30 - 3 = 17\Omega$

Terminal voltage of the resistor

According to Ohm's law,

V= IR

$= 0.5 \times 17$

$= 8.5\,V$

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

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

Sol.

There are three resistors of resistance,

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

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

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

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

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

Emf of the battery, V 20 V

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

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

$= \frac{20}{2} = 10A$

Current (I_2) flowing through resistor R_2 given by,

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

$= \frac{20}{4} = 5A$

Current (I_3) flowing through resistor R_3 given by,

$$I_3 = \frac{V}{R_3}$$

$$= \frac{50}{4} = 4A$$

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.

4. 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.

Sol.

Temperature, T_1 27.5 °C

Resistance of the silver wire at T_1, R_1 = 2.1 Ω

Temperature, T_2 = 100°C

Resistance of the silver wire at T_2, R_2 = 2.7 Ω
Temperature coefficient of silver = α
It is related with temperature and resistance as

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

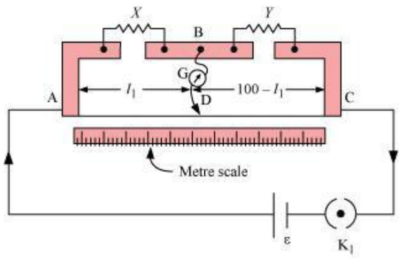
$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039\,^{\circ}C^{-1}$$

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

5. In a metre bridge [Fig. 3.27], the balance pint 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?
Determine the balance point of the bridge above if X and Y are interchanged.
What happens if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?

Sol.

A metre bride 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 Ω

Condition for the balance is given as,

$$\frac{X}{Y} = \frac{100 - L_1}{l}$$

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

Therefore, the resistance of resistor X is 8.2 Ω.

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.

$100 - l_1 = 100 - 39.5 = 60.5$ cm

Therefore, the balance point is 60.5 cm from A.

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.

6. 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?

Sol.

Emf of the storage battery, $E = 8.0\ V$

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

DC supply voltage, V =120 V

Resistance of the resistor, 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,

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

$= \frac{112}{15.5+5} = \frac{112}{16} = 7\ A$

Voltage across resistor R given by the product, $IR = 7 \times 15.5 = 108.5\ V$

DC supply voltage =Terminal voltage of battery + Voltage drop across R

Terminal voltage of battery = 120 – 108.5 = 11.5 V

A series resistor in a charging circuit limits the current drawn from the external source. The current will be extremely high in its absence. This is very dangerous.

7. In a potentiometer arrangement, a cell of emf 1.55 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?

Sol.

Emf of the cell, E_1 = 1.25 V

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,

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

$$E_2 = E_1 \times \frac{l_2}{l_1}$$

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

Therefore, emf of the second cell is 2.25V.

8. 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.

Sol.

Number density of free electrons in a copper conductor, $n = 8.5 \times 10^{28}$ m^{-3} Length of the copper wire, $l = 3.0\,m$

Area of cross-section on the wire, $A = 2.0 \times^{-6} m_2$

Current carried by the wire, $I = 3.0\,A$,which is given by the relation,

I= $nAeV_d$

Where,

e = Electric charge = 1.6 × 10^{-19} C

$$= \frac{Length\ of\ the\ wire(l)}{Time\ taken\ to\ cover\ l\ (t)}$$

V_d = Drift velocity

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

$t = \frac{nAel}{1}$

$= \frac{3\times8.5\times10^{28}\times2\times10^{-6}\times1.6\times10^{-9}}{3.0}$

$= 2.7 \times 10^{4}\ s$

Therefore the time taken by and electron to drift from one end of the wire to the other is 2.7×10^4 s.

9. Answer the following questions:
   A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor: current, current density, electric field, drift speed?
   Is Ohm's law universally applicable for all conducting elements?
   If not, give examples of elements which do not obey Ohm's law.

   Sol.

   When a steady current flows in a metallic conductor of non-uniform cross-section, the current flowing through the conductor is constant. Current density, electric field, and drift speed are inversely proportional to the area cross-section. Therefore, they are not constant.

   No, Ohm's law is not universally applicable for all conducting elements. Vacuum diode semi-conductor is a non-ohmic conductor. Ohm's law is not valid for it.

10. A low voltage supply from which one needs high currents must have very low internal resistance. Why?
    A high tension (HT) supply of, say, 6 kV must have a very large internal resistance. Why?

    Sol.

    According to Ohm's law, the relation for the potential is V = IR

    Voltage (V) is directly proportional to current (I).

    R is the internal resistance of the source.

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

    If V is low, then R must be very low, so that high current can be drawn from the source.

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.

11. The deflection in a moving coil galvanometer falls from 50 to 10 divisions when a shunt of 12 Ω is connected across it. The resistance of the galvanometer coil is

A. 24 Ω
B. 36 Ω
C. 48 Ω
D. 60 Ω

Sol.

Right Answer Explanation:
If k is the current sensitivity of the galvanometer, the current in the galvanometer is

$I_g = 50\ k$ (i)

When a shunt S is connected across it the current through the galvanometer becomes

$$I'_g = \frac{I_g S}{G + S} = 10\ k$$

where G is the resistance of the galvanometer. Dividing (i) and (ii) we get

$$\frac{G + S}{S} = 5$$

which gives G = 4 S = 4 × 12 = 48 Ω. Hence the correct choice is (3).

12. An electric bulb has a rating of 500 W, 100 V. It is used in a circuit having a 200 V supply. What resistance must be connected in series with the bulb so that it delivers 500 W?

A. 10 Ω
B. 20 Ω
C. 30 Ω
D. 40 Ω

Right Answer Explanation:
The current flowing in the bulb of 500 W operating at 100 V is

$$I = \frac{500}{100} = 5\ A$$

Resistance of the bulb = $\frac{100}{5}$ = 20 Ω (say, R).
To deliver 500 W, the current in the bulb must remain 5A when it is operated with 200 V supply.
The resistance R to be connected in series for this purpose is given by

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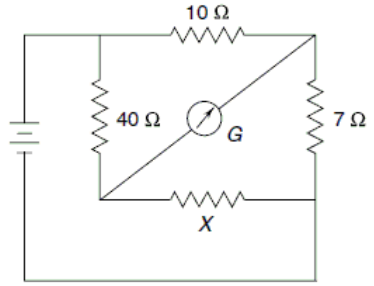
$$\frac{200}{R+R_1} = 5$$

or $R + R_1 = 40$ or $R + 20 = 40$ or $R = 20\ \Omega$. Hence the correct choice is (2).

13. In figure, the galvanometer shows no deflection. What is the resistance X?



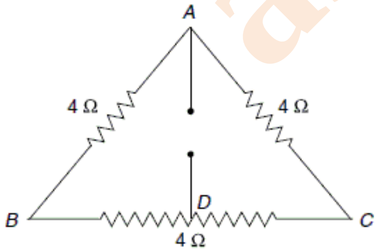
A. 7 Ω
B. 14 Ω
C. 21 Ω
D. 28 Ω

Right Answer Explanation:
This is a balanced Wheatstone's bridge. Therefore

$$\frac{10}{40} = \frac{7}{X}$$

which gives X = 28 Ω, hence the correct choice is (4).

14. Three resistances of 4 Ω each are connected as shown in figure. If the point D divides the resistance into two equal halves, the resistance between points A and D will be



A. 12 Ω
B. 6 Ω
C. 3 Ω
D. $\frac{1}{3}\ \Omega$

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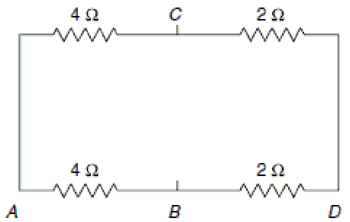
Right Answer Explanation:
The circuit can be rearranged as shown in figure. The resistance between points A and D is given by



$\frac{1}{R} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3}$

or R = 3 Ω. Hence the correct choice is (3).

15. A copper wire of length 50 cm and area of cross- section 10^{-6} m^2 carries a current of 0.5 A. If the resistivity of copper is 1.8 $\times$ 10^{-8} Ωm, the electric field across the wire is

A. 9 Vm^{-1}
B. 0.9 Vm^{-1}
C. 0.09 Vm^{-1}
D. 0.009 Vm^{-1}

Right Answer Explanation:
Potential difference across a wire of length l is

$$V = IR = \frac{I\rho l}{A}$$

$\therefore$ Electric field E = $\frac{V}{l} = \frac{I\rho}{A} = \frac{0.5 \times 1.8 \times 10^{-8}}{10^{-6}}$ = 0.009 V m^{-1}

16. An electric bulb has a rating of 100 W, 200 V. If the supply voltage drops to 100 V, then what is the total heat and light energy produced by the bulb in 20 minutes?

A. 10 kJ
B. 20 kJ
C. 30 kJ
D. 40 kJ

Right Answer Explanation:
Power P = $\frac{V^2}{R}$ or $R = \frac{V^2}{P} = \frac{(200)^2}{100} = 400\ \Omega$ is the resistance of the filament of the bulb. The total energy produced in time t = 20 $\times$ 60 = 1200 s when the voltage drops to V' is

$$W = \frac{V'^2 t}{R} = \frac{(100)^2 \times 1200}{400}$$

$$= 3 \times 10^4 \text{ J} = 30 \text{ kJ}$$

17. The current through a bulb is increased by 1%. Assuming that the resistance of the filament remains unchanged, the power of the bulb (i.e. its wattage) will

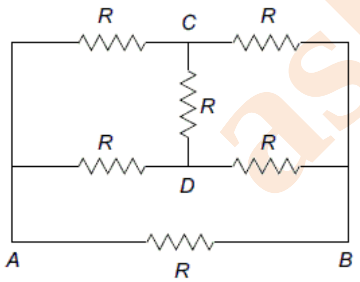
A. increase by 1%
B. decrease by 1%
C. increase by 2%
D. decrease by 2%

Right Answer Explanation:
Power P = I^2 R. Therefore, ΔP = 2I Δ IR. Hence

$$\frac{\Delta P}{P} = \frac{2\,\Delta I}{I}$$

Now $\frac{\Delta I}{I} = 1\%$. Therefore $\frac{\Delta P}{P}$ = + 2%. Hence the correct choice is (3).

18. In the circuit shown in figure, the effective resistance between A and B is



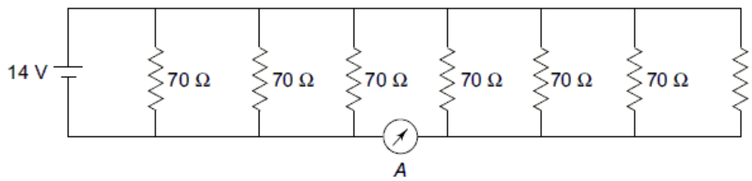
A. $\frac{R}{2}$
B. R
C. 2 R
D. 4 R

Right Answer Explanation:
The upper part of the circuit is a balanced Wheat- stone's bridge. Hence resistance R between CD is ineffective as no current will flow in this branch. The circuit, therefore, reduces to three parallel branches having resistance R, R + R and R + R, i.e. R, 2R and 2R. The effective resistance R' is given by

$$\frac{1}{R'} = \frac{1}{R} + \frac{1}{2R} + \frac{1}{2R}$$

which given R' = $\frac{R}{2}$. Hence the correct choice is (1).

19. The reading of the ammeter in the given circuit is

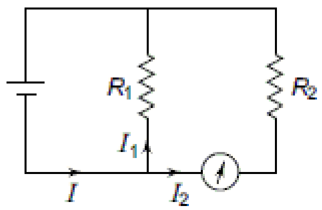


A. $\frac{3}{5}$A
B. $\frac{4}{5}$A
C. $\frac{6}{5}$A
D. $\frac{7}{5}$A

Right Answer Explanation:
Since the seven resistances are in parallel, the effective resistance is R = 70/7 = 10 Ω. Therefore, the current in the circuit is I = 14/10 = 7/5A. The given circuit can be redrawn as shown in figure.

where $R_1 = \frac{70}{3}$ Ω and $R_2 = \frac{70}{4}$ Ω. The current I_2 is given by

$$I_2 = I \times \frac{R}{R_2}$$



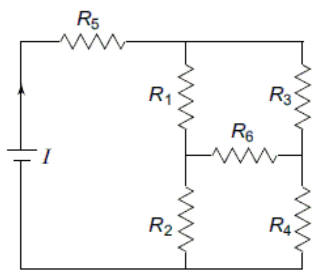
$= \frac{7}{5} \times \frac{10}{70/4} = \frac{4}{5}$A, which is choice (2).

20. A piece of copper and another of germanium are cooled from room temperature to 40 K. The resistance of

A. each of them decreases
B. each of them increases
C. copper increases and of germanium decreases
D. copper decreases and of germanium increases

Right Answer Explanation:
The correct choice is (4).

21. In the given circuit it is observed that the current I is independent of the value of the resistance R_6. Then the resistance values must satisfy



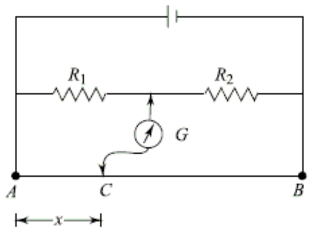
A. $R_1 R_2 R_5 = R_3 R_4 R_6$
B. $\frac{1}{R_5} + \frac{1}{R_6} = \frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4}$
C. $R_1 R_4 = R_2 R_3$
D. $R_1 R_3 = R_2 R_4 = R_5 R_6$

Right Answer Explanation:
Since no current flows through R_6, resistances R_1, R_2 R_3 and R_4 constitute the four arms of a balanced Wheatestone's bridge. Hence

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$ or $R_1 R_4 = R_2 R_3$

Thus the correct choice is (3).

22. In the meter bridge experiment shown in figure, the balance length AC corresponding to null deflection of the galvanometers is x. What would be the balance length, if the radius of the wire AB is doubled?



A. $\frac{x}{2}$
B. x
C. 2x
D. 4x

Right Answer Explanation:
The condition for no deflection of the galvanometer is

$$\frac{R_1}{R_2} = \frac{R_{AC}}{R_{CB}}$$

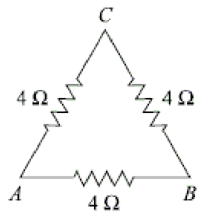
where R_{AC} and R_{CB} are the resistances of the bridge wire of length AC and CB respectively. If the radius of the wire AB is doubled, the ratio R_{AC} R_{CB} will remain unchanged. Hence, the balance length will remain the same. Thus, the correct choice is (2).

23. A conductor of resistance 3 Ω is stretched uniformly till its length is doubled. The wire is now bent in the form of an equilateral triangle. The effective resistance between the ends of any side of the triangle (in ohms) is

A. $\frac{9}{2}$
B. $\frac{8}{3}$
C. 2
D. 1

Right Answer Explanation:

$$R = \frac{\rho l}{A} = \frac{\rho l^2}{Al} = \left(\frac{\rho}{V}\right) l^2$$



$$R_e = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{4 \times 8}{4 + 12} = \frac{8}{3}\ \Omega$$

24. If a wire is stretched to make it 0.1% longer, its resistance will

A. increase by 0.05%
B. increase by 0.2%
C. decrease by 0.2%
D. remain unchanged

Right Answer Explanation:
The mass of a wire of length l, cross-sectional area A and density d is given by

$$m = Ald \text{ or } A = \frac{m}{l\,d}$$

∴ The resistance of wire of resistivity ρ is

$$R = \frac{\rho l}{A} = \frac{P d l^2}{m} = kl^2 \qquad (1)$$

where k = ρ d/m is a constant of the wire. Taking logarithm of both sides of (1) we have

$$\log R = \log k + 2 \log l$$

Differentiating

$$\frac{\delta R}{R} = 0 + \frac{2\,\delta l}{l} = \frac{2\delta l}{l}$$

Given $\frac{\delta l}{l}$ = 0.1%. Therefore, $\frac{\delta R}{R}$ = 2 × 0.1% = 0.2%. Thus, the resistance of the wire increases by 0.2%, which is choice (2)

25. Two electric bulbs are designed to operate with a power of 500 W in a 200 V supply line. They are connected in series to a 100 V supply line. The power generated in each bulb is

A. 31.0 W
B. 31.25 W
C. 31.5 W
D. 31.75 W

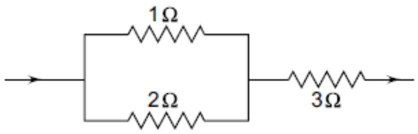
Right Answer Explanation:

Resistance of each bulb is R = $\frac{(200)^2}{500} = 80\ \Omega$.
When the bulbs are connected in series to a 100 V source, the potential difference across each

bulb is V = 100/2 = 50 V. Therefore, power generated in each bulb is

$$P = \frac{V^2}{R} = \frac{(50)^2}{80} = 31.25 \text{ W}$$

26. In the circuit shown in figure, the current in the 1 Ω resistor is 2 A. The power developed in the 3 Ω resistor is



A. 3 W
B. 9 W
C. 27 W
D. 81 W

Right Answer Explanation:
Since the current through the 1 Ω resistor is 2 A, the current in the 2 Ω resistor will be 1 A. So the current in the 3 Ω resistor = 1 + 2 = 3 A. Hence power developed in the 3 Ω resistor = $(3)^2 \times 3$ = 27 W. So the correct choice is (3).

27. A battery of emf E and internal resistance r is connected to a resistor of resistance r_1 and Q joules of heat is produced in a certain time t. When the same battery is connected to another resistor of resistance r_2, the same quantity of heat is produced in the same time t, the value of r is

A. $\frac{r_1^2}{r_2}$
B. $\frac{r_2^2}{r_1}$
C. $\frac{1}{2}(r_1 + r_2)$
D. $\sqrt{r_1 r_2}$

Right Answer Explanation:

In the first case, the current in the circuit is

$$I_1 = \frac{E}{r_1 + r}$$

$$\therefore \qquad Q_1 = I^2 r_1 t = \left(\frac{E}{r_1 + r}\right)^2 \times r_1 t \qquad \text{(i)}$$

In the second case,

$$Q_2 = \left(\frac{E}{r_2 + r}\right)^2 \times r_2 t \qquad \text{(ii)}$$

Equating (i) and (ii) we get

$$\frac{r_1}{(r_1 + r)^2} = \frac{r_2}{(r_2 + r)^2}$$

or $$r_1 (r_2 + r)^2 = r_2 (r_1 + r)^2$$

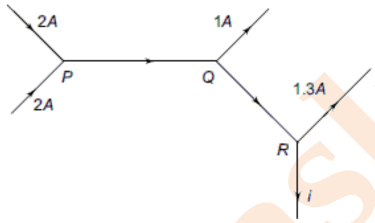
or $$r_1 (r_2^2 + 2r r_2 + r^2) = r_2 (r_1^2 + 2r r_1 + r^2)$$

or $$r^2 (r_1 - r_2) = r_1 r_2 (r_1 - r_2)$$

or $$r = \sqrt{r_1 r_2}$$

Hence the correct choice is (4).

28. Figure shows currents in a part of an electrical circuit. The current i is



A. 1 A
B. 1.3 A
C. 1.7 A
D. 3.7 A

Right Answer Explanation:
From Kirchhoff's first law, the current in branch PQ = 2+ 2 = 4 A and in branch QR the current = 4 A – 1 A = 3 A. Hence current i = 3 A – 1.3 A =1.7 A. Thus the correct choice is (3).

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29. A battery of emf E and internal resistance r is connected across a pure resistive device (such as an electric heater) of resistance R. The power output of the device will be maximum if

A. R = r
B. R = $\sqrt{2}$ r
C. R = 2r
D. R = 4r

Right Answer Explanation:
The current in the circuit is

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

Therefore the power output of the device is given by

$$P = I^2 R = \frac{E^2 R}{(R+r)^2} \qquad \text{(i)}$$

For given values of E and r, power output P will be maximum if $dP/dR = 0$ and $d^2P/dR^2 < 0$. Differentiating (i) with respect to R we get (with E and r fixed)

$$\frac{dP}{dR} = \frac{E^2}{(R+r)^2}\left\{1 - \frac{2R}{(R+r)}\right\} \qquad \text{(ii)}$$

Now $dP/dR = 0$ if

$$1 - \frac{2R}{(R+r)} = 0$$

which gives $R = r$. Thus, P will be either maximum or minimum when $R = r$. To decide whether P is maximum at $R = r$, we find d^2P/dR^2 at $R = r$. If its value is negative, P will be maximum. Differentiating (ii) we have

$$\frac{d^2P}{dR^2} = \frac{2E^2}{(R+r)^3}\left\{\frac{3R}{(R+r)} - 2\right\}$$

$$\therefore \left(\frac{d^2P}{dR^2}\right)_{\text{at } R=r} = -\frac{E^2}{8r^3}$$

which is negative. Hence P is maximum when $R = r$.

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

30. A constant voltage is applied between the two ends of a metallic wire. Some heat is developed in it. The heat developed is doubled if

A. both the length and the radius of the wire are halved
B. both the length and the radius of the wire are doubled
C. the radius of the wire is halved
D. the length of the wire is doubled

Right Answer Explanation:

Q = $\frac{V^2}{R}$. But R = $\frac{\rho l}{\pi r^2}$. Therefore

$$Q = \left(\frac{\pi V^2}{\rho}\right)\frac{r^2}{l}$$

Q is doubled if both I and r are doubled. Hence the correct choice is (2).